Earthquake Disaster Assessment on May 27 Ms 6.2 Yogyakarta Earthquake of Indonesia

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National Earthquake Response Support Service, China Earthquake Administration

23, Oct. 2006

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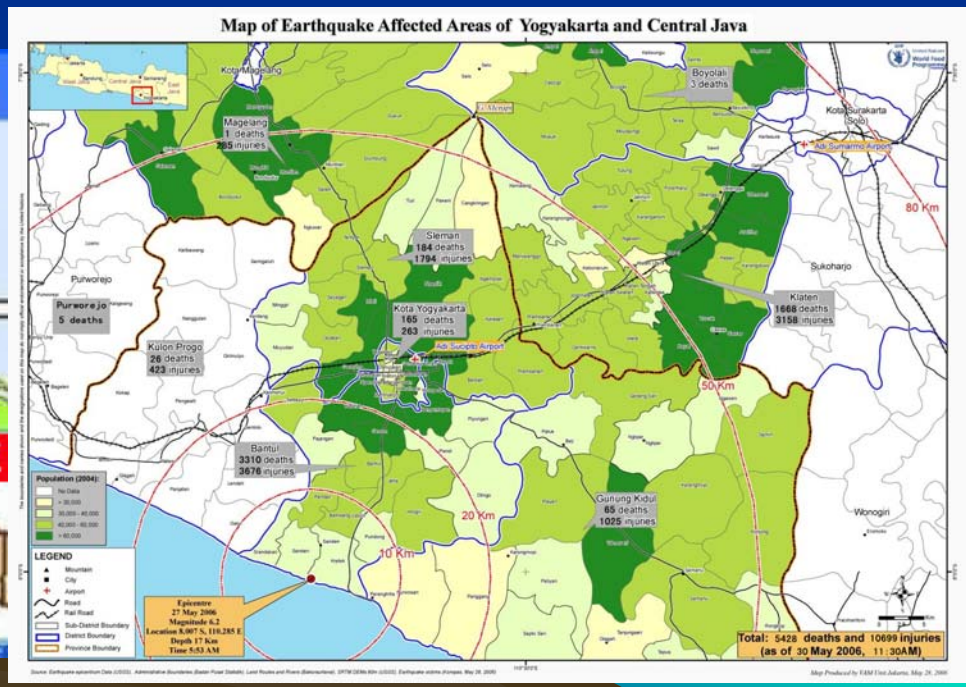
I. Introduction

A Ms 6.4 earthquake on Richter scale (China Earthquake Networks Center (CENC)) occurred in Yogyakarta, central Java, Indonesia, at 05hrs 54 minutes,, 27 May, 2006 (local time). As of 6 June 17.00 h, the death toll stood at 5,872. The number of injuries reached 37,229. 84,643 houses have been completely destroyed. 323,282 additional houses have suffered from various degrees of damages .



I. Introduction

The Parameters of the earthquake:

Magnitude: 6.4 (Recorded at CENC), USGS 6.2 (Recorded at CENC)

Date-Time: Saturday, May 27, 2006 at 00:55:54 (UTC) =Coordinated Universal Time

Saturday, May 27, 2006 at 5:55:54 AM = Local time at epicenter

Location: 7.65° S, 109.85° E

Depth: 10km set by location program (USGS)

Region: Indonesia

Distances:

40 km SSW of Yogyakarta, Java, Indonesia

115 km S of Semarang, Java, Indonesia

140 km SSE of Pekalongan, Java, Indonesia

445 km ESE of JAKARTA, Java, Indonesia

CISAR was required to provide the assistance to the disaster-striken area on May 29 with three functions of delivery medical service to the injured, conducting comprehensive disaster assessment that could provide advices for relief activities and reconstruction effort and the search and rescue operation.

On May 30, CISAR arrived in Bantul and set up the Mobile hospital at SMA 2 BANTUL. Immediately after the base of operation was set up, all the relief activities were conducted in the three areas of medical service, disaster assessment and search & rescue operation. The following report was presented as the result of disaster assessment conducted by the disaster assessment experts.

II. Classification of Earthquake Disaster

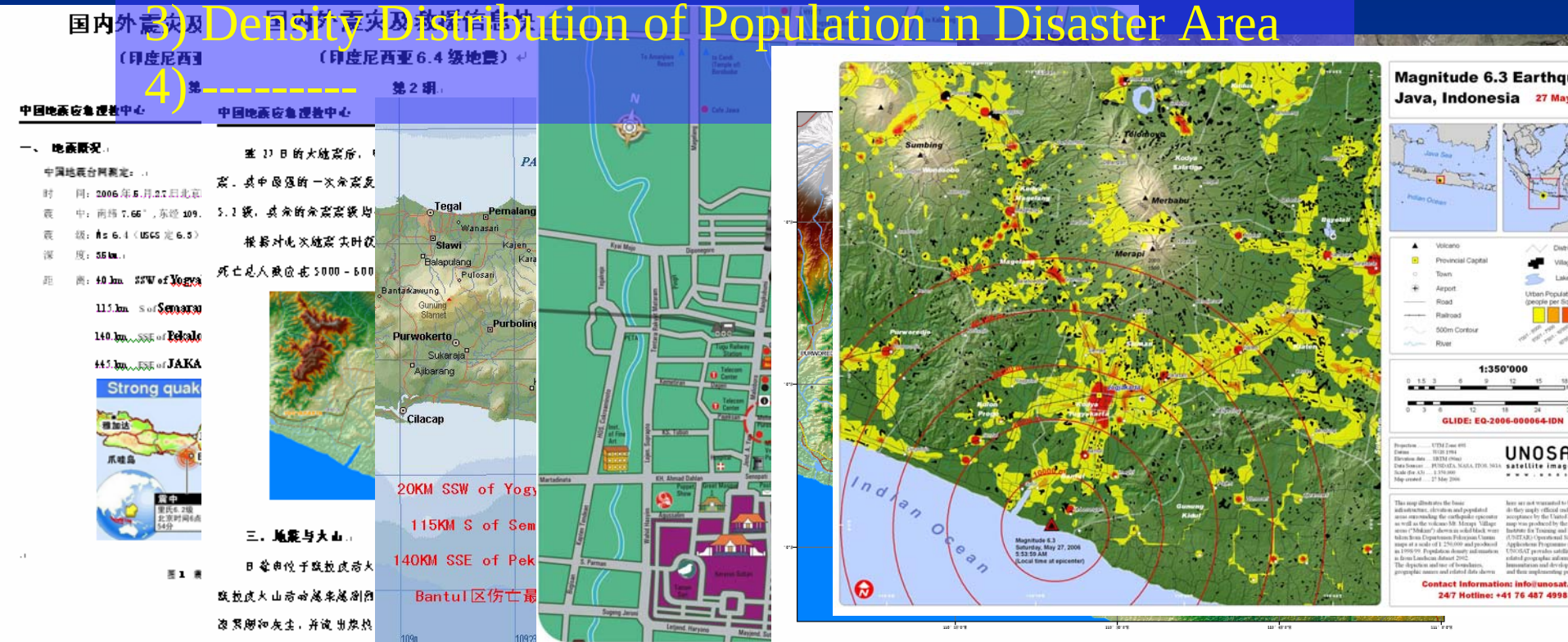
Earthquake intensity is the index of the damage severity in earthquake disaster area. Due to the standards for the classification of intensity are different in different countries, to make it simple, we classify three damage degree of Yogyakarta into three categories: *light damage*, *moderate damage and heavy damage*. Here the heavy damage covers the range of intensity VIII-IX, moderate damage is equal to intensity VII－VIII, and light damage ranges from VI to VII. The highest intensity incurred from Yogyakarta earthquake reaches about IX.

In this report, *we focus mainly on heavy damage and moderate damage area*. Due to the time limited and disaster areas are so large, only part of light damaged area included in our report.

III. Emergency Responses and Assessments of Earthquake Disaster

1. Disaster Information Supports and Emergency Response before the Operation of Disaster Rescue

1) Information of Topography and Infrastructures
2)On-Site Disaster Information Collection
3) Density Distribution of Population in Disaster Area
4)----------



III. Emergency Responses and Assessments of Earthquake Disaster

2. Disaster Information Supports and Emergency Response during the Operation of Disaster Rescue

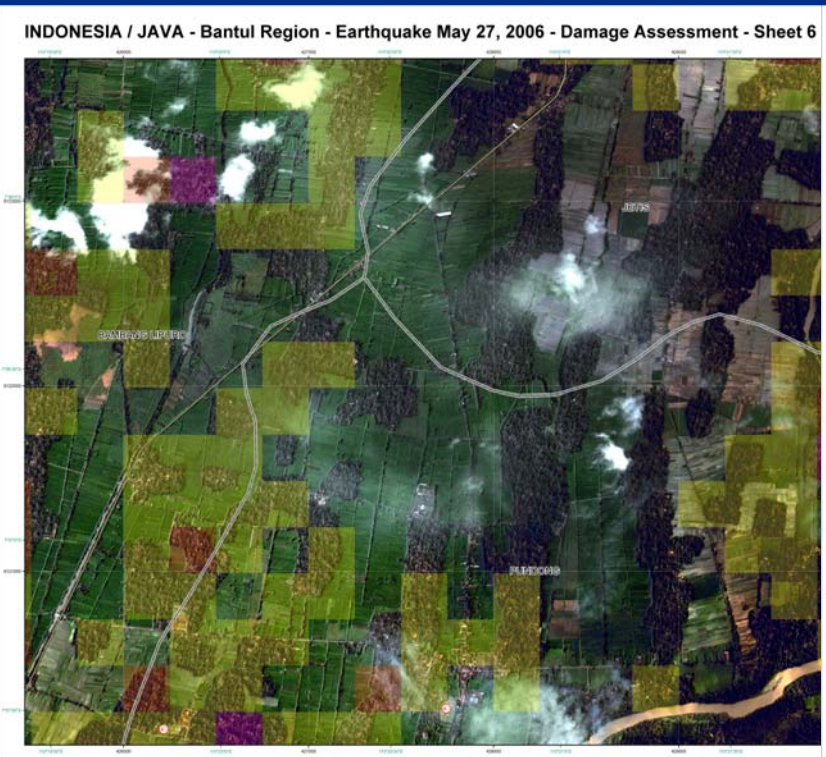
1) Start up at 3:00, 29, May. Arrived Solo Airport in 0:15, and Bantul in 5:00 am, 30 May.

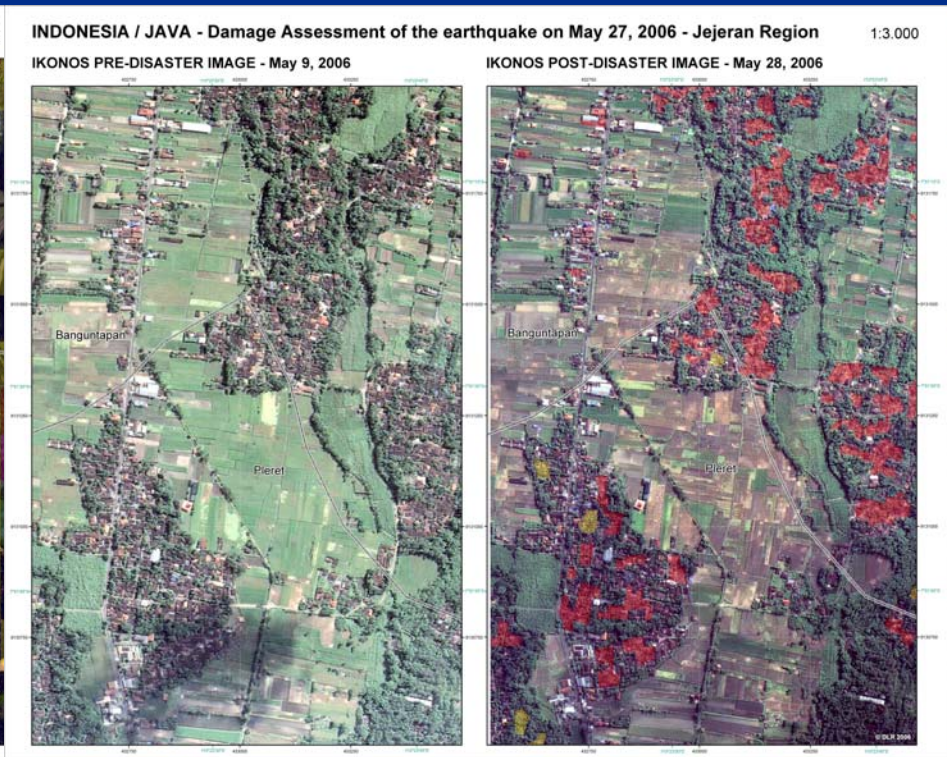
2) To select the encampment for rescue operation.

