Design of Volcanic Educational-based Natural Tourism at Giriloyo, Wukirsari Village, Imogiri District, Bantul Regency, Yogyakarta-Indonesia

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Abstract: Previous study determined Giriloyo was Tertiary ancient volcano. Dyke, lava, and andesitic breccia which comprise this region strongly support the geological conditions, but the central facies of the ancient volcano had already associated with so many cracks, so that need further geotecnical handlings. Design technic for the geotecnical engineering is required to support it. This study aims to develop a geotechnical planning design in the context of a potential landslide management. On the other hand, Giriloyo has a potential volcanic educational-based tourism, supported with beautiful landscapes. The geotechnical planning design was packaged in the form of educational-based natural tourism development. Research related to the purpose has been carried out supported with geotechnical mapping to describe the carrying capacity. The results found southwest-northeast normal faults (N290-320ºE), north-south shear faults (0-15ºE), and oblique normal faults (northwest-southeast). All of them have potentially move to generate landslides. In anticipate the active rock movements, sloping terraces into 25-30º to obtain safety factors of at least 1.5-1.8 have been designed. Thus, the technical design to reduce the potential mass movements is addressed to obtain the natural cruising tourism. The terraces are designed to expose 5 ancient volcanic stratums, i e. Central Facies Stratum, Dyke Stratum, Lava with Hydrovolcanic Stratum, Lava with Collumnar Joints Stratum, and Agglomerates with Autoclastic Breccia Stratum. Each of these stratums is connected with a multilevel educational pathway to reduce burden on the land.

1 INTRODUCTION

An ancient volcano was identified at Giriloyo, Wukirsari Village, Imogiri District, Bantul Regency, Yogyakarta Special Region (Figure 1). There was a long periode of superimposed volcanism, building Kebo-Butak Formation and Nglanggeran Formation, during Early to late Middle Miocene (Mulyaningsih et al., 2019). The exposed volcanic rocks were deformed generating active cracks that potentially to move. A big landslide was noted in 17 March 2019, remaining very wide sloping plane of 47º (Figure 2). The slope was progressing to erode time by time, not only by running water but also by the active fault.

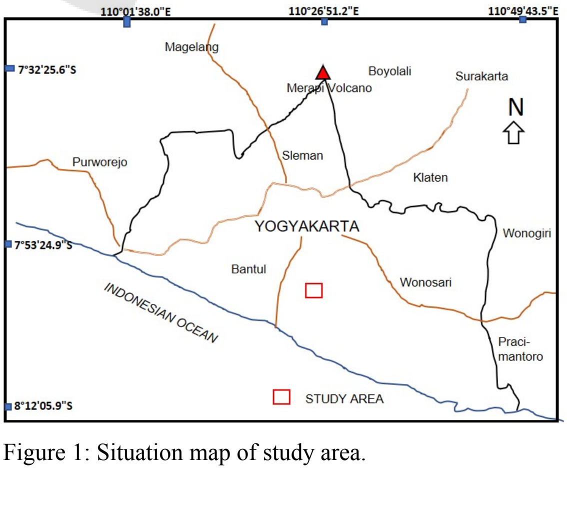

Figure 1: Situation map of study area.

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Dykes, lava, tuff, and andesitic breccia compose Nglanggeran Formation, that covering older volcanic rocks of Kebo-Butak Formation, exposed at Watulumbung, near the landslide. While Kebo-Butak Formation consists of black color of layered tuff, palagonite tuff and lapillistone. About 40-60cm of calcareous sedimentarry rocks of claystone and sandstone intersected the Kebo-Butak Formation and the Nglanggeran Formation, having ages of N5-6 (Early Miocene). So that the Kebo-Butak Formation must be older than Early Miocene.

Actually, those volcanic rocks should strongly support the geological conditions, but a high density of deformations and weathering, so it become fragile. It needs further geotechnical treatments. Design technic after the geotechnical study in early step is necesarry to assist the geotechnical engineering.

This study aimed to design the geotecnical engineering, related to the mass movements management. By the presence of the interesting volcanic rocks of the central facies ancient volcano, design of the geotechnical engineering should be composed curously and arty. Those purpose to obtain Giriloyo ancient volcano to be community-based geotourism.

