Slope Movement Characteristics and Models based on Engineering-geological Properties of the Menoreh Hills, Purworejo Regency, Central Java, Indonesia

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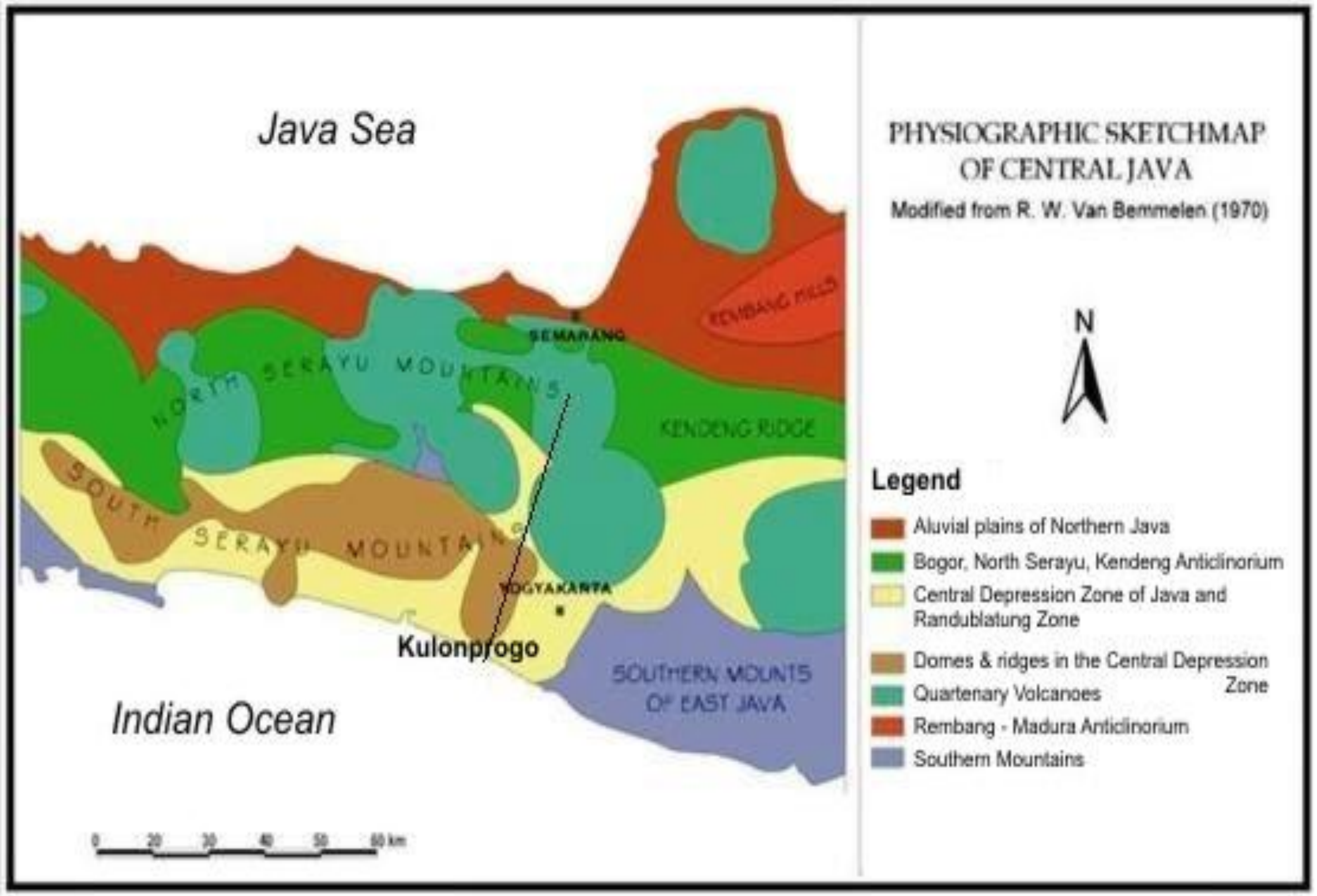
INTRODUCTION