3) Assessment of earthquake disaster site by site.

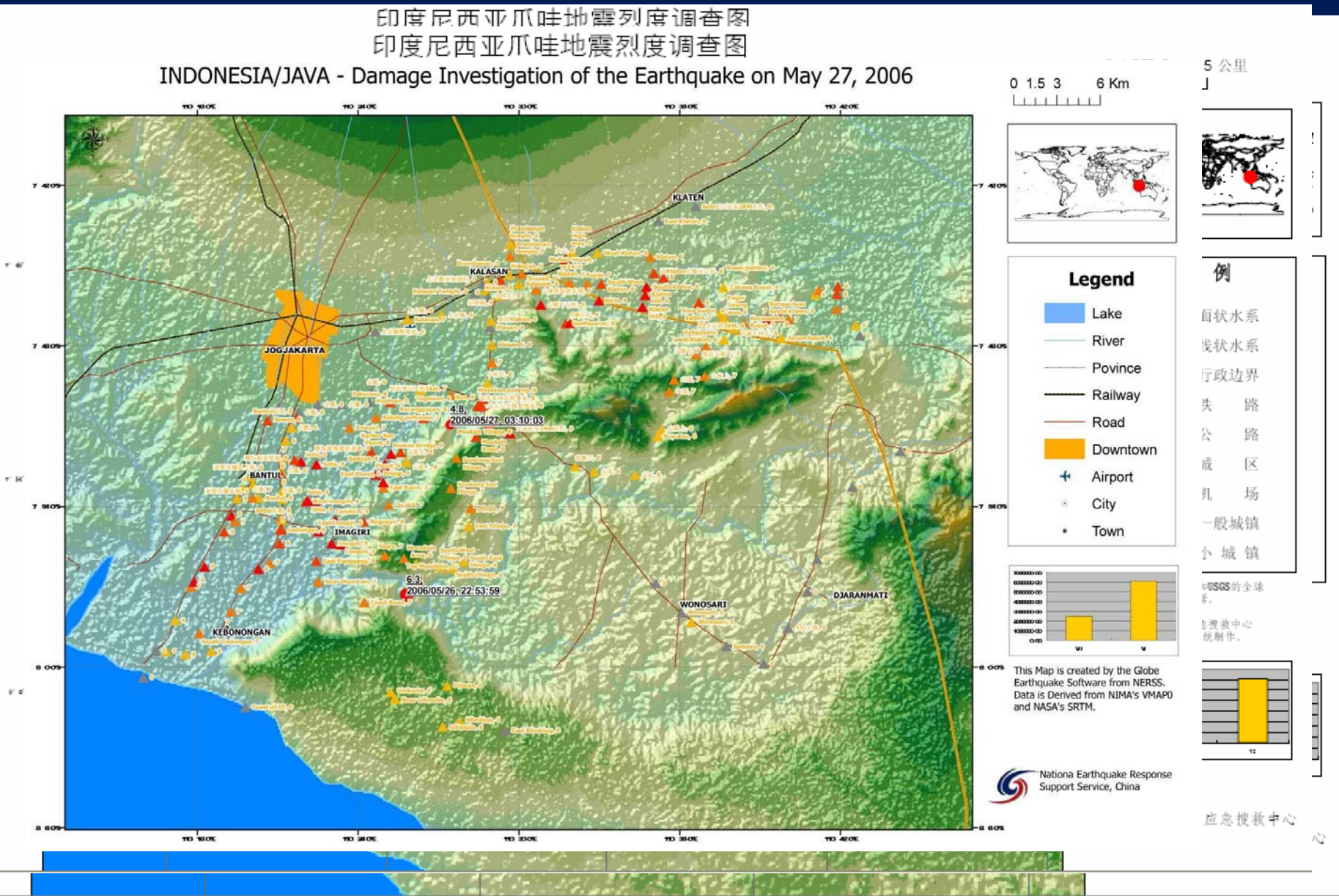
III. Emergency Responses and Assessments of Earthquake Disaster

- **Provide more high resolution images of QuickBird for disaster assessment and more message from impacted area by disaster in rear support center.**



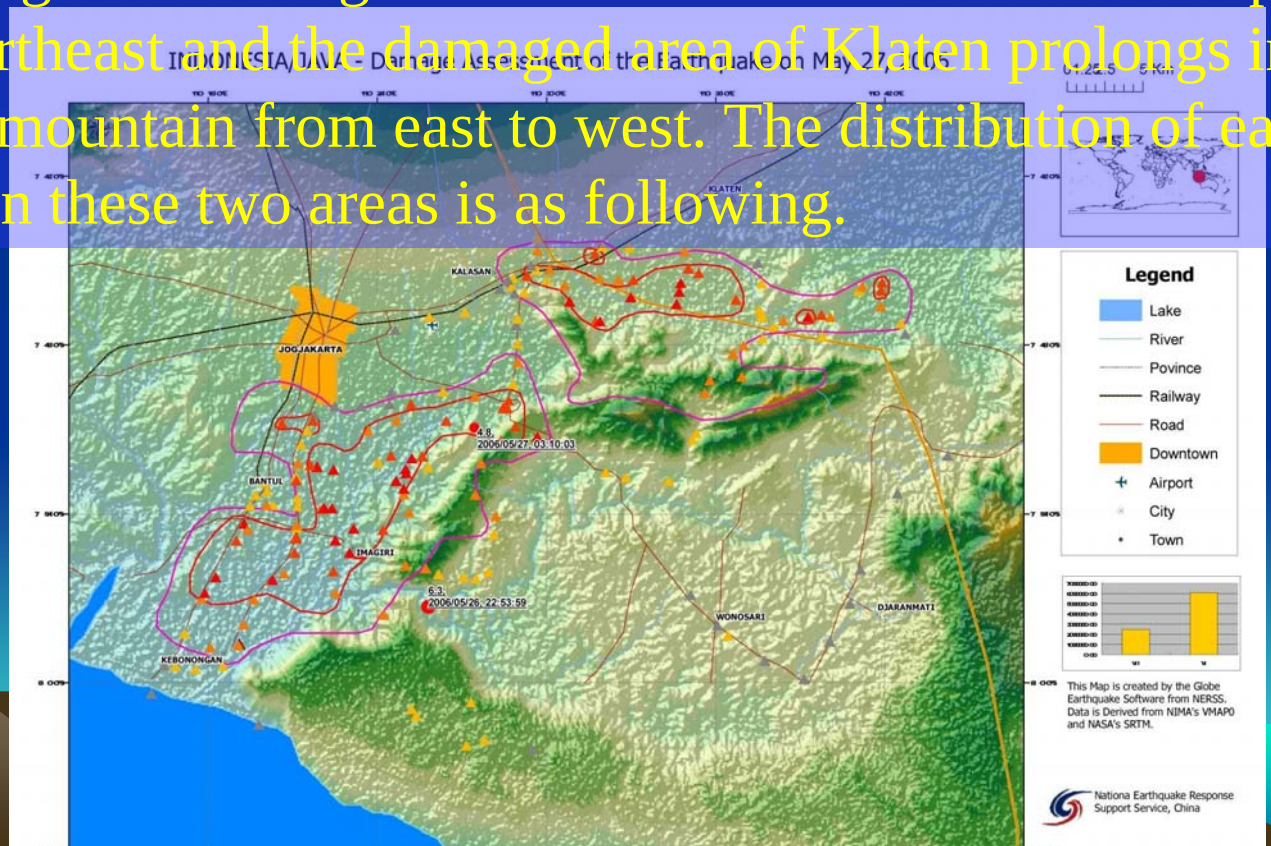


- **Data collection of damages buildings and highway on-site day by day. 190 site data for damage assessment.**



IV. Types and Distributions of Earthquake Disaster

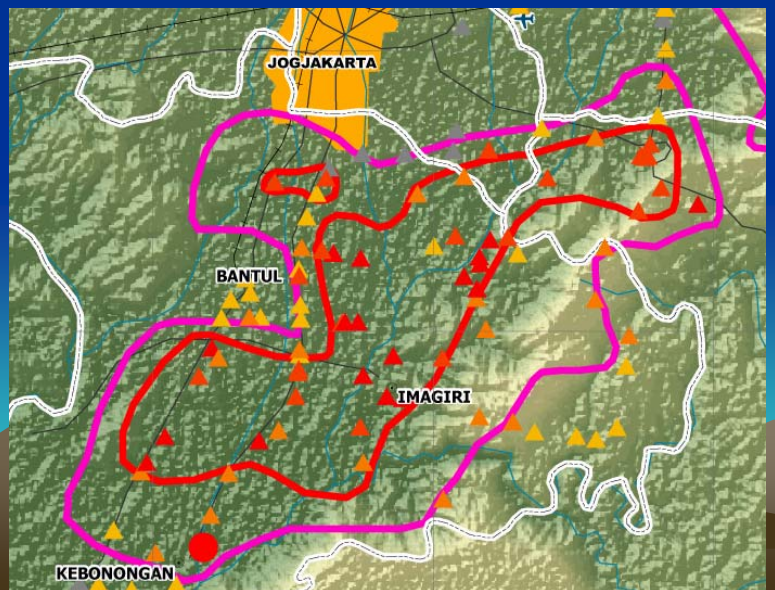
The disasters caused by Yogyakarta earthquake are mainly located in the middle of the plain and the foot hill of the mountains. Volcano Merapi is on the north of the damaged area. Based on more than 190 investigation spots in this area, Bantul and Klaten are classified into the heavy damaged area and these two areas are not connecting. The damaged area of Bantul looks like an ellipse with axis along northeast and the damaged area of Klaten prolongs in parallel with the mountain from east to west. The distribution of earthquake disaster in these two areas is as following.

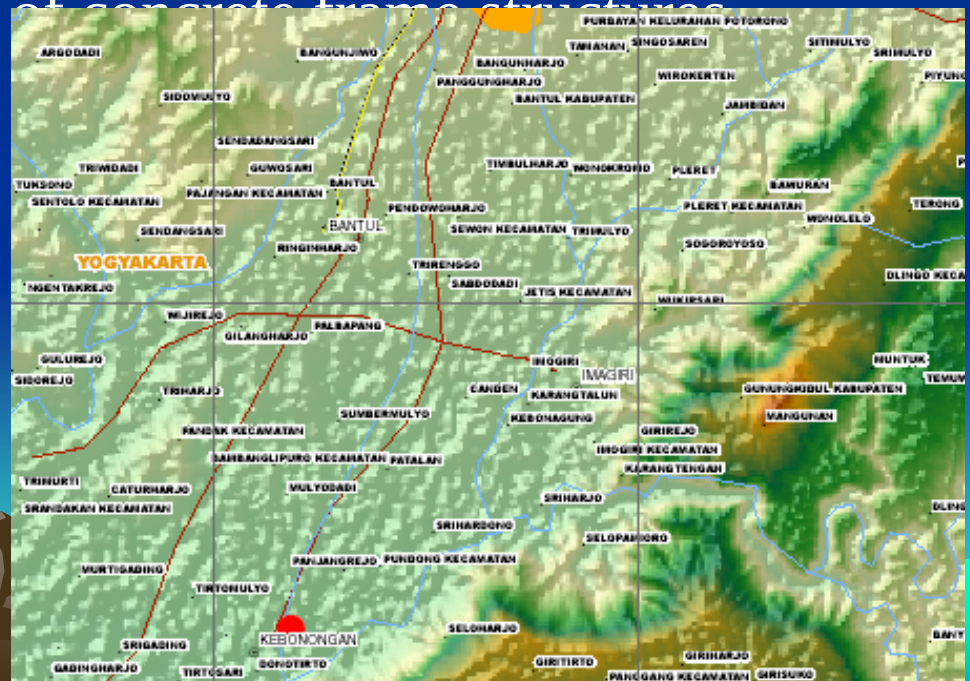


IV. Types and Distributions of Earthquake Disaster

1. Bantul damaged area

1) Heavily damaged area: Heavily damaged area are mainly distributed in the southern, eastern, and northern part of Bantul along the foothill and basin area with the direction of NE, from Sewon in north to Pundong in south, including Jetis, Imogiri, Sewon, Pundong, Pleret and Bangonpapan et al. Heavy damaged and collapsed houses are about 80-90%. Houses in this area are mainly wood or brick structure with some of concrete frame structures.





IV. Types and Distributions of Earthquake Disaster

1. Bantul damaged area

Imogiri is located in the east foothill area of the mountain and 90% of the houses in this area are heavily damaged and totally collapsed. The collapsed houses are mainly brick structure and the wall is very thin (120mm) with one layer of brick. The roof is usually made of wood and tiles. Many houses are collapsed in the center of Imogiri and the houses along the street are severely damaged. Compared to the east mountain area, more houses are collapsed in this area.