Figure 2: Landslaide happened on 17 March 2019 at the meter of 720th (a) and the potential landslides along the track of Giriloyo (b,c).

2 METHOD

The study was started by geotechnical mapping with surface and subsurface investigation. Those mapping described lithology distributions, faults (deformation) and the potential creeps, slumps and falls. Surface mapping carried out by tracking, measuring and compiling the geological data. Subsurface mapping used microseismic soundings. This research used H/V method, also called Nakamura technique. The device was seismometer Lennartz Electronic with brand LE-

3Dlite, to describe the HVSR spectrum ratio (~microzonation), following the formula is:

$$R(f) = \frac{\sqrt{H_{EW}{}^2(f) + H_{NS}{}^2(f)}}{V_{UD}(f)} \quad (1)$$

Which:
$R(f)$: HVSR spectrum ratio
H_{EW} : Horizontal component spectrum (East-West)
H_{NS} : Horizontal component spectrum (North-South
V_{UD} : Vertical component spectrum

Site response analysis is important in seismic hazard assessment such in earthquake prone zones (Bray and Rodriguez-Marek, 2004) and mass movements. Tohwata (2008) argued that microzonation can predict the response and behaviour of soil and rocks by the external energy around the soils/rocks.

Fifteen spots have sounded using H/V method. The microseismic device identifed vibration decays along the identified surface fault planes. This method was intended to identify the distribution of the faults below the surface. Along with the broadband seismometer measuring in the real time, the vibration were recorded using the main sources of hits sounding into the medium. The ground movements were verified as a function of time in local site.

Analysis and synthesis of research data is based on all data that is compiled using the library data collection system, then synthesized using overlie system. Calculation and simulation of slopes is carried out manually and computed using ESRI and / MapInfo Arc-GIS software.

3 RESULTS

3.1 Secondary Data

Secondarry study found stratigraphy of study area from the bottom to the top were Kebo-Butak, Semilir, Nglanggeran, Sambipitu, Oyo and Wonosari Formations (Elliezer et al., 2019; Rahardjo et al., 1995; and Surono et al., 1992). The third earlier mention were volcanic constituents. Kebo-Butak Formation and Nglanggeran Formation were exposed at study area (Mulyaningsih et al., 2019).

3.2 Field Data Record

Surface field mapping described Kebo-Butak Formation consists of black tuff intersects with brecciated and compacted basalt lava in about 60m thickness. Above them are less calcareous sedimentarry rocks consist of laminated tuffaceous claystone and sandstone in about 60cm. Creammy color of coarse tuff and lapillistone lie on the sedimentarry rocks. That volcanic rocks are coarsening upward and replaced with intersectings of thick layers of breccia, lava and lapillistone in pyroxene-rich basalt composition. The thickness of the volcanic sequence is ~200m. Above them are agglomerate, andesitic lava and dike (Figure 3), which is interpreted as Nglanggeran Formation, as a product of constructive phase volcanism occured within central facies. The last volcanic rocks are exposed in the top of the track, i.e. in the meter of 1000th at Watulumbung (1927th).

These volcanic rocks strongly supported the geological conditions, but the inflation and deflation during the volcanism located at the central facies had already associated with the deformations. Mapping recognized geological structures, consist right normal slip faults. There are south-west-northeast normal faults (N290-320ºE), north-south shear faults (0-15ºE), and oblique normal faults (northwest-southeast) (Figure 4a-b). All of them have potentially move to generate landslides.

3.3 Subsurface Mapping

The soil vulnerability index (Table 1, Figure 5) displays soil and rocks stability; the greater the vulnerability value the smaller the soil/rocks structure. The high vibration decays of the lections of micrometer are found at S04-S07 with 33.2-45.55kgs in the elevation of 134-186m asl (Table 1, Figure 5). Those corners are described having small values of the soil vulnerability index, so that interpreted as unstable conditions (movable). Low vibration decays are found at S012-S015; that zone are interpreted having higher vulnerability index, so that calculated as more stable blocks.

Table 1: The mass vulnerability index recorded during microseismic measurements.