- The Menoreh Hills belong to three regencies, Purworejo District, and Magelang District in Central Java province, and Kulonprogo Regency of Yogyakarta Special Region. There are mass movement occurrences almost in every rainy season, that may involve either soil, rocks, or debris, frequently result in losses, both material, infrastructure, and life. The last disaster occurred in December 2018, in the village of Tlogorejo, Kaligesing district, as many as 4 (four) families/16 peopel were affected. Landslides also caused access to the village road Tlogorejo - the village of Sudimoro was covered by avalanches and could not be passed by 4 wheels-vehicle.
- In order for prevention and anticipation of further landslides, it is necessary to identify the characteristics of common mass movement occurrence in Menoreh hills. Therefore, the purpose of this study is to identify and analyze, investigate the causes or influencing factors, learn their characters, and draw a conceptual model of mass movements of Menoreh lndslides.
- The study area is located in the Purworejo Regency, including Kaligesing, Purworejo, Bener, Gebang and Bagelen districts, Central Java province, and small portion is si in Kulonprogo Regency, Yogyakarta Special Region.

Location Map of the Study Area

The Physiographic Map of Central Java (Van Bemmelen, 1949)

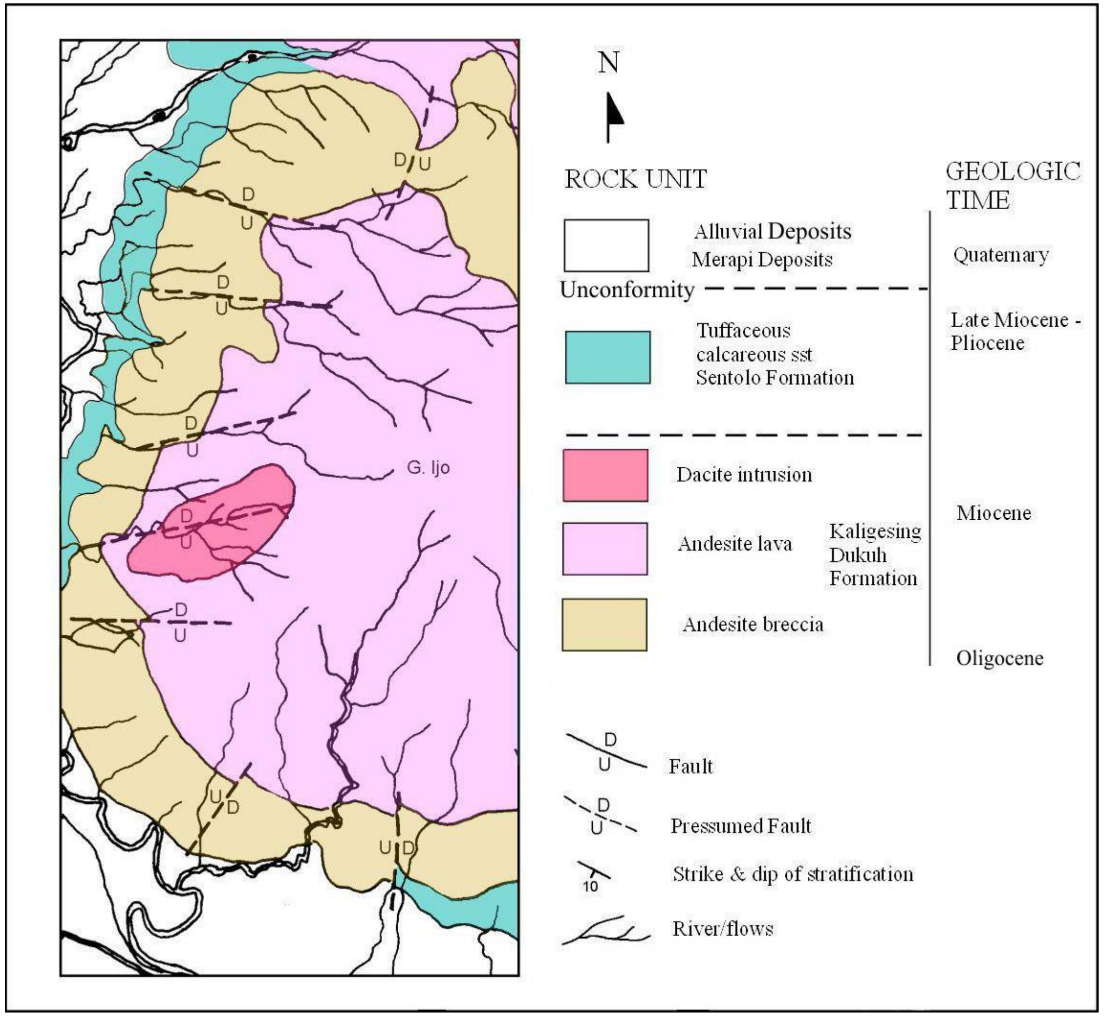


Yogyakarta, 3 October 2019

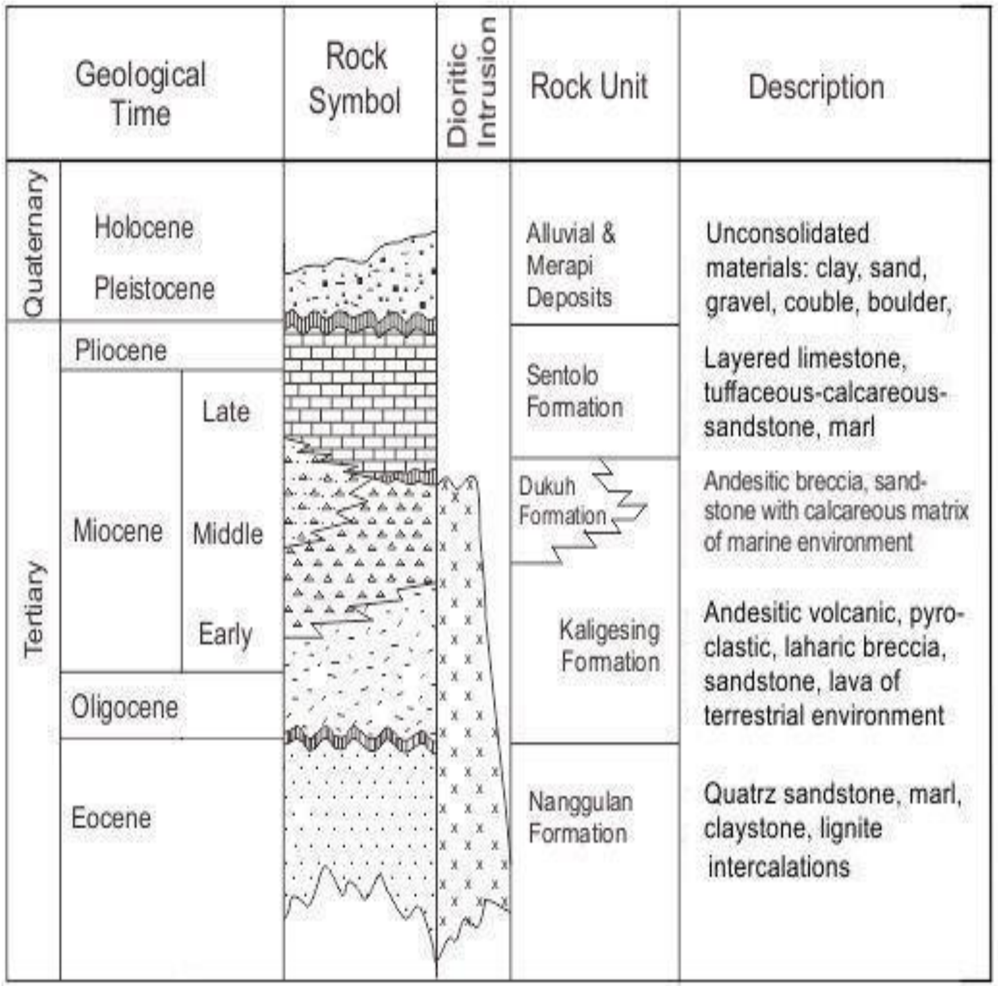
METHOD OF STUDY

- Approach method applied in the study was field surveying, surface geologic and geomorphologic mapping, topographic interpretation, remote sensing, petrologic analysis, rock/soil properties analysis, and geologic structure assessment.
- Survey and mapping were done to identify the variation of physical characteristics and distribution of the lithology. Geologic structure assessment and measurements were held for recording the strike and dip of the joint or fault planes, and also for identifying the morphology such as hills, ridges, and valleys. Topographic and image interpretation were utilized for determining pattern and orientation of fracture system (joint, fractures, fault) also hills and valleys lineaments.
- To do mass movement analysis especially that involving soil, it is supported by the use of slide v.6 software. The parameters used include physical properties and mechanical properties of rock/soil samples taken from several slopes in the stu area. Determination of safety factors of the slopes is based on the principle b Bowles (1991).