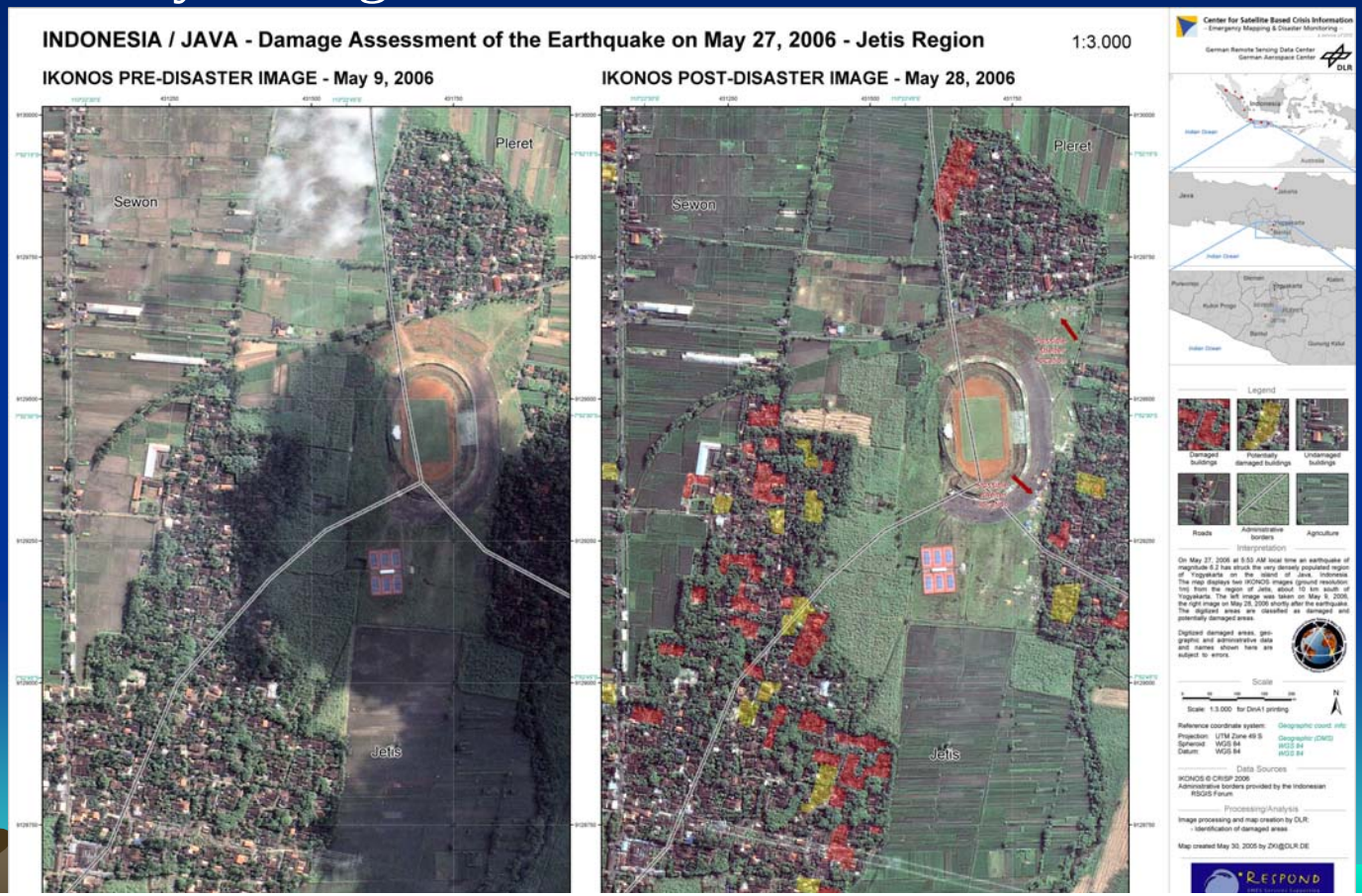



Pictures of damaged houses and disaster distribution in Imogiri

IV. Types and Distributions of Earthquake Disaster

1. Bantul damaged area

The interpretation of Quickbird images and field investigation indicate that 60% of the houses in Jetis are totally collapsed and 30% are severely damaged.



Pictures and image show the severely damaged area of Jetis

IV. Types and Distributions of Earthquake Disaster

1. Bantul damaged area

Pleret is located on the north of Imogiri. 90% of the houses are severely damaged or collapsed and the collapsed houses are mainly brick structure whose walls are made from one layer of bricks. The roof is made from woods and very heavy tiles. Many houses are collapsed in this area which makes Pleret the most severely area in Bantul

IV. Types and Distributions of Earthquake Disaster

1. Bantul damaged area

The situation of roads and bridges in the severely damaged area

Slope failure along the roads and break at the end of the bridges are found in Imogiri, Pleret and other severely damaged areas.

In the east of Imogiri, there are cracks on the piers of one bridge in the east of the river bank. In the west bank, slopes failures are found and need to be reinforced

IV. Types and Distributions of Earthquake Disaster

1. Bantul damaged area

A 10-meter bridge was collapsed and has been repaired after the earthquake in the north of Pleret.

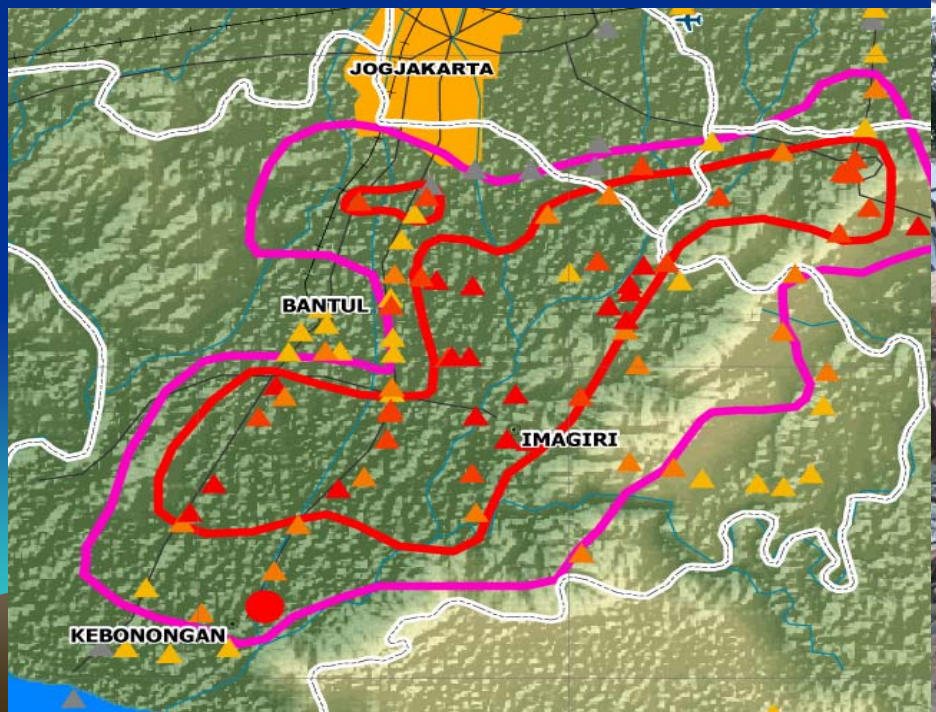
Slope failure of a roadbed is found in the south of Imogiri which will not affect the traffic after being repaired.

IV. Types and Distributions of Earthquake Disaster

1. Bantul damaged area

2) Moderately damaged area

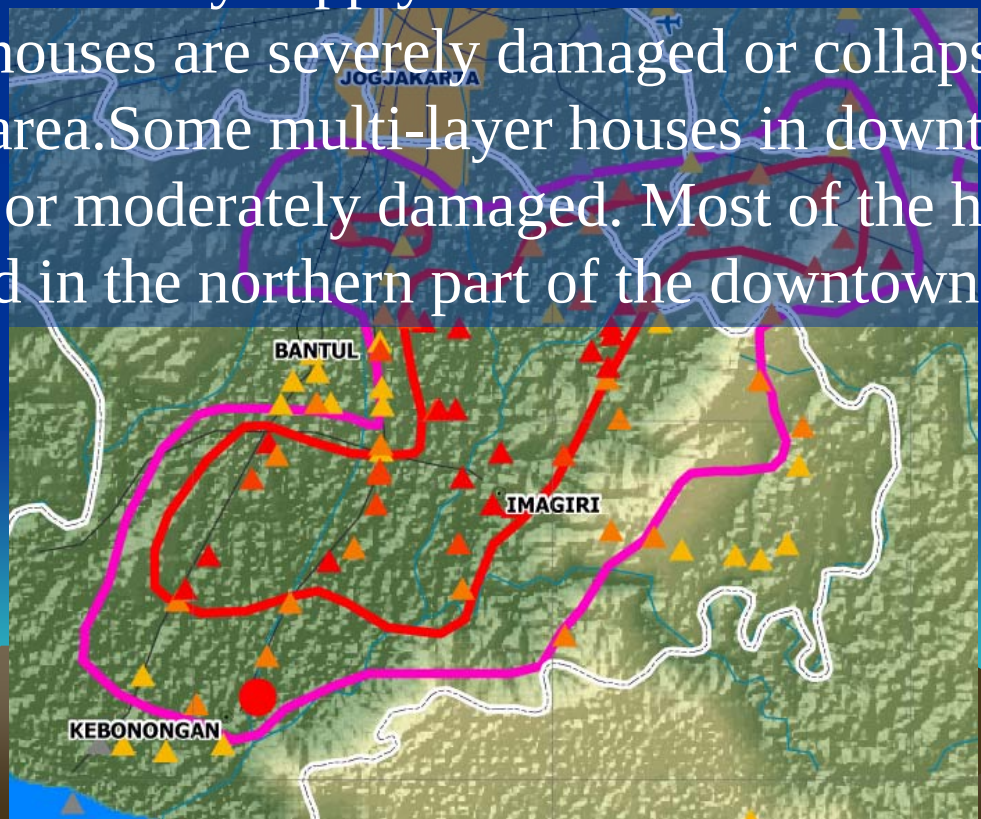
Outside the severely damaged area, including downtown Bantul, Sawanhan, Celep, Bun, Gadungan and other areas are moderately damaged where 30% to 50% houses are heavily damaged or collapsed and 30% to 50% are moderately damaged. The lifeline structures are without any damage.



IV. Types and Distributions of Earthquake Disaster

1. Bantul damaged area

The areas in the eastern and southern parts of Bibal, from south of Celep to the Indian Oceanic beach, the western part of Bantul are the lightly damaged area. Landslide, slope failure and bridge bed failure are found, but the road and bridge are still passable. Electricity supply and communication are undamaged. Only few houses are severely damaged or collapsed in the mountain area.Some multi-layer houses in downtown Yogyakarta are lightly or moderately damaged. Most of the houses remain undamaged in the northern part of the downtown area.

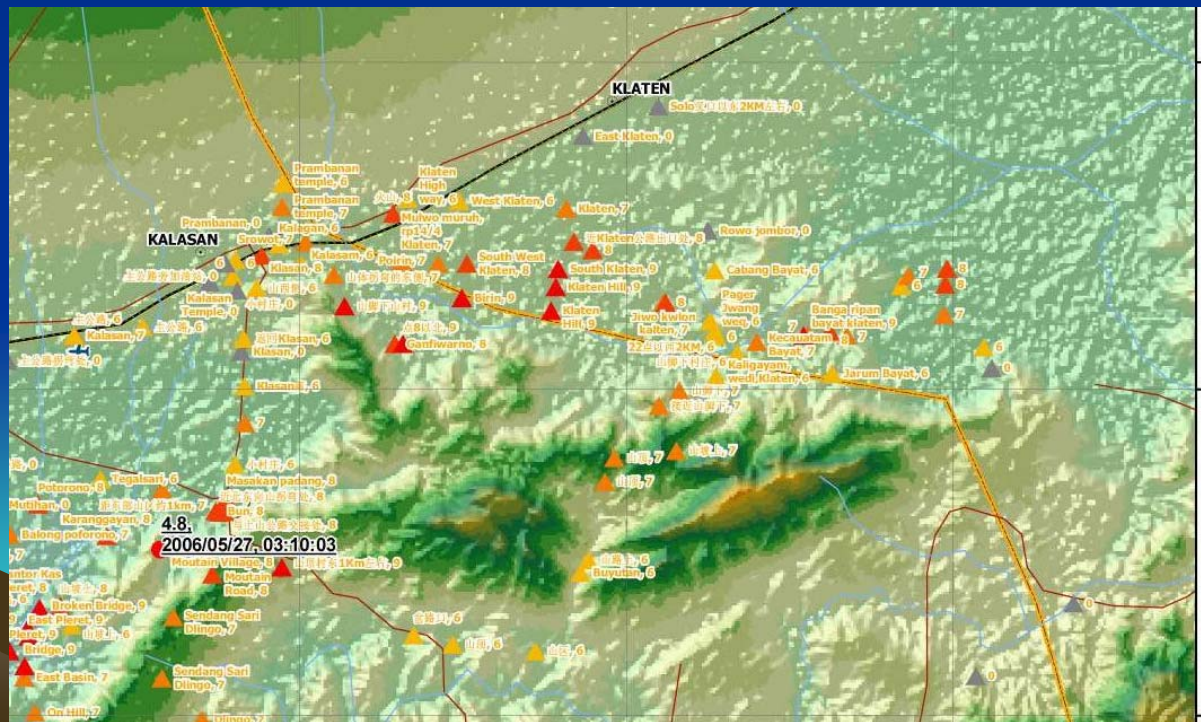


IV. Types and Distributions of Earthquake Disaster

2. Klaten damaged area

1) Heavy damaged area

The heavy damaged area distributed in the southern and western part of Klaten, along the plain of foothill of mountain, with a strike of northwest to east-west. The villages located in the eastern part of foothill of NW small mountains in south of Kalasan and the villages in south of the Kalasan-Klaten highway are also heavily damaged.

