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Analysis of Potential Landslide Areas Using Geoelectric Methods of Resistivity in The Kastoba Lake, Bawean Island, Indonesia

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Article Info

Abstract: Kastoba Lake in Bawean Island Indonesia is a tourist attraction that has a level of vulnerability in landslide disasters. The landslides has been happen. From the large and small scale in the Kastoba Lake. Base on the problem, the landslides occured due to the field of derailment. According to the above statement, it was necessary to know the subsurface structure and the field of avalanche derailment in the kastoba lake area. This data was allowed by geophysical resistivity method which a dipole-dipole configuration with 4 measurement points. The acquisition of data was based on preliminary studies from the analysis of landslide vulnerability level maps (DEM Alos data processing) that have been done first. The results of lithological analysis with geoelectric resistivity methods in this research obtained three layers of subsurface structure, namely top soil (top layer) with a resistivity value of 7-110 Ωm, clay (middle layer) which was a resistivity value of 110-210 Ωm and lava (bottommost layer) which was a resistivity value of 210-357 Ωm. The field of gelincir in the research area was on the top layer of soil composed of weathering of rocks mixed with organic material or leaf/tree decay with an average depth of 7.25 meters. Thus, this research can be one of the parameters of landslide disaster mitigation in the development of geotourism in Kastoba Lake.

Keywords: Landslide; Gelincir field; Geoeletrical resistivity; Polished; Lake kastoba

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Introduction

Disaster is a series of event caused by natural, nonnatural and human factors, thus causing natural damage and loss. One of the most frequent disasters in Indonesia is landslides. From January to April 2021, there have been 233 landslides. Both of the factors which cause of landslides are trigger factors and control factors (Jati, 2021). Control factor is a factors that are influenced by material conditions. Such as geological conditions, lithology, slope slopes, faults and burly rocks. Trigger factor is a factor that cause the movement of such materials such as rainfall, earthquakes, erosion of slope legs and human activities (Naryanto et al., 2019). Natural disasters can be caused by a lack of information obtained by the community, thus causing high losses experienced by the community. Preliminary information about disaster risks and potential can be used as disaster preparedness or basic education for the community in tackling natural disasters (Damanik & Restu, 2012).

In east Java, there are 50 districts that are prone to landslides. For 50 subdistricts there are 3 sub-districts in *Gresik* Regency that have high potential to be prone of landslides, the district includes *Ujungpangkah* District, *Panceng* Subdistrict, and *Bawean* Island District (*Sangkapura* Subdistrict: *Balikterus* Village). *Bawean* is an island in the sea of Java that belongs of *Gresik* district, *Provensi* East Java. Morphologically, *Bawean* local and *Masalembo* sheets have calderas, lakes or wells and craters filled with water, such as Kastoba Lake located in Sangkapura District, *Balikterus* Village. Landslide-prone areas that often occur in new areas, namely in the *Kastoba* lake area, after being geologically studied the *Kastoba* lake area is composed of soil/wet layers (leaf/plant decay products), clay rocks, and basalt andesite rocks that are on top of *Balibak* mountain rocks.

The research area conducted in Lake *Kastoba* is a volcanic lake as a result of pleistocene-aged volcanic activity. This mountain is a mountain in the back arc basin of East Java as a result of the Eurasia-Indo Australia collision, based on geological maps, research areas, formed from the *Balibak* Volcano Rock Formation (Qv), namely lava distribution, breccia volcano, and tuf (Azis, 1993).

Lake *Kastoba* as a research object will be used as a geotourism object of Gresik Regency, so it needs several factors that must be studied first, one of which is based on disaster mitigation research area. One of the disaster mitigations that often occurs in *Kastoba* lake. It is the occurrence of landslides. The factors that affect landslide events are the dominant factor, the mechanism of the event is studied in order to reduce the risk of landslide disasters. One geophysical method that is often used to identify the field of the derailment is the geoelectric method of the prisoner type. he subsurface investigation methods commonly used in exploration are: geological methods, gravity methods, magnetic methods, seismic methods, and geoelectric methods. Of the several methods, the most commonly used method is the

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geoelectric method with good results and is environmentally friendly (Onojasun, 2015; Sajeena et al., 2014). This method has several advantages, namely having good measurement accuracy, not damaging the environment, relatively cheap cost, and able to detect soil coverings up to above 100 m. Therefore, this method can be used to survey landslide-prone areas, especially to determine the thickness of the potentially landslide layer and the lithology of subsurface rock cover. This method will provide preliminary information to find out the subsurface structure of the *Kastoba* lake area as an initial study of landslide mitigation in the Lake *Kastoba* area. The geophysical method was the first method used in the research area in determining the subsurface structure of the area.