Station	Coordinate (m)		Elevation (m)	Vulnerability Index (kgs)
	South	East		
S01.	434823	9124498	50	32.45
S02.	434778	9124451	104	23.68
S03.	434783	9124362	146	18.42
S04.	434786	9124312	145	45.55
S05.	435126	9124308	186	38.75
S06.	435044	9124366	137	37.56
S07.	434995	9124430	134	33.12
S08.	434922	9124450	115	27.49
S09.	434845	9124597	105	16.54
S010.	434881	9124518	94	17.77
S011.	434759	9124693	103	21.45
S012.	434920	9124600	157	19.87
S013.	435055	9124516	211	17.55
S014.	435238	9124359	244	15.45
S015.	435255	9124336	262	12.73

Figure 3: The volcanic rocks exposed at study area; a. Agglomerate; b. Dike; c. Altered rocks with sulphid minerals, d. Volcanic neck; and e. Lava with collumnar joints. Those are used to deposited very close to the crater or within the crater.

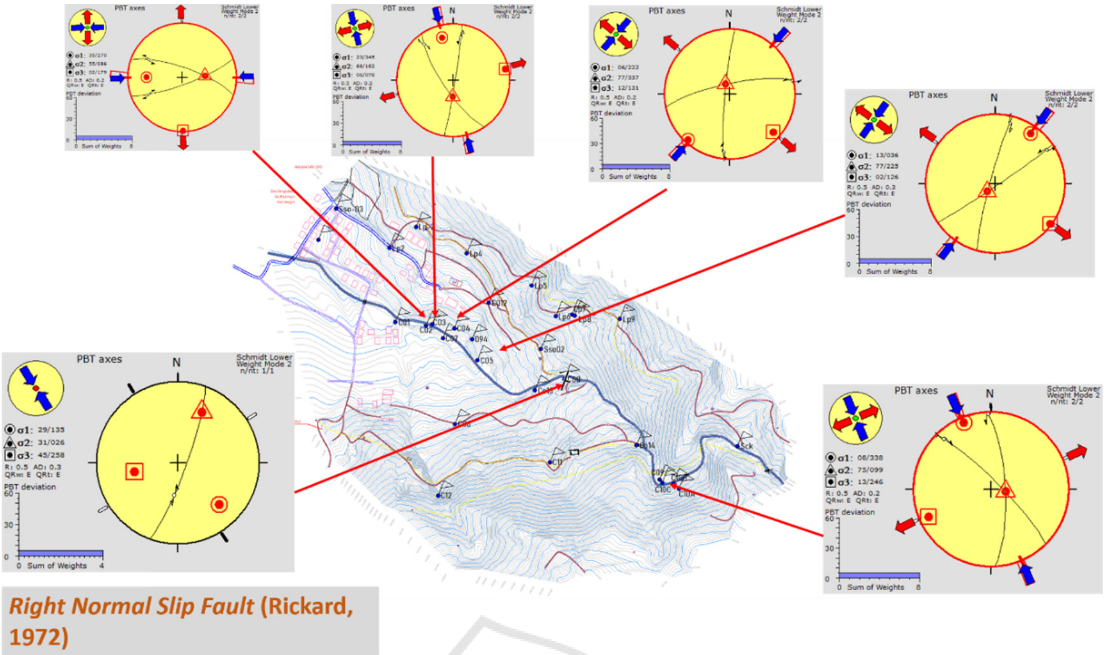

Figure 4a: The geological structure measured and computed at study area; the right normal slip faults.