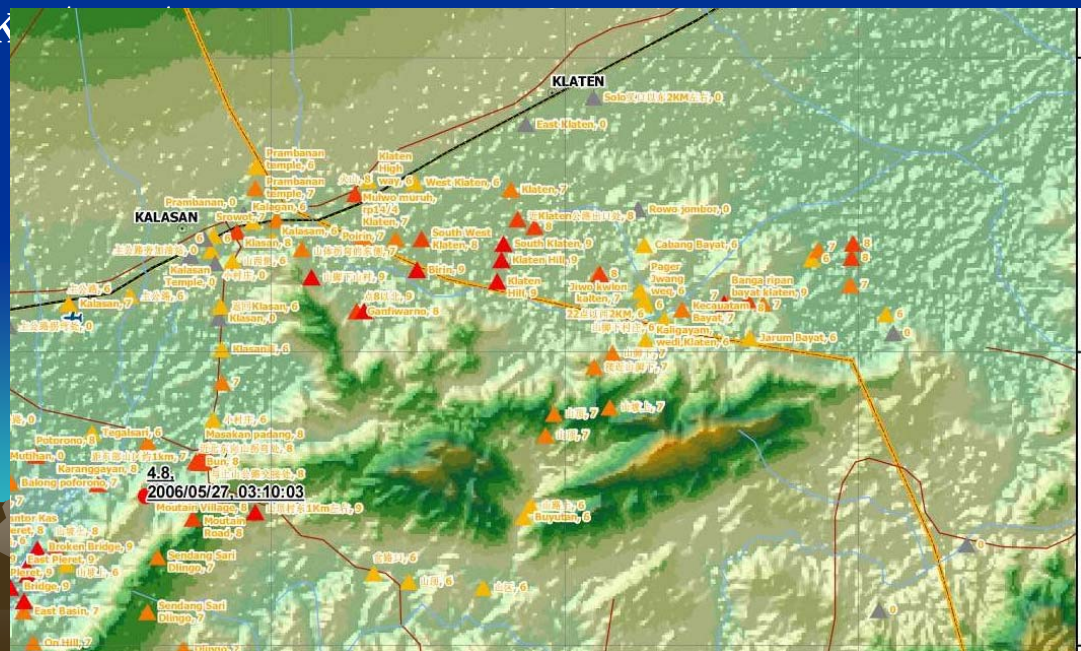


IV. Types and Distributions of Earthquake Disaster

1. Klaten damaged area

1) Heavy damaged area

To the southeast of Klaten, the damage is decreasing. The severely damaged villages in Klaten area include Gantiwarno, Poirin, Tegalrejo etc.. Intensity in the area are from VIII to IX and almost 60% to 80% of the houses are severely damaged or collapsed. Poirin is the most severely damaged area, where the intensity reached IX and over 90% of the houses are severely damaged or totally collapsed. The types of houses are mainly wood or brick



IV. Types and Distributions of Earthquake Disaster

2. Klaten damaged area

Poirin is located in the south of Kalasan - Klaten highway. 90% to 100% of the houses in this village are severely damaged or totally collapsed with one layer brick walls and roofs made from woods and tiles. Almost all the buildings in this village are collapsed which made Poirin the most severely damaged area in Klaten.




IV. Types and Distributions of Earthquake Disaster

1. Klaten damaged area

Mulwo Muru, RT 14/4 Klaten

These village are located in the south of Kalasan - Klaten highway. 90% of the houses are severely damaged or totally collapsed which are mainly made from tuff blocks. Thus tuff blocks have lower resistance ability and are vulnerable to the damage in the earthquake. Mulwo Muru and RT 14/4 Klaten is one of the most severely damaged village in Klaten area.

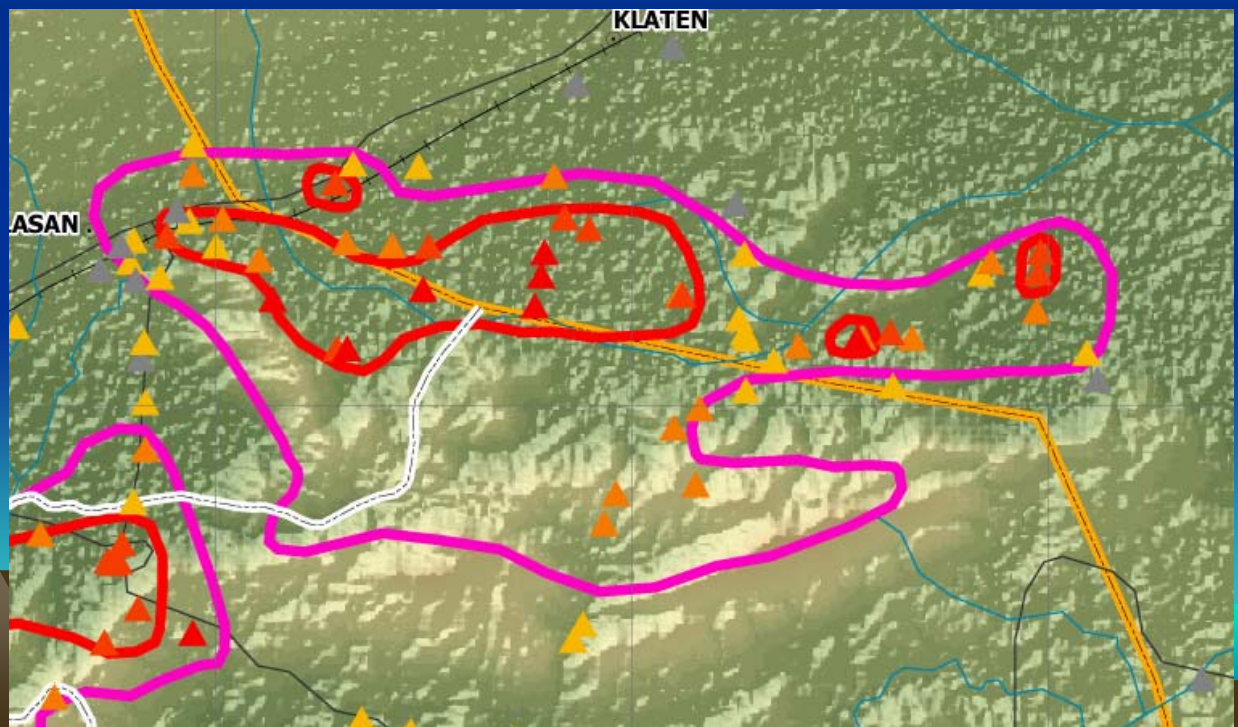



IV. Types and Distributions of Earthquake Disaster

2. Klaten damaged area

2) Moderately damaged area

Outside the heavy damaged area, including Kalasan, Prambanan Temples, south side area of Kalasan - Klaten highway, Jarum Bayat are moderate damaged area. 30% to 50% of the houses are severely damaged and collapsed. The lifeline systems are almost undamaged. There are about 200 landslides in the south mountain areas.



IV. Types and Distributions of Earthquake Disaster

2. Klaten damaged area

(1) Kalasan

30-50% houses are severely damaged or totally collapsed. The collapsed houses are mainly one layer brick structure. Walls and roofs of house made from woods, bricks and red tiles. Kalasan is one of moderately damaged area of Klaten area.

IV. Types and Distributions of Earthquake Disaster

2. Klaten damaged area

(2) Prambanan Temple

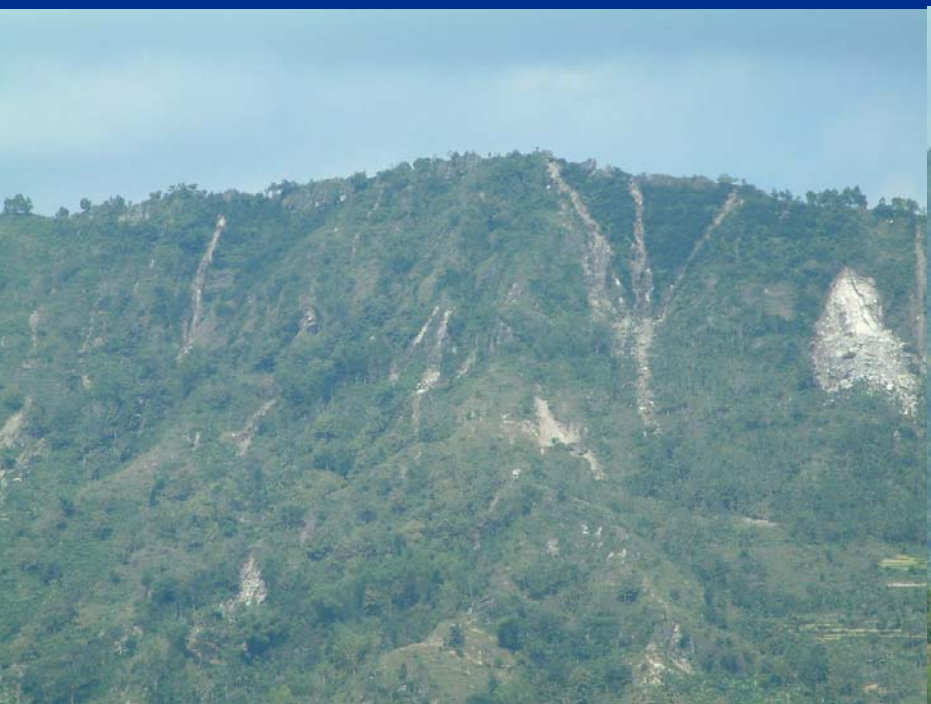
The Hinduism Prambanan temples are on list of the world culture heritage list, which compose of more than ten stupas with the height from 10 to 40 meters. More than 500 pieces of stones from the stupa are detached by the earthquake in which almost 400 pieces are from there main stupas. Some cracks are found on the foundation of the stupas. These stupas are built from tuff stones in the 8th century and experienced several earthquakes afterward. The earthquake caused moderately damage to the stupas this time.