Geological Map of the Study Area



Stratigraphy of the Study Area



Typical Landslides involving thin soil (left), and involving thick soil (right) found at the main road of Kaligesing District

Result of Soil Slope Stability Analyses in the Study Area

No	Location	Lithology	Morphology & topography	Soil/Rock Properties	Factor of Safety & Type of Failure	Remarks
1	Kalijambe, Village,	Soil of andesite breccia	Moderately steep to steep slope (14%–55%), Structural Hills	H = 11.7 m W = 20 m, L = 12.2 m slope = 73^{o}, c = 8.2 kg/cm^{2} f = 5^{o}, g = 10.04	rotational debris slide 0.448 (unstable)	On the top of the slope there are some houses and farming. Terracing for footpath.
2	Kertosari Village	Soil of andesite breccia	Moderately steep slope, (14%–20%), Structural Hills	H =19,1 m, W = 20 m, L = 26.5 m, slope = 46^{o} c = 8.9 kg/cm^{2} f = 12^{o}, g = 11.83	debris slide rotational 0.62 (unstable), Bowles (1991)	This slope is located near to the main road Purworejo-Magelang, On the top of the slope, there are perrenials

Result of Soil Slope Stability Analyses in the Study Area

No	Location	Lithology	Morphology & topography	Soil/Rock Properties	Factor of Safety & Type of Failure	Remarks
4	Sukowuwuh Village	Soil of andesite breccia	Moderately steep slope (14%–20%), Structural Hills	H = 12 m, W = 16.2 m, L = 17.7 m, slope = 41^o c = 4.1 kg/cm^2 f = 3^o, g = 11.8	debris slide rotational 0.36 (unstable),	The slope is located near to main road in ter connecting villages. The slope has ever slided, but already overcome by drainage system
5	Wadas Village	Soil andesite lava	Steep slope (21%–55%), Lava Hills	H = 7.2 m, W = 19.3 m, L = 8.8 m, slope = 52^o c = 2.5 kg/cm2 f = 21^o, g = 20.23	debris slide rotational 0.54 (unstable),	The location of the slope is near the villager houses

No	Location	Lithology	Morphology & topography	Soil/Rock Properties	Factor of Safety & Type of Failure	Remarks
6	Kamijoro Village	Soil of andesite breccia	Steep slope (21%–55%), Structural Hills	H = 5.4 m, W = 21.9 m, L = 5.6 m, slope = 67^o c = 7.8 kg/cm^2 f = 9 ^{o}, g = 14.54	debris slide rotational 0.73 (unstable),	The location of the slope is near the villager houses
7	Jati	Soil of andesite breccia	Moderately steep slope (14%–20%), Structural Hills	H = 7.5 m, W = 18.5 m, L = 7.8 m, slope = 68^o c = 2.5 kg/cm^2 f = 21^o, g = 15.01	debris slide rotational 0.44 (unstable),	The location of the slope is near the villager houses
8	Mayungsari Village	Soil of andesite breccia	Moderately steep slope (14–20%), Structural Hills	H = 6.2 m, W = 22.1 m, L = 6.8 m, slope = 62^o c = 2.5 kg/cm^2 f = 23^o, g =16.77	debris slide rotational 0.54 (unstable),	On the top of the slope, there are perrenials