Referring to the above, efforts to determine the condition of the *Kastoba* Lake area that will be used as Geotourism located in *Gresik* Regency are very necessary to be researched. The research was conducted using geophysical methods. Geophysical methods are carried out to determine the shape of 2-D so that the results of subsurface structures and the field of the research area.

Method

Reference studies is conducted by previous research studies on landslides that occurred. It is including about the location of the study. The population stories, geology, geomorphology, geological structures, engineering geology, land using thr population and others. The stages carried out in this research are data acquisition, 2D modeling.

Data acquisition

a. Acquisition of Satellite Imagery Data

The parameters used in this study to determine the level of landslide insecurity. The data used is elevation data, topographic position index, topographic wetness index, slope, stream power index, and land cover (Badan Penanggulangan Bencana Daerah (BPBD) Kabupaten Gresik, (2021). The parameters are obtained from the processing of DEM Alos data, except in land cover obtained through manual digitization. The area of research conducted is 2.2 km x 2.2 km. This is done to get variations in the level of landslide vulnerability in the *Kastoba* lake area.

b. Acquisition of Geoelectric Data

Geoelectrical Resistivity Method is one of the geophysical methods that aim to determine the resistivity changes of the subsurface rock layers by flowing high voltage DC (Direct Current) into the ground through two current electrodes.[8,9] The method used in data acquisition is geoelectric method of polishdipole configuration. The dipole-dipole configuration has the ability to read subsurface conditions of the Earth with the good sensitivity both vertikanly and horizontally (Loke & Barker, 1996).

The principle of resistivity method is to inject an electrical current into the earth through two current electrodes, then the potential difference is measured by two potential electrodes, so that the resistivity value can be calculated as seen in figure 1. The apparent resistivity value of the dipole-dipole configuration is shown by this formula:

$$P = \prod na\ (n + 1)\ (n + 2)\ \Delta V/I \qquad (1)$$

where: P is apparent resistivity (Ωm), n is integer number, ΔV/I is resistance (R, ohm) and I is current (Ampere) (Susilo et al., 2018). In addition, "r" is distance between electrode C1 C2 and P1 P2 and "nr" is distance between electrode C1 C2 and P1 P2, because electrode P1 P2 is moving to the right until the maximum line. The measurement using dipole-dipole configuration is done by moving the potential electrode (P1-P2) with a distance of "n" to the right until the maximum line and the current electrode remains in the starting position. Furthermore, the current electrode (C2-C1) is moved with a distance of "n" followed by the displacement of the potential electrode and so on as the initial step until the measurement of the current electrode at the maximum line.

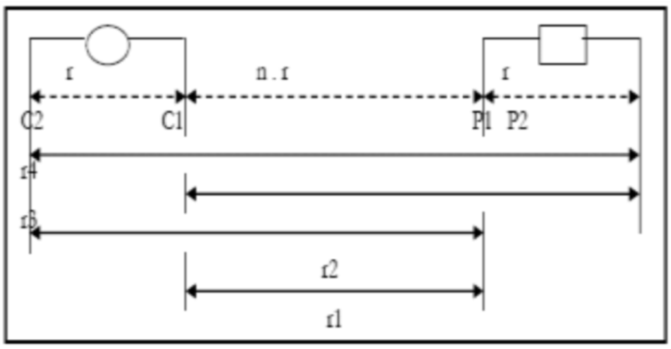

Figure 1. Dipole-Dipole Configuration (Loke & Barker, 1996).

The study was conducted at coordinates 5°46'32.50"S - 5°46'34.50" S and 112°40'08.42" E-112°40'08.42" E, with the survey design of the study trajectory shown in figure 2. The physical parameters obtained are K, i and V. The 3-D results obtained from the acquisition of data in 4 trajectories that cut each other. The length of the obtained track ranges from 100 m – 150 m. Trajectories 1 and 2 obtained a long span of 150 m, trajectories 2 and 3 obtained a stretch along 100 m. the space distance of the electrode is 10 meters, measurements are made until it reaches the 13th datum (n) point.

Data Processing

DEM Alos data obtained directly from the QGIS3 application in the form of shp data. The data obtained aims to find out landslide areas in the research area. The physical parameters obtained in the acquisition of geoelectric data are carried out to determine the geological modeling of the subsurface layer. On the Map aspect of the landslide area of Lake Kastoba is obtained from several parameters. As for each class parameter that has the highest level of insecurity is: 1) elevation 193-240 mdpl, 2) slope >55, 3) Aspect with northwards, 4) topographic wetness index 5-6, 5) topographic position index 15-19, 6) stream power index >240, and 7) land cover in the form of forests (Badan Penanggulangan Bencana Daerah (BPBD) Kabupaten Gresik, (2021).