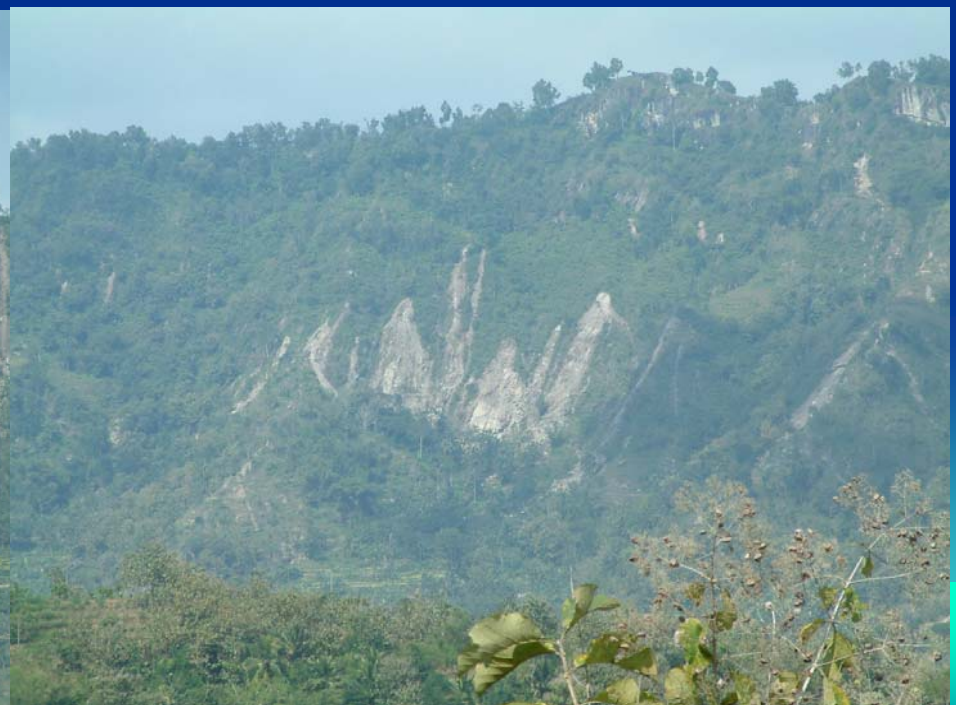
IV. Types and Distributions of Earthquake Disaster

2. Klaten damaged area

(5) The southern mountainous area

There are more than 200 small to middle scale landslides in this area. The landslides are mainly on the north slope of the mountains and stop at the middle of the mountain slope (Fig.21). No damages are caused to those villages in the foothill of the mountains.



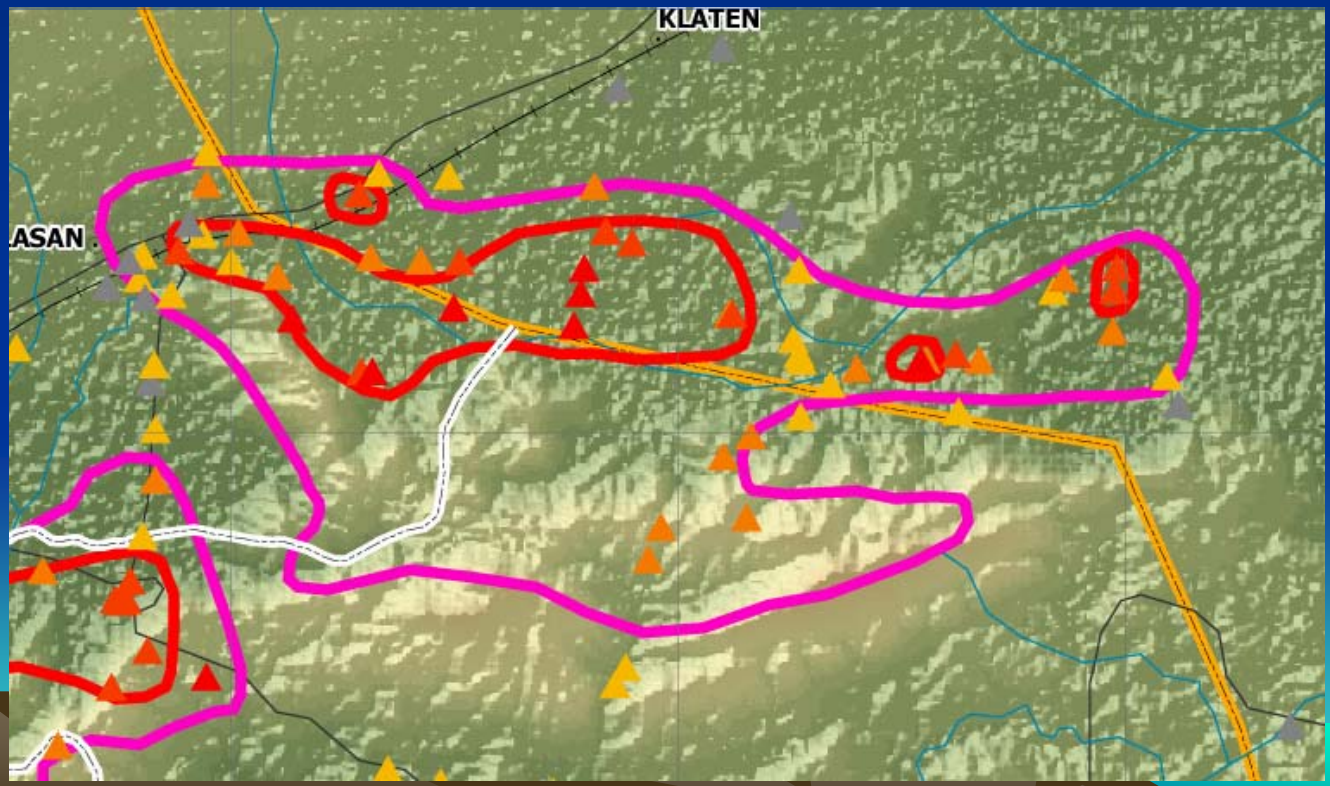


IV. Types and Distributions of Earthquake Disaster

2. Klaten damaged area

3) Lightly damaged area

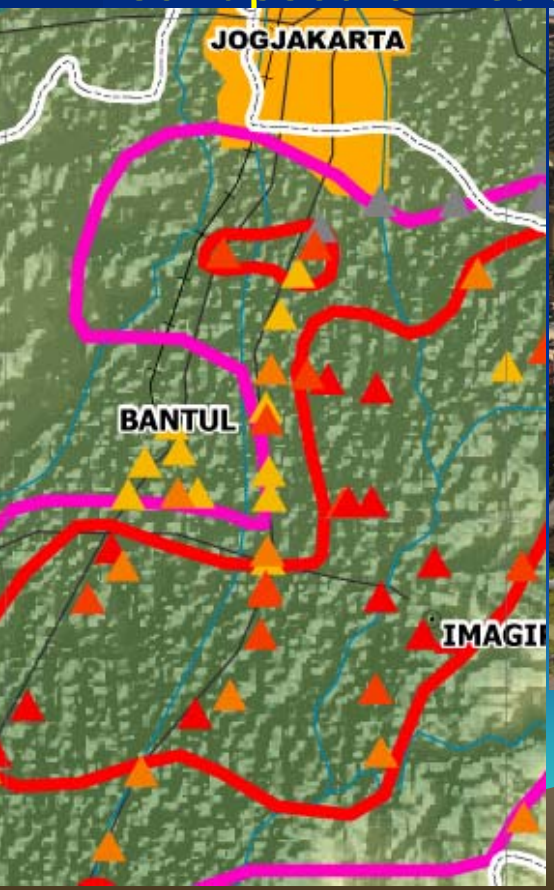
The area in west and north of Kalasan, Klaten and the area close to the Kalasan-Klaten highway, the southeast area of Klaten and the south mountain area are lightly damaged.

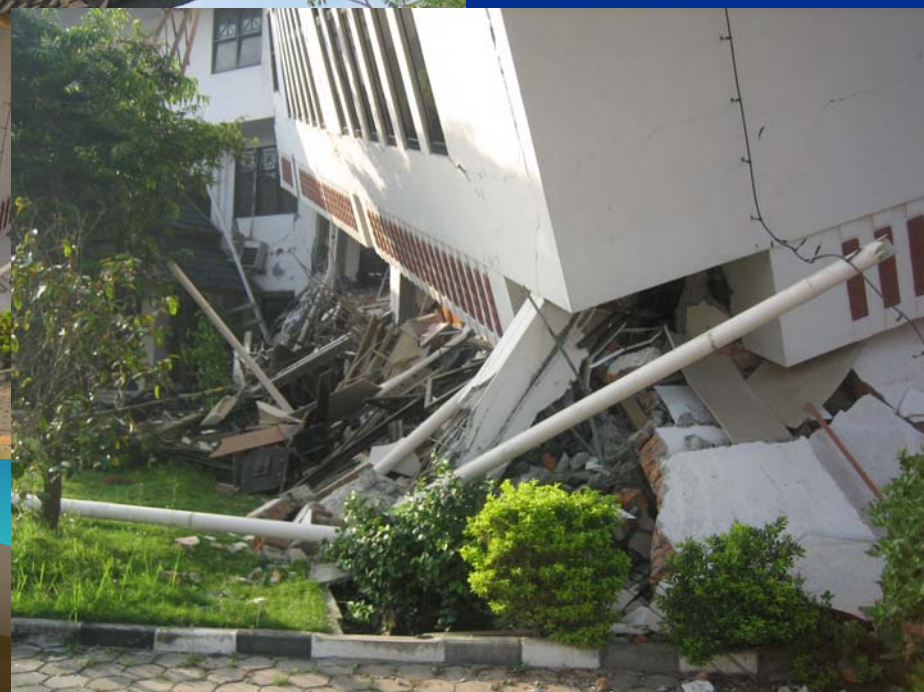


IV. Types and Distributions of Earthquake Disaster

3. Jarakan damaged area

Jarakan damaged area are located on the north of Bantul, this is a relatively small severely damaged area where a three- story office building is collapsed (Fig.22) and some brick houses are also collapsed or heavy damaged.



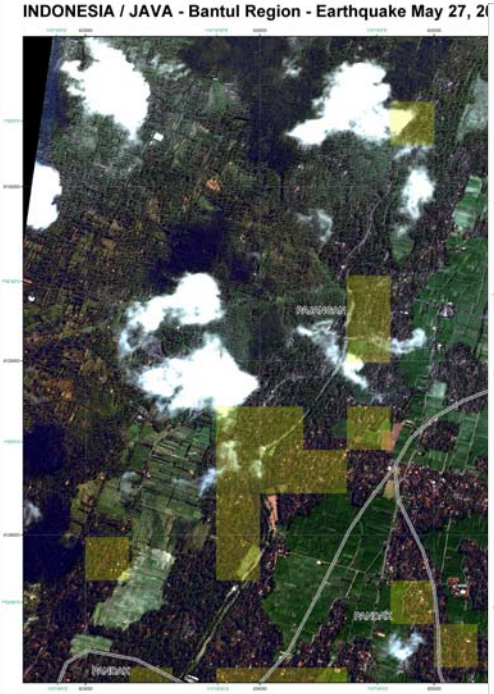


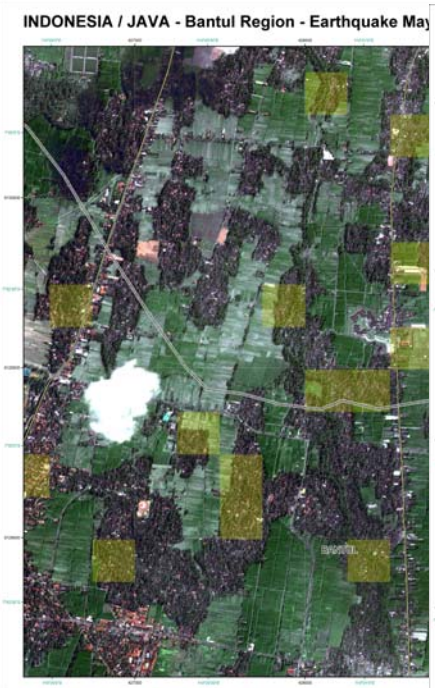
V. Comprehensive earthquake disaster assessment and their feature analyses

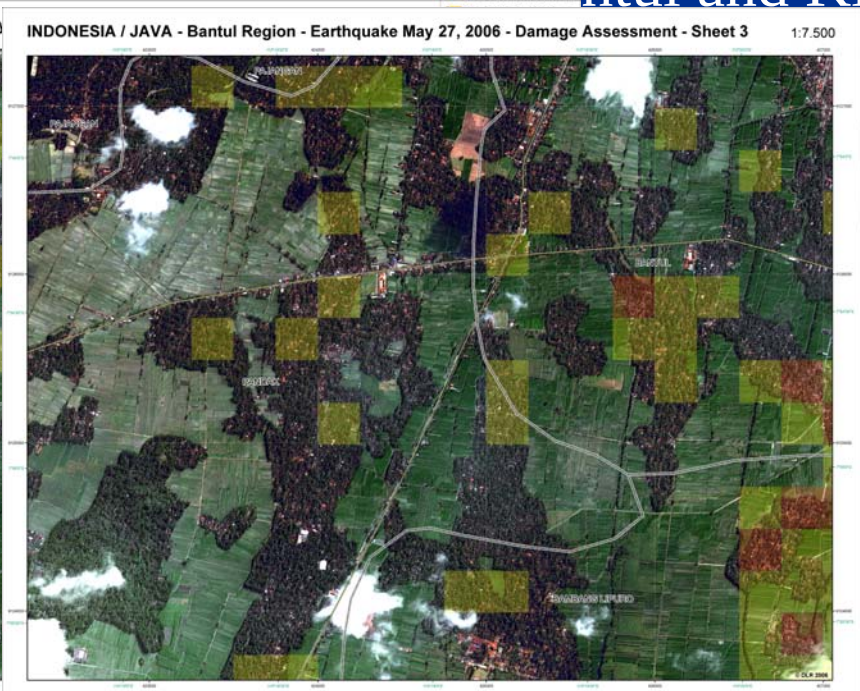
1. Comprehensive earthquake disaster assessment and map compiling

1) In order to evaluate the earthquake disaster and its distribution, and further analyze the disaster patterns and causes, we investigated the buildings and lifelines damage in the two severely damaged areas.