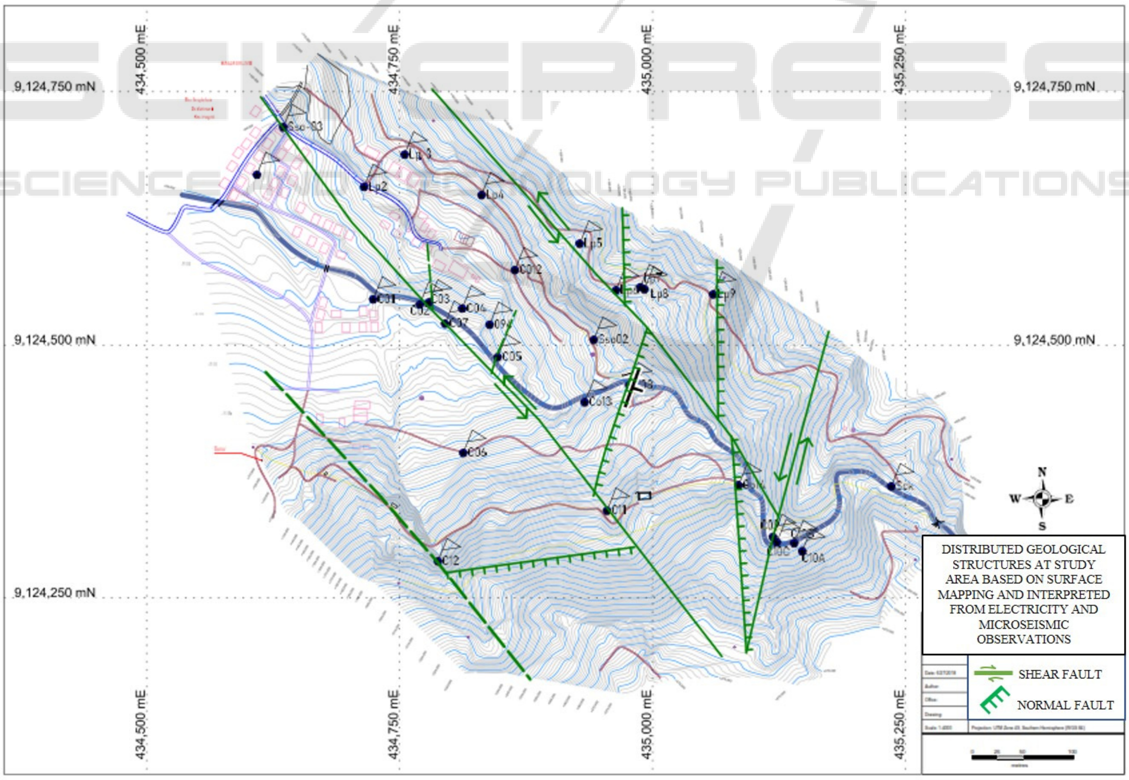

Figure 4b: The distrubuted normal and right slip faults interpreted based on surface mapping and subsurface mapping using dipole-dipole resistivity method and microseismic method.

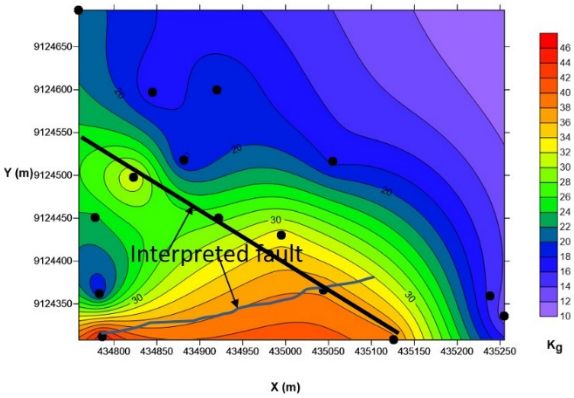

Figure 5. Map of vulnerability index at study area interpreted from microseismic soundings.

3.4 Geomorphological Analyses

Geomorphology of study area are characterized by gently to undulating topography sloping to 5-10^o (at Giriloyo), undulating to steeply at Cengkehan to Nogosari (sloping between 10-30^o), roughy elevated hills near upper Nogosari, Watulumbung and Grenjeng (~30-60^o) and very steeply scarpments with ~60-70^o on upper cliffes (Figure 6). The scarpments are impending to fall (Figure 2). Creeps are recognized along Grenjeng and lower Bukit Makbul (Figure 2).

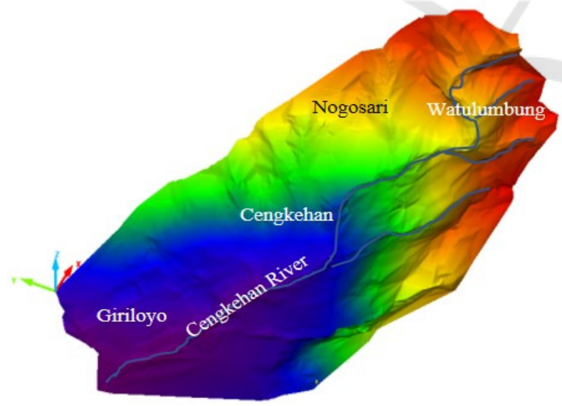

Figure 6: Digital Elevation Model (DEM) at study area.