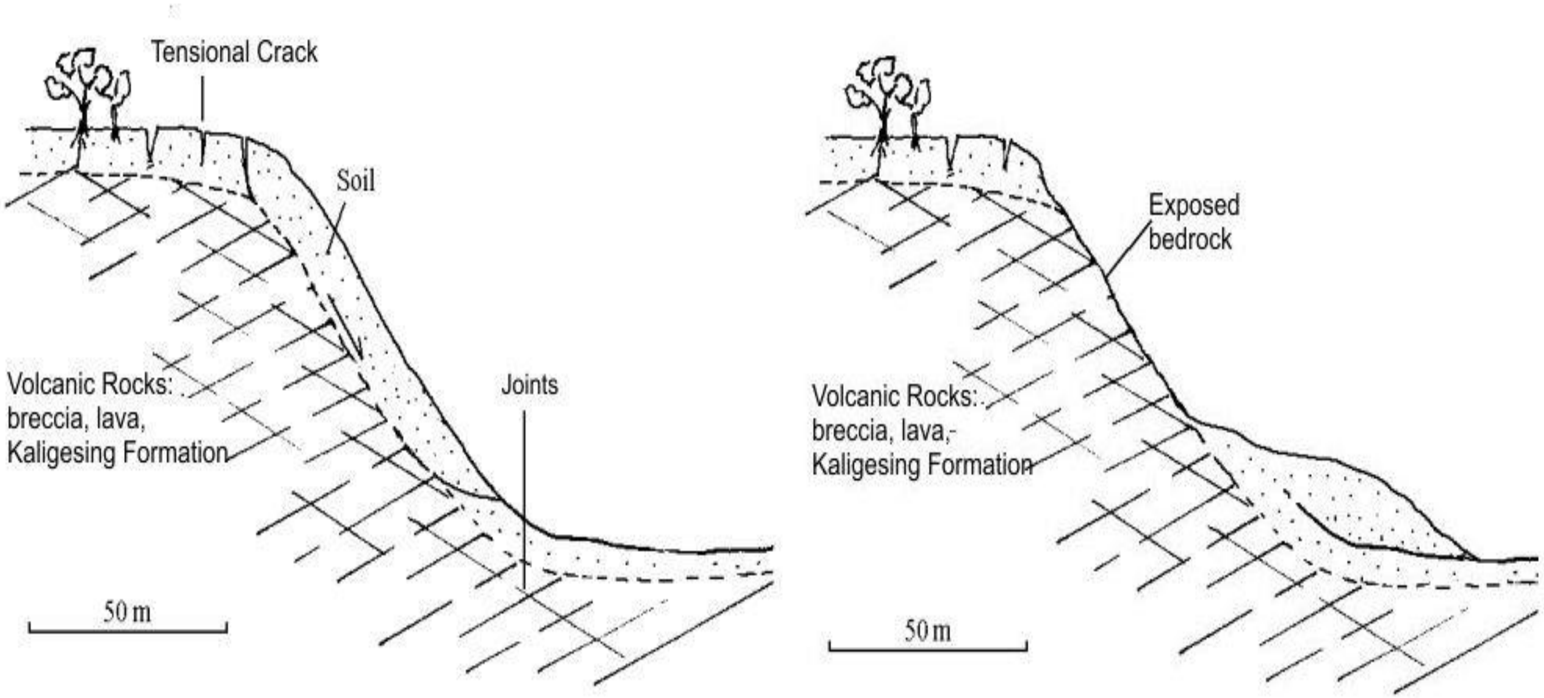
Result of Rock Slope Stability Analyses in the Study Area

No.	Name of Slope Location	Lithology	Rock Properties & Class	Type of Rock Slope Failure Potential
1	Wadas	Andesite Lava .	c = 39.1 kPa, f = 47°, g = 2.08 g/cm3, s = 6.62 MPa, RMR = 48	Planar slide, sliding direction N254^{o}E Wedge, sliding direction: N271^{o}E
2	Kaliwader A	Volcanic Breccia	c = 21.8 kPa, f = 40°, g = 1.81 g/cm3, s = 12.41 MPa., RMR = 45	Wedge, sliding direction: N138^{o}E
3	Kaliwader B	Weathered Andesite Lava	c = 15 kPa, f = 32°, g = 2.07 g/cm3, s = 6.62 MPa, RMR = 48	Wedge, sliding direction: N128^{o}E