2) Using the disaster interpretation from high resolution satellite images and the reports from villages and towns, we give the isoseismic lines to show the spatial distribution of damages in the Bantul and Klaten.



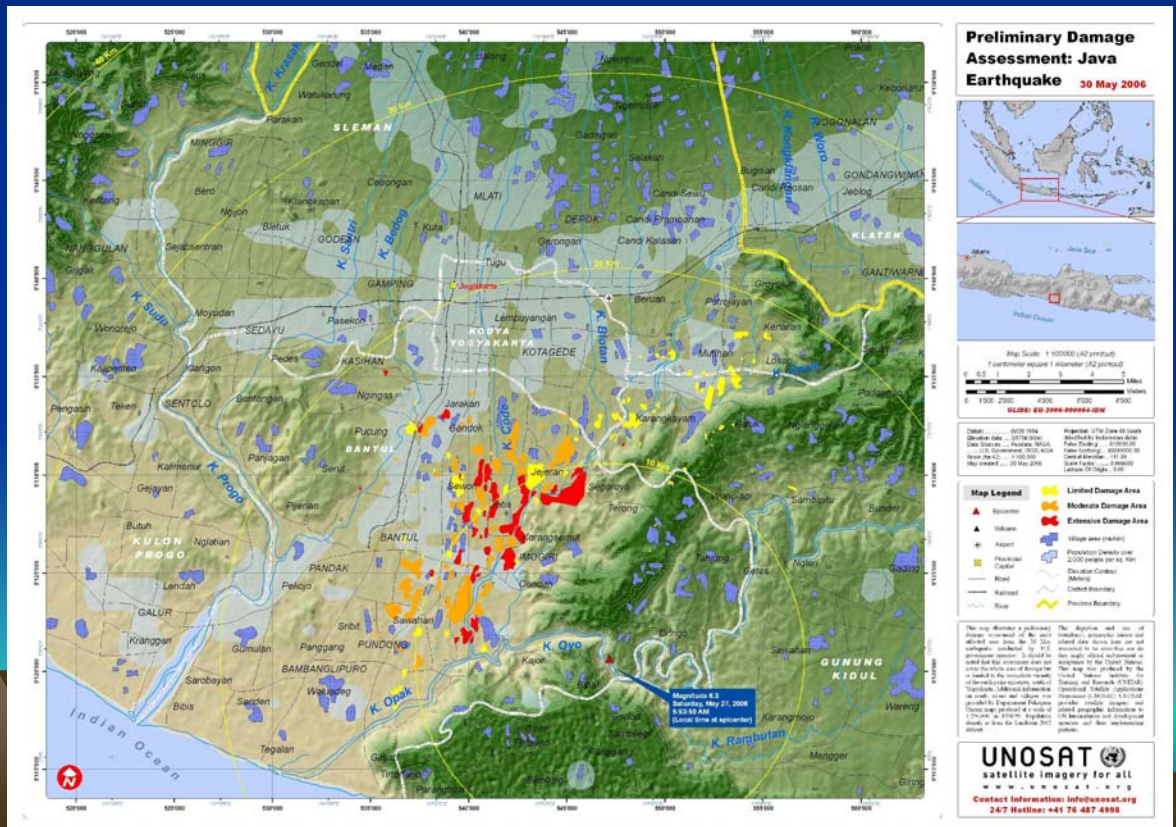




V. Comprehensive earthquake disaster assessment and their feature analyses

3)Earthquake damage reports from villages and towns.

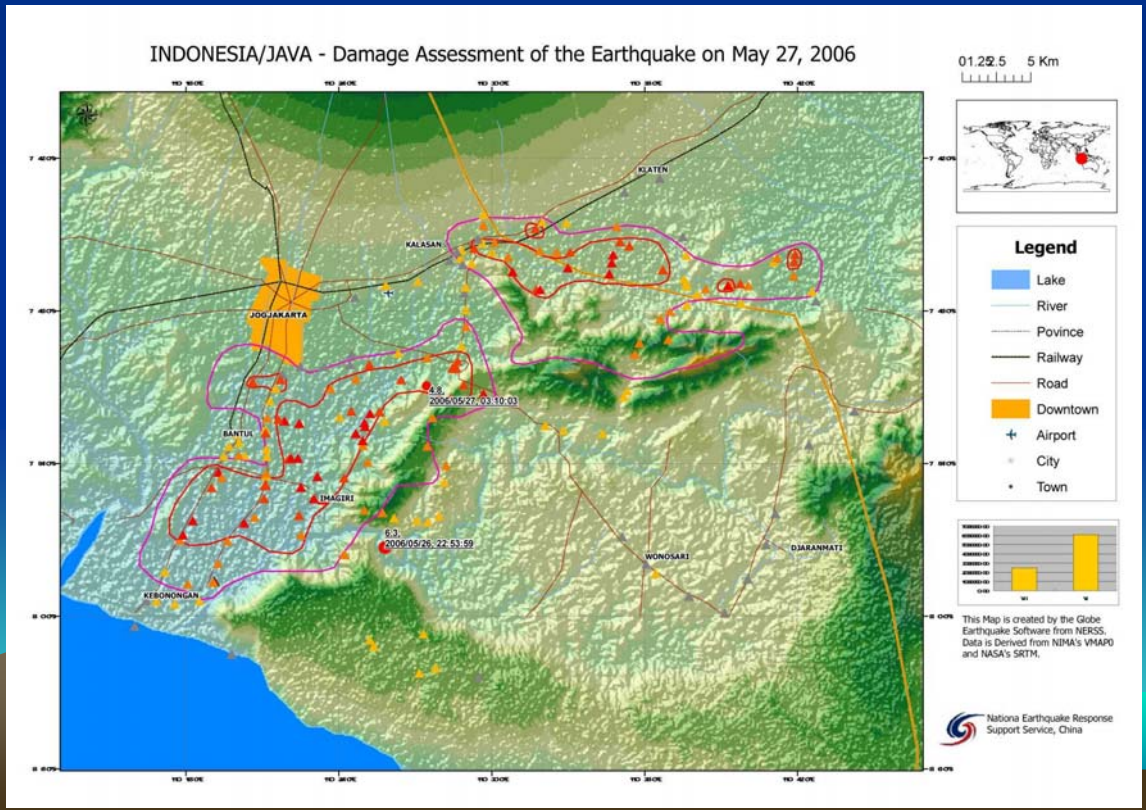
UNOSAT provides the results about this earthquake disaster (Fig. 69) which shows that the severely damaged area is in the plain on the east of Bantul while there is no damage report in Klaten area.



V. Comprehensive earthquake disaster assessment and their feature analyses

4) Comprehensive earthquake disaster assessment

Figure shows the earthquake disaster degree and distribution mainly from the results of disaster investigation, as well as disaster interpretation results from high resolution satellite images and disaster evaluation results from UNOSAT.



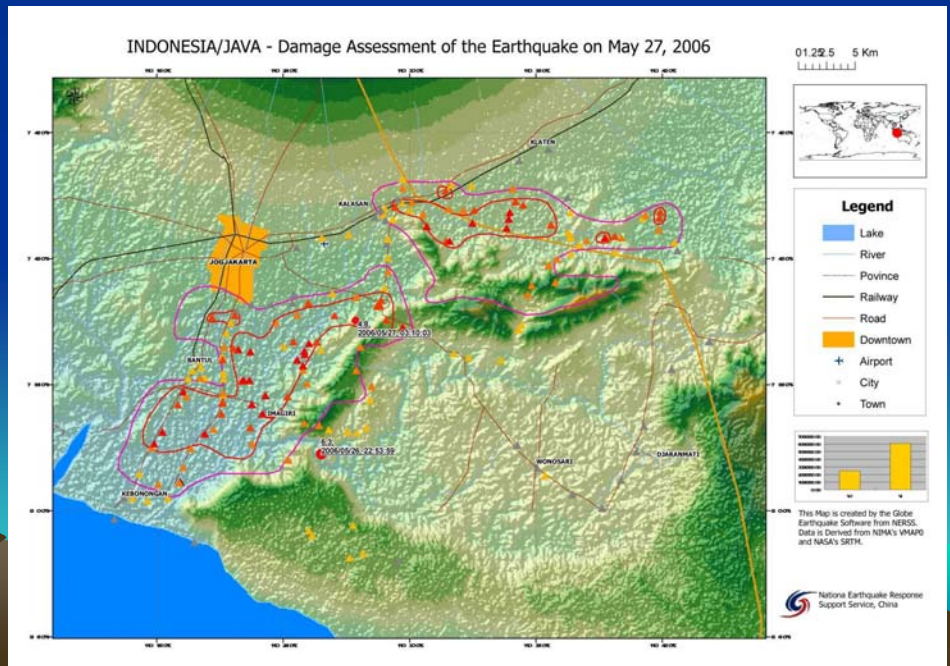
V. Comprehensive earthquake disaster assessment and their feature analyses

2. The characters of Macro-earthquake disaster distribution

1) Bantul severely damaged area

(1) Macro-epicenter is located between the alluvial plain and foothill on the east of Bantul which trends from southwest to northeast where 80-90% buildings are collapsed and severely damaged.

(2) The mountain areas on the east and southeast are near the relocated epicenter by USGS where the buildings are damaged slightly.

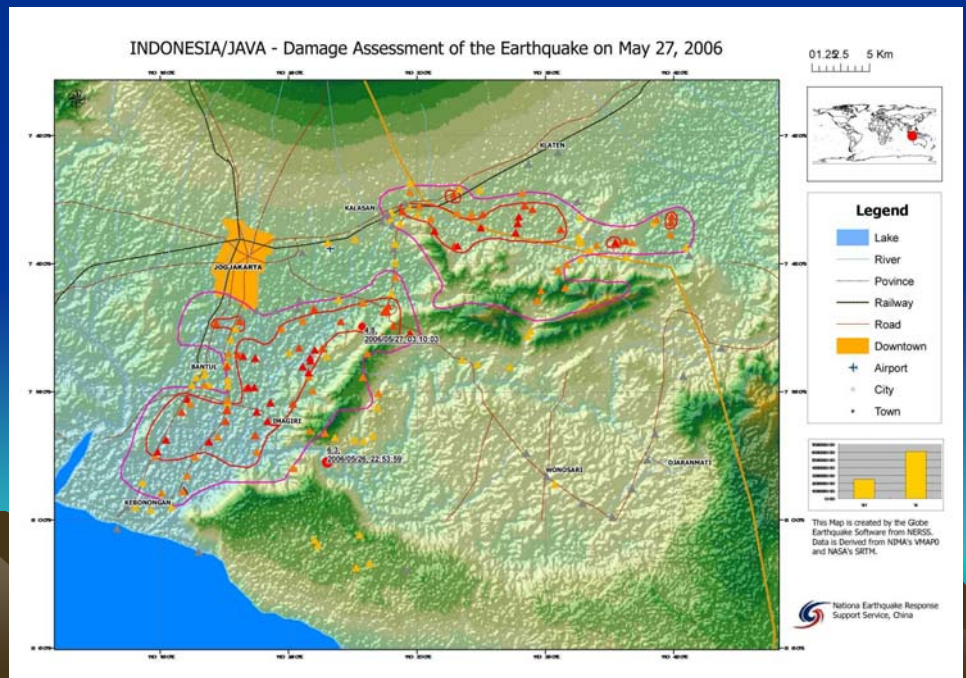


V. Comprehensive earthquake disaster assessment and their feature analyses

(3) There are obvious difference of the damages between the mountainous areas and alluvial plains on the east of Bantul reflecting the aggravated damages by the basin effect.

(4) The losses along the streets are obviously severe in most damaged area which is caused by big open space for shopping activities.

(5) The most damaged and collapsed building type is one-layer wooden or brick houses with thin walls and heavy roofs.