4 DISCUSSION

Both surface and subsurface mappings recorded active faults that potential moving at study area. According to the data, whenever and at any time, such in water saturated condition (in rainny sesion), it will immediately collapse. Sloping will reduce the rate of mass movement. Design for the hazard mitigation is necesarry following the potential landslide/ rock falls. It's following the internal shear angle (ϕ), the density of soil/rocks (γ), cohesion (c) and water contents (ω). Terraces will be also able to minimize the impact caused by the mass movements. Technically, designing terrace are following Figure 7.

The problems are how to manage the slope stability, at once the kinds of strategic management in protecting the geoheritage related to the Giriloyo-Cengkehan's ancient volcano phenomenon. Safe storage with good aesthetics can be done through the terracing. Making artistic terraces will not only reduce the rate of mass movements but also add to the aesthetics of the study area. Slope management can be improved through risk analysis and systematic assessment of slope stability.

Terrace morphometry has been analyzed based on size, width (horizontal/horizontal interval (HI)) and distance of each edges (vertical distance/vertical interval (VI)). The terrace interval (HI) was assumed according to the ease of anthropogen activities. The size of terrace (VI) was calculated using the equation of FAO (1986, in Blanco, 2008) as follows. $VI = \frac{S*Wb}{100-(S*U)}$= where as VI = vertical distance (m), Wb = terrace width (m), hereinafter referred to as HI (m); S = slope (%) and U = HI and VI ratio (using 0.75 for manually built terraces (Blanco, 2008). So that it was calculated that slopes of ≤20^o is advisable a distance to be 15m; while slopes of ~30^o should be more than 10m distance. Bennett's criteria to calculate distances between terraces are the more advisable being closely related with experimental results in the area. Each terrace consists of 5m for landfill, 5m bamboo parks with landfilling to the top, the last 5m is keep to be the original slopes. The overall slope has changed to ~20^o in the teak garden, and ~35^o around the 1.5-5m and obtain safety factor of 1.5-1.8 for the sloping terraces.

Bamboo park is chosen to be an effective soil conservation at study area. Bamboo groves can maintain land and groundwater stability. The dense bamboo root system, which spreads in all directions, is able to strengthen the stability of the land, and rain water is easier to infiltrate into bamboo-covered soil. Bamboo stems have advanced natural capillary, which absorbs and stores water. Bamboo is able to release 35% oxygen and is a very useful plant in terms of reforestation of unproductive or degraded land. Planting bamboo at study area as land conservation is designed take place in the tarrace planes (Figure 7.a), while the hillslopes are designed as a retaining walls (Figure 7.b).

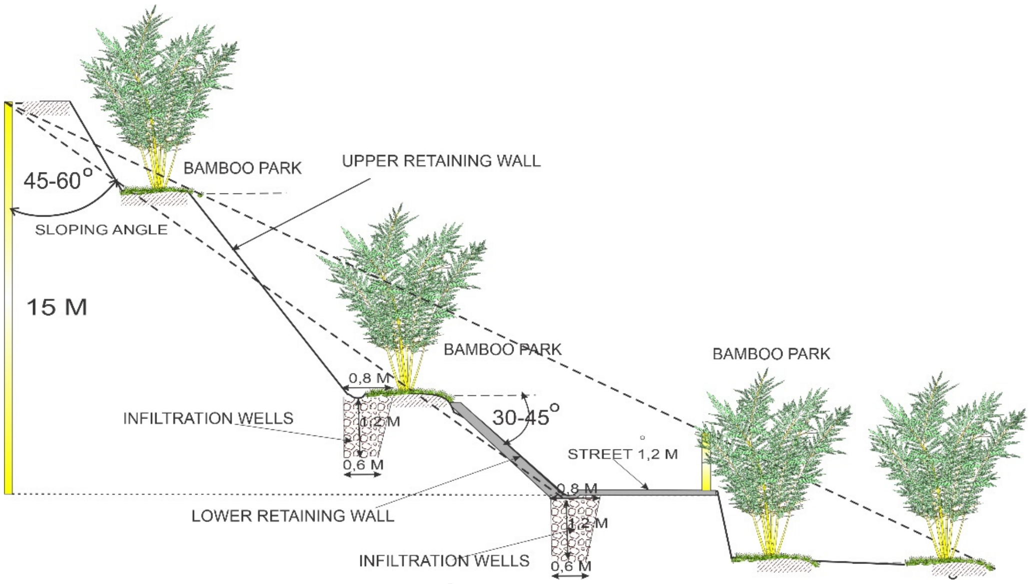

Figure 7: Design for the terracing (grounding) the slopes in reducing mass movements