Data Interpretation

Data obtained directly from the field is raw data. The initial processing of data is to look for pseudoresistivity values (ρ) with geometric factors (K). Then the process of inversion is minimal squared, which is the method of approach to the formation of equations from the point (regression) (Loke & Barker, 1996). This inversion process aims to convert the value of pseudoresistivity into a resistivity value that is close to its actual state. Stage two processing is carried out using Res2Dinv msoftware, so that a 2D cross-section is obtained that describes the distribution of rock resistivity at the underground surface and the boundary of the derailment field (Telford et al., 1990). The process is correlated with geological maps of the bawean and masalembu sheet research areas and as well as rock resistivity tables to support in the interpretation of the research area. The purpose of the Geoelectric Interpretation is to know the subsurface layer of soil, and to know the distribution of the layers of the derailment horizontally and vertically.

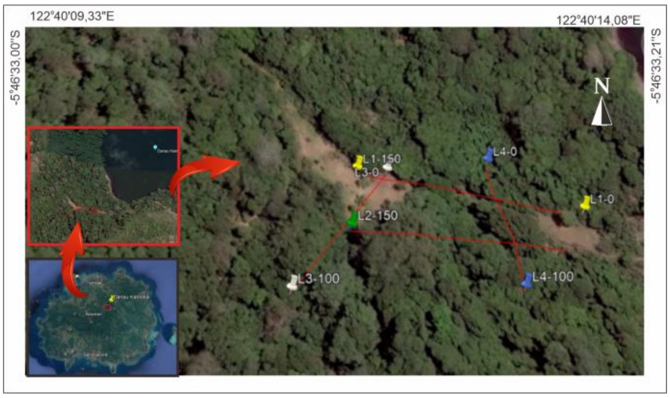

Figure 2. Geoelectric data collection location map.

Result and Discussion

On the Map aspect of the landslide area of Lake Kastoba is obtained from several parameters. As for each class parameter that has the highest level of insecurity is: 1) elevation 193-240 mdpl, 2) slope >55, 3) Aspect with northwards, 4) topographic wetness index 5-6, 5) topographic position index 15-19, 6) stream power index >240, and 7) land cover in the form of forests. The distribution of landslide insecurity levels is divided into five classes, namely very low, low, medium, high and very high. Areas with a very high distribution of landslide insecurity rates are in the northwest, east, and salatan areas around Lake Kastoba as figure 3.

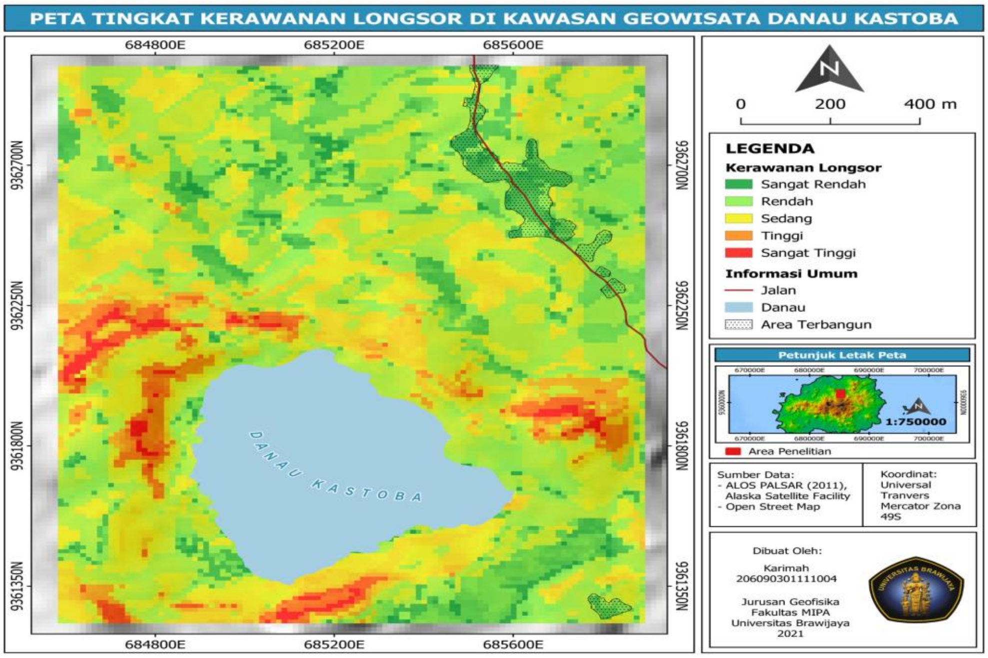

Figure 3. Map of landslide vulnerability level in the Geotourism area of Lake Kastoba

The results of the processing of geoelectric data showed that the composition of subsurface soil layers in the Jawar area is top soil, clay, and lava. The data processing stage in geoelectric methods shows subsurface condition.