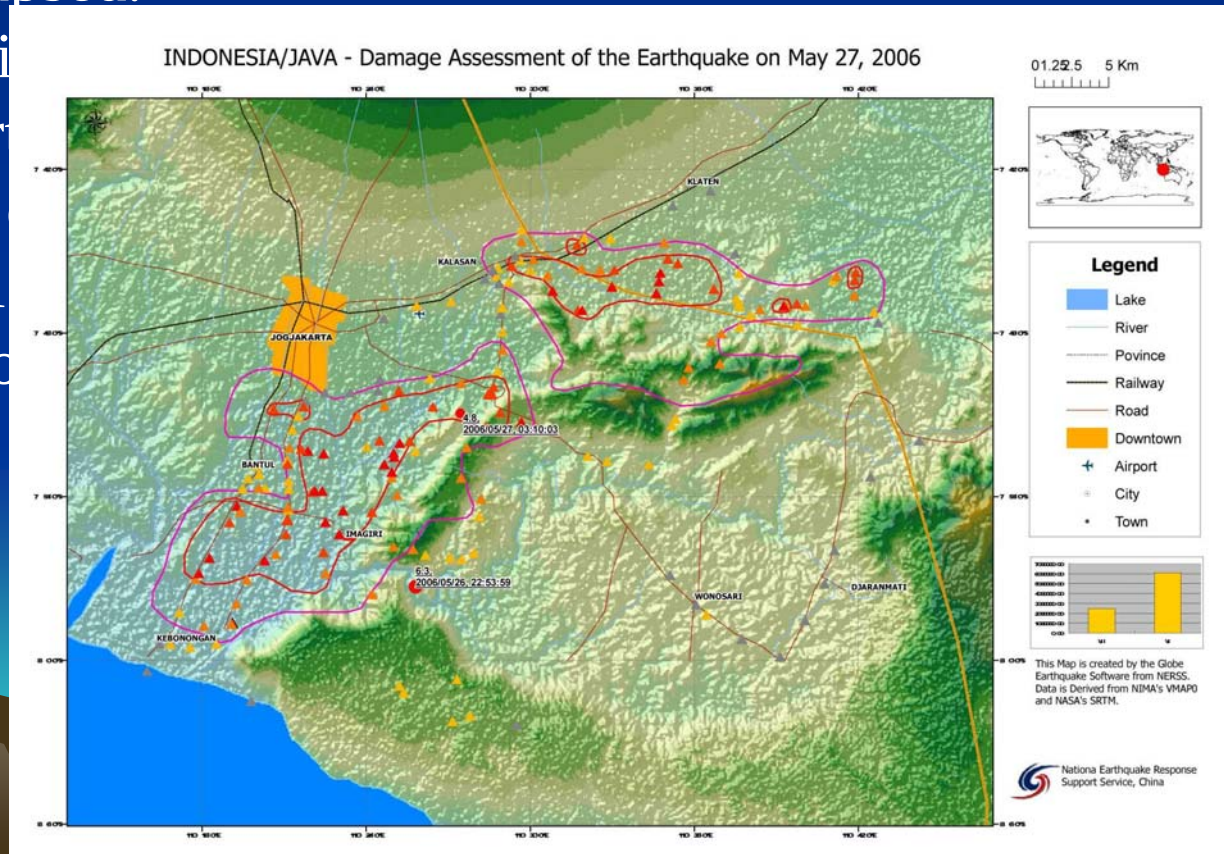
V. Comprehensive earthquake disaster assessment and their feature analyses

2) Klaten: The heavily damaged area

(1) Most damaged area lies in the alluvial plain between the southern Klaten and mountainous area which trends west-east and north-west along the basin in front of the foothill, where 80-90% buildings are heavily damaged and collapsed.

(2) The damages are li
Merapi volcano on the nor

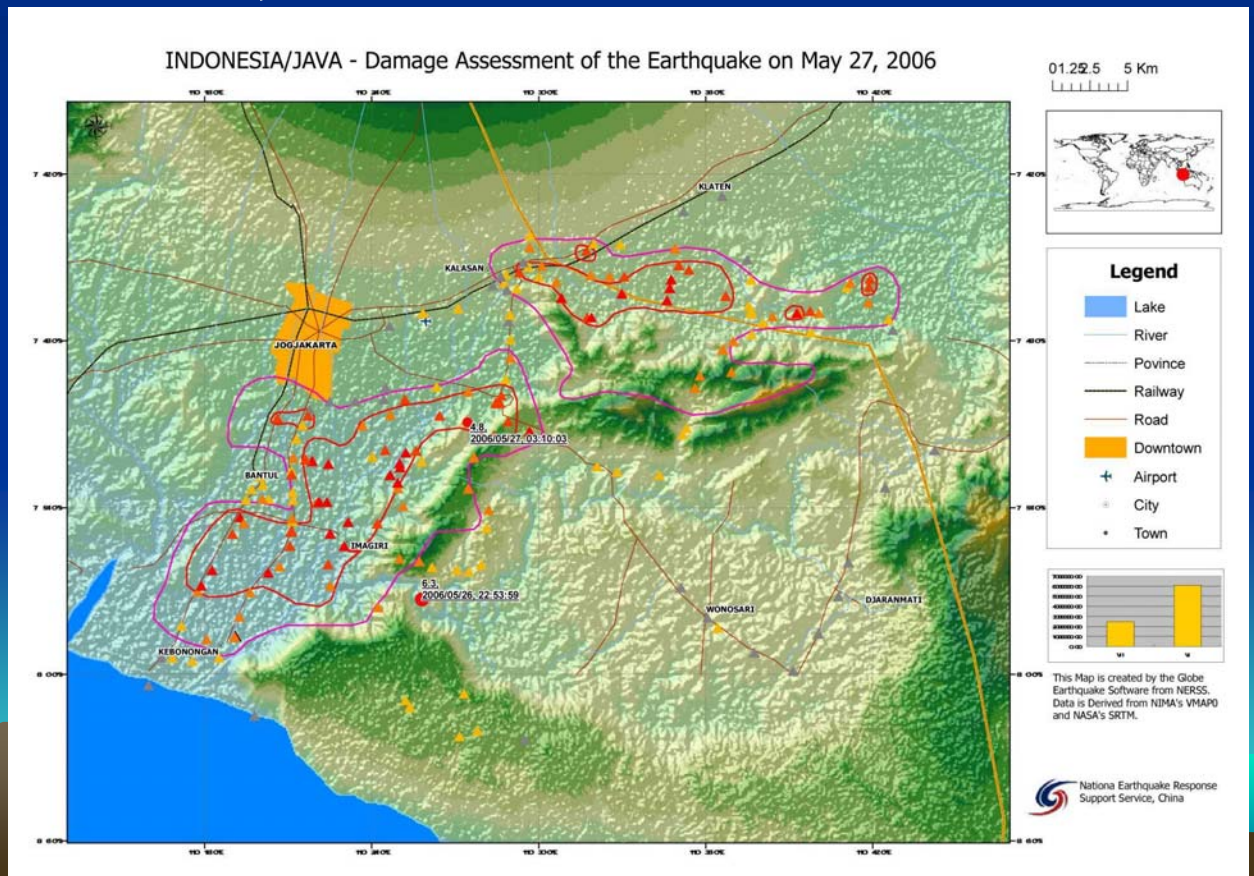
(3) There are obvious
mountain area and alluvial
aggravated damages due to



V. Comprehensive earthquake disaster assessment and their feature analyses

(4) The loss along the streets are obviously severe in most damaged area which caused by big open space for shopping activities.

(5) The most damaged and collapsed building type is one-layer wooden, tuff blocks, or brick houses with thin walls and heavy roofs.



V. Comprehensive earthquake disaster assessment and their feature analyses

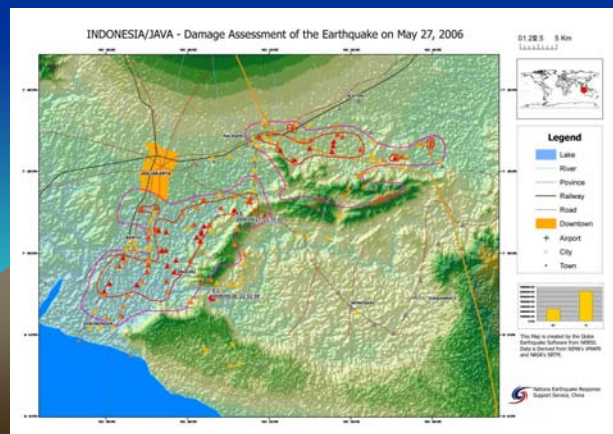
3. Results of earthquake disaster assessments

1) The heavily damaged area

The total squares of severely damaged area by Yogyakarta earthquake (over intensity VIII) is about 155Km², in which the squares of Bantul heavily damaged area is about 115 Km², the squares of Klaten severely damaged area is about 40 Km².

2) The squares of moderately damaged area

The total squares of moderately damaged area by Yogyakarta earthquake (over intensity VII) is about 300Km², in which the squares of Bantul moderately damaged area is about 160 Km², the squares of Klaten moderately damaged area is about 140 Km².



VI. Reasons of severe earthquake disaster

The Yogyakarta earthquake has caused serious casualties and damages to properties, though its magnitude is not so big. The contributing factors are as follows :

1. Unsuitable structure of buildings

The thickness of walls is too thin, or only about 120mm. The brick/concrete columns are slender, while the steels in concrete components (beams and columns) are slender and insufficient. Also, some roofs of buildings are too thick or too heavy.

VI. Reasons of severe earthquake disaster

2. Poor quality of building materials

1) The earthquake resistant behavior of buildings is low in disaster areas, which causes serious casualties. Most buildings in Yogyakarta areas are made up of bricks and tiles, the earthquake resistant capability of which is lower. A moderate scale earthquake may cause a great deal of collapses of buildings and a lot of casualties. The quality of buildings in severely damaged area is lower. Those buildings are mostly made up of bricks, in which walls are the main load-bearing system and the practice of shallow foundation and wood roof frame are adopted. This kind of buildings is not designed strictly and the entire performance of earthquake resistance is relatively low.

2) In two heavily damaged areas, the concrete material used in walls and columns is loose and its strength is low. Moreover, the bond of mortar between bricks of walls is not strong enough.

VI. Reasons of severe earthquake disaster

2. Poor quality of building materials

3) Some buildings in Klaten are made up of loose volcano tuff blocks, and the bond of mortar between bricks is not strong, which reduces the earthquake resistant capability of buildings enormously.

4) Most of buildings collapsed in the earthquake have heavy roofs, while the wood roof frames or thin brick walls couldn’t support the weights.

VI. Reasons of severe earthquake disaster

3. Site condition

The two heavily damaged areas in this earthquake are both located in alluvial plain in front of mountains. The character of distribution of the damages has shown that the damages in plain area are worse than those of mountainous areas nearby, especially in Klaten disaster area which is far away from the microcosmic epicenter. The fact demonstrates that local site conditions further intensify the quake damages. The main reasons for casualties in this earthquake are that most of buildings are located in this type of site conditions.

VI. Reasons of severe earthquake disaster

4. Dense population

The magnitude of earthquake is only 6.4, which is considerably lower as compared with the previous strong shocks occurring in Indonesia. However, this earthquake occurred in plain area, in which the density of population is so high that the casualties are great.

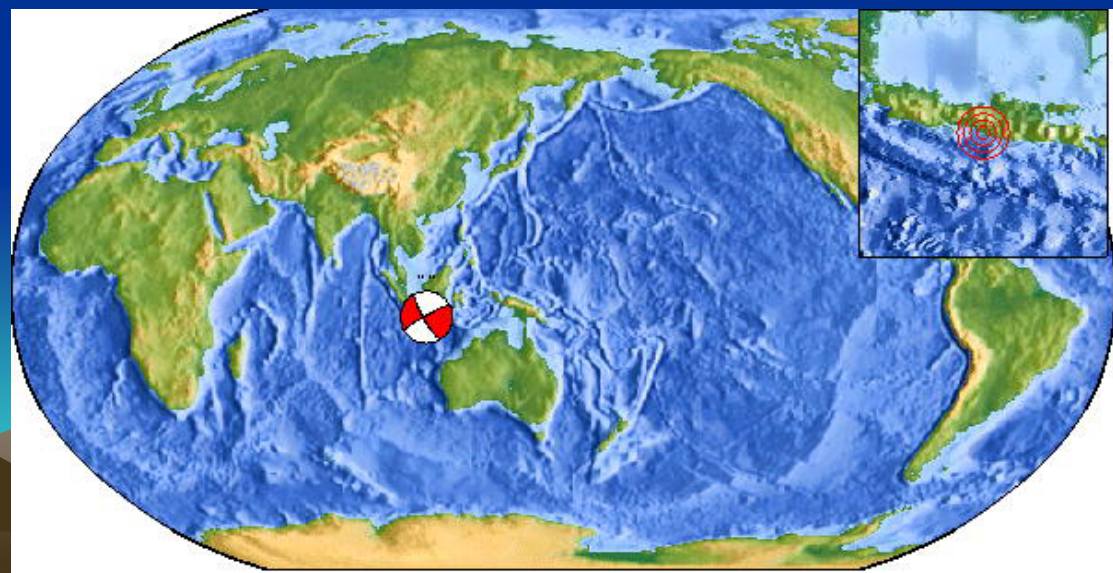
5. Timing

The earthquake occurred at the daybreak of weekend, while most of residents were sleeping. Therefore they were trapped under the ruins of the houses or injured by the falling objects, which aggravates the casualties.