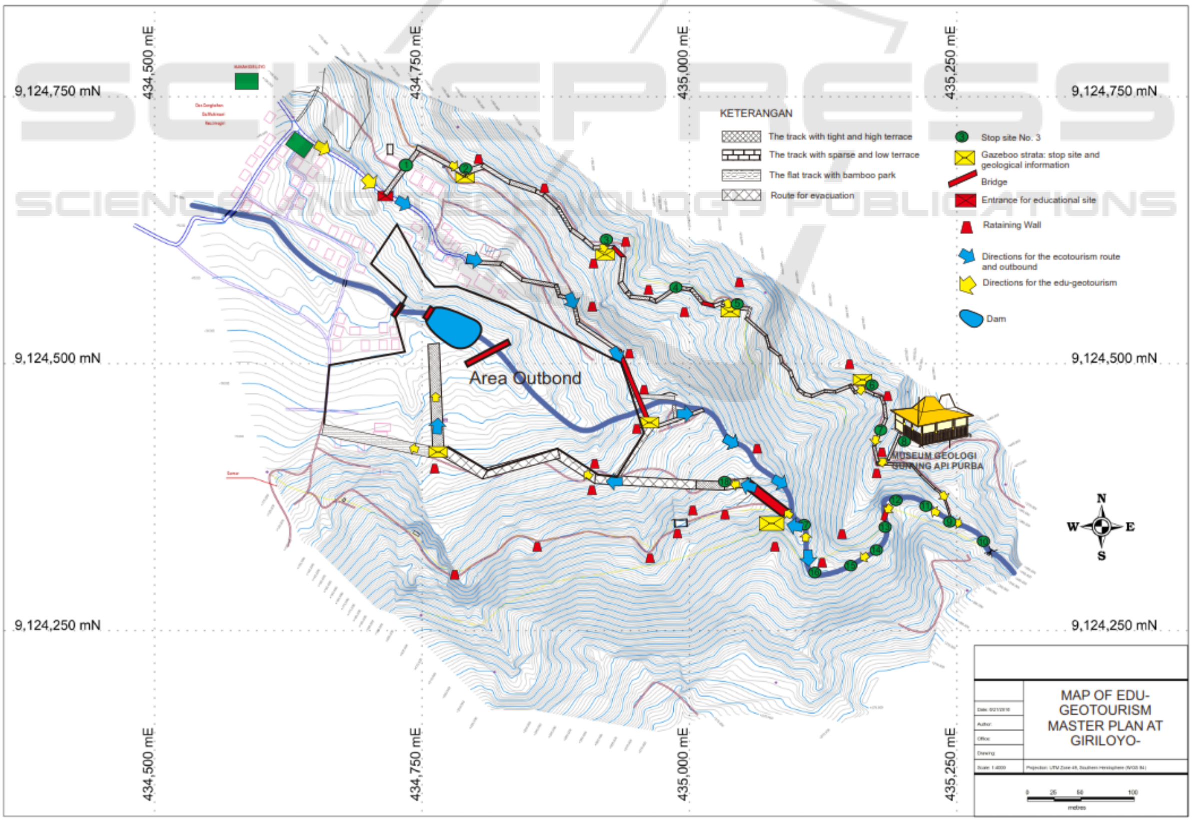

Figure 8: Design of the volcanic educational-based tourism at study area; as a conservation plan to manage landslide and other potential mass-movements.

5 CONCLUSIONS

Study area has potential mass-movements, such as landslides. It threats to the civilization below the slopes. But study area also potential with special interest of ancient volcanological tourism. Land conservaton and developing heritages (land, culture and geology) is designed following the natural resources and their potential movements. Terracings are chosen to be developed at study area. Those are designed by sloping landscape into 20-35^o, to obtain slope stability under safety factor of 1.5-1.8.

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