Result of Rock Slope Stability Analyses in the Study Area

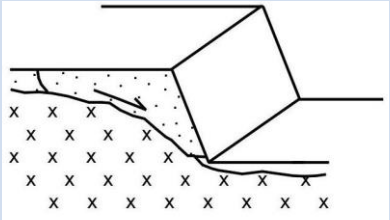
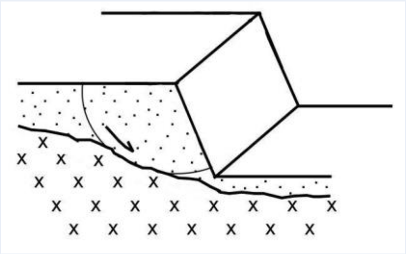
No.	Name of Slope Location	Lithology	Rock Properties & Class	Type of Rock Slope Failure Potential
4	Kaliwader C	Andesite Lava	c = 39 kPa, f = 51°, g = 2.08 g/cm3, s = 6.62 MPa., RMR = 48	Unpotential
5	Kaliwader D	Andesite Lava	c = 39 kPa, f = 51°, g = 2.08 g/cm3, s = 6.62 MPa., RMR = 47	Planar slide, sliding direction: N340ºE Wedge, sliding direction: N002ºE
6	Argosari	Weathered Andesite Lava	c = 39 kPa, f = 35°, g = 2.07 g/cm3, s = 6.62 MPa., RMR = 48	Wedge, sliding direction: N225ºE

Typology of slope movements involving soil of Kaligesing Formation in the Menoreh Hills

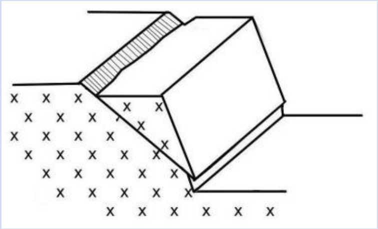
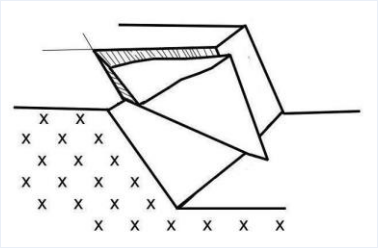


Lava with columnar joint structure, exposed after landslide occurence 2016 in Sidamulya village, Purworejo District

Based on characteristics and slope movements analyses, the conceptual model of soil and rock slope failures of Menoreh Hill can be established as the following:

Type of Rock	Involving Materials	Geologic Structures	Model	Figure
Soil	Soil, weathered rocks, debris	Joints, faults	Type: Landslide, Sliding Plane: boundary between soil and fresh rock Translational movement	
	Thick to very thick soil, highly weathered rocks (> 3m)	Joints, faults	Type: Complex soil & debris slide Sliding Plane: Combination of circular and the boundary between soil and the bed rock, complex movement	

Based on characteristics and slope movements analyses, the conceptual model of soil and rock slope failures of Menoreh Hill can be established as the following:

Type of Rock	Involving Materials	Geologic Structures	Model	Figure
Rock	Fresh volcanic rocks, breccia, lava	Joints, Faults	Type: Wedge Sliding Plane: intersection of 2 joint planes	
	Fresh volcanic rocks, breccia, lava	Joints, sheeting joint, faults	Type: Block glide Sliding Plane: joint plane, planar shape, translational movement	

CONCLUSIONS

- The Menoreh Hills are a dome-shaped physiographic zone, stratigraphy from the oldest to the youngest is Nanggulan Formations, Kaligesing-Dukuh Formation, Jonggrangan Formation, Sentolo Formation, and Quaternary Deposits.
- Because the morphology and topography generally display steep to very steep slopes, composed of rocks with quite high weathering rates, controlled by geological structures in the form of joints and faults, and added by high average rainfall, then the area is prone to landslides.
- The most common type of mass movement in the Menoreh Hills is landslide. The specific characteristics of landslide in the study area are generally showing the sliding plane which is not an ideal circular shape, but is a plane that is the boundary between soil and fresh rock, or combinati of circular plane and boundary between soil and fresh rocks.

CONCLUSIONS

- The conceptual model of mass movements in Menoreh Hills can be grouped into 4 (four), namely landslide with sliding plane in the form of boundary between soil and fresh rocks, landslides with sliding plane as the combination of circular and the boundary between soil and fresh rock, rock planar slides, and rock wedge failure.
- This conceptual model is expected able to be used as a reference and guidence for slope stability analysis studies in other locations, especially that is controlled by volcanic (magmatic) arc tectonic environment.

THANK YOU FOR YOUR ATTENTION