VII. Preliminary explanations on earthquake mechanics and its relationship with Merapi volcano

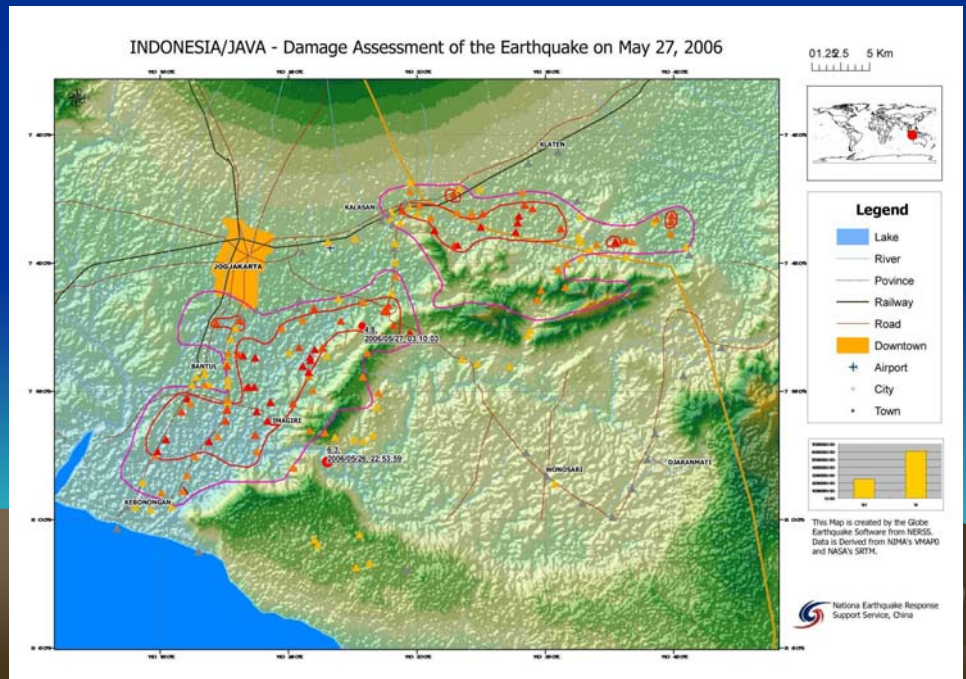
1. Earthquake mechanics and relationship with disaster distribution

After analyzing the spatial distribution of disaster and parameters of Yogyakarta earthquake, our preliminary estimation is that the earthquake generated fault will be normal fault with the strike of NE-SW which dips to the NW along the eastern mountain front plain area of Bantul. The parameters of Yogyakarta earthquake are follows: the micro-earthquake epicenter is 7.65° S and 109.85° E (CENC), the depth of epicenter is 10km (USGS).



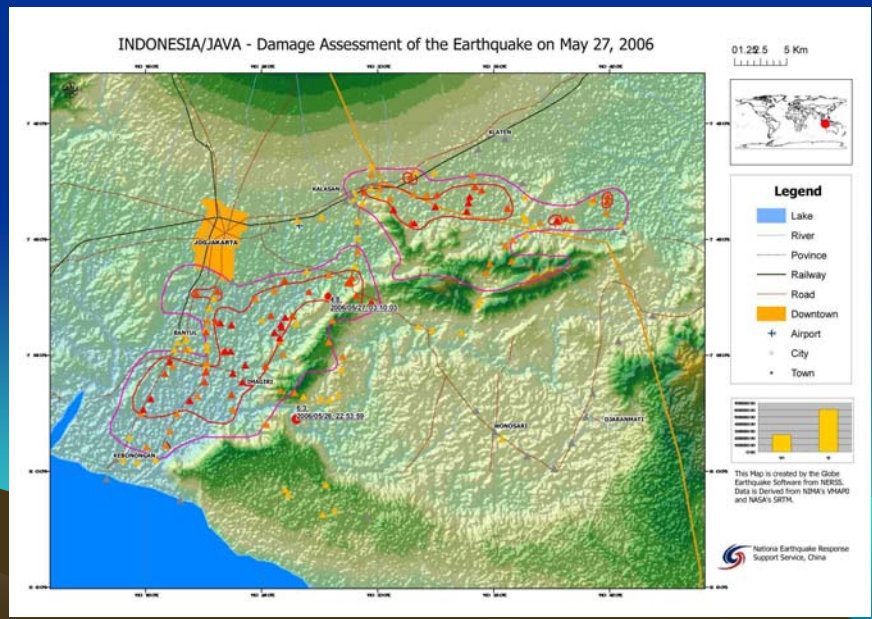
VII. Preliminary explanations on earthquake mechanics and its relationship with Merapi volcano

There are no surface ruptures founded in damaged area, we estimate that the earthquake rupture begins at the micro-earthquake epicenter in the SW, and propagate to the NE which results in the severely damaged area along the front plain area of east part of Bantul. The earthquake fast moment tensor solution by USGS supports this result.



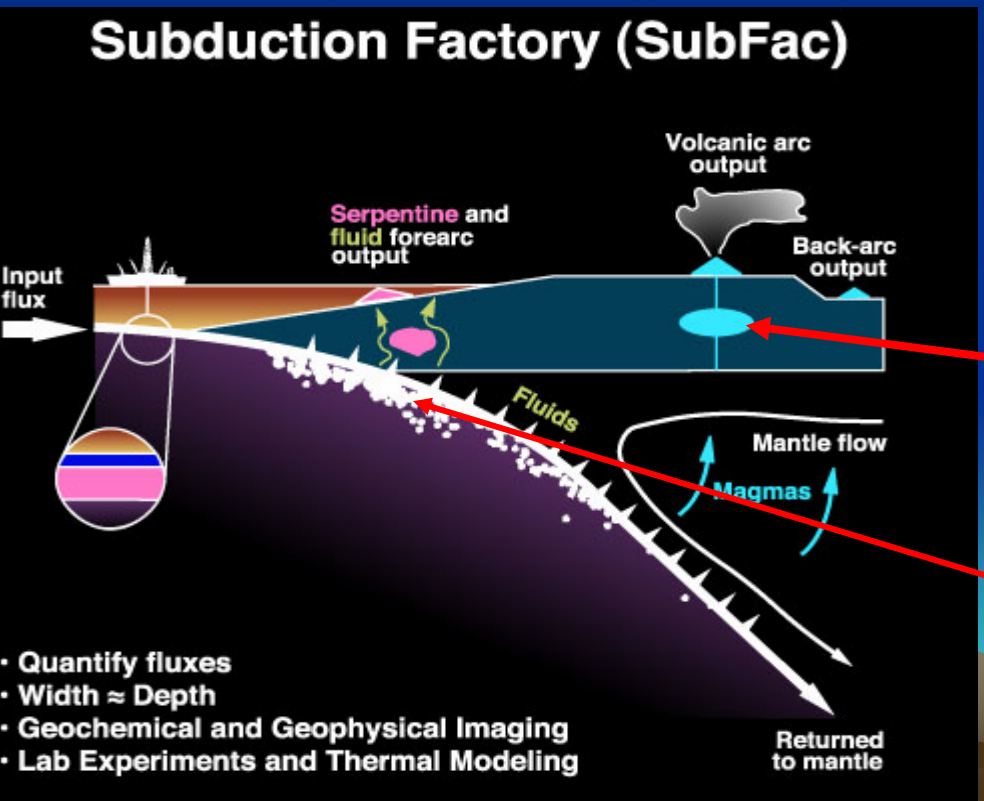
VII. Preliminary explanations on earthquake mechanics and its relationship with Merapi volcano

On the formation of Klaten severely damaged area, our investigation has shown that Klaten severely damaged area was formed at the same time with Bantul severely damaged area at 5 : 54, 27, May, 2006. Due to Klaten severely area is located in the NE part of Bantul severely damaged area, we estimate that Klaten severely damaged area is formed by the site effects in the area with site condition during the main shock of the earthquake.



VII. Preliminary explanations on earthquake mechanics and its relationship with Merapi volcano

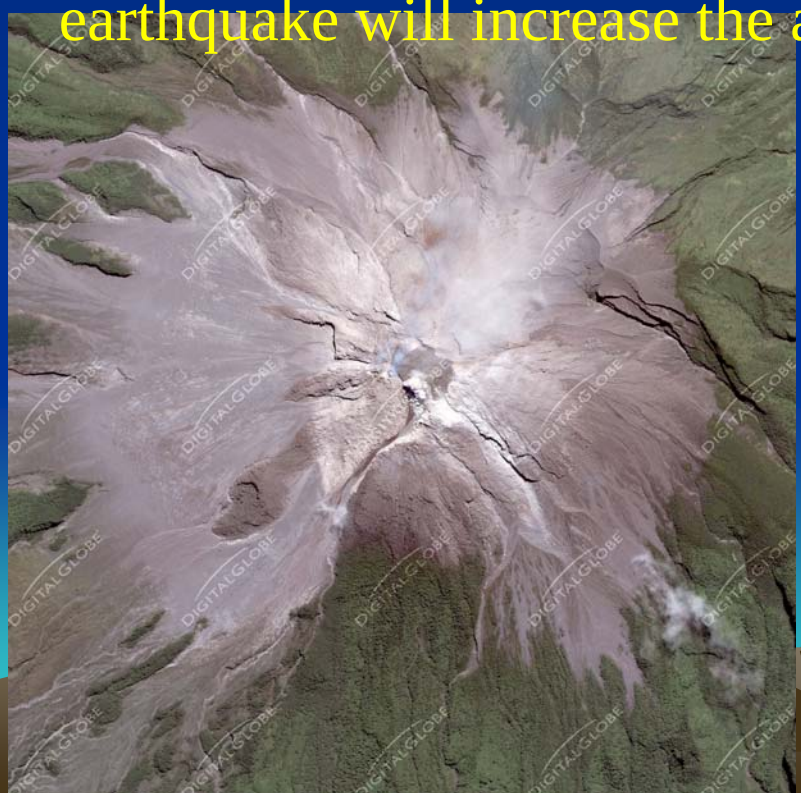
Based on the analysis of parameter and mechanics of Yogyakarta earthquake and the preliminary determination of fault generated earthquake, the Yogyakarta earthquake forms by a shallow crustal ruptured normal fault, which is different with thrusting fault caused by the subduction along the boundary of Indian Ocean plate.



Volcano

Subduction and earthquake belt

The earthquake mechanic solution by USGS shows that Yogyakarta earthquake was formed in an extensional environment in the shallow crust. Based on the regional seismotectonic environment, the Java islands are in the compressive environment by subduction of Indian Ocean plate. The local extensional environment of Yogyakarta earthquake would be formed by deep movement of Merapi volcano. So we estimate that Yogyakarta earthquake is generated by the faults networks surrounding the Merapi volcano. The Yogyakarta earthquake will increase the activity of Merapi volcano.



Conclusions and Suggestions

1. Conclusions

1) The assessments show that although the magnitude of Yogyakarta earthquake is relatively small, but the damages are relative heavy. Two heavy damaged areas caused by this earthquake, are Bantul and Klaten.

2) The factors contributing to the severe damages:

(1) The structures of buildings and the quality of the building materials are responsible for the severe damages.

(2) Lower grade concrete made the walls and columns easy to damage.

(3) Thin walls can not provide enough resistance to earthquake force.

(4) Rare and thin reinforcing steel bar caused buildings to be breakable.

(5) Weak foundation makes the buildings easy to collapse.

2. Suggestions

1) Improving the resistance of the buildings to earthquake shaking
2) Site planning
Fault detection, (2) Seismic microzonation, 3) Earthquake Monitoring, 4) Scientific studies

Will the Yogyakarta earthquake increase the activity of Merapi volcano? Or will the violent eruption of Merapi volcano make a larger earthquake in the near future? Up to now, there are no definite answers. We suggest that it is necessary to make a deep seismic reflection profile of crust cross the Merapi volcano and Yogyakarta earthquake impacted areas. Based on these results, we suggest to conduct the researches on the relationship between Yogyakarta earthquake and Merapi volcano, and to compile the earthquake and volcano hazard preparedness plan.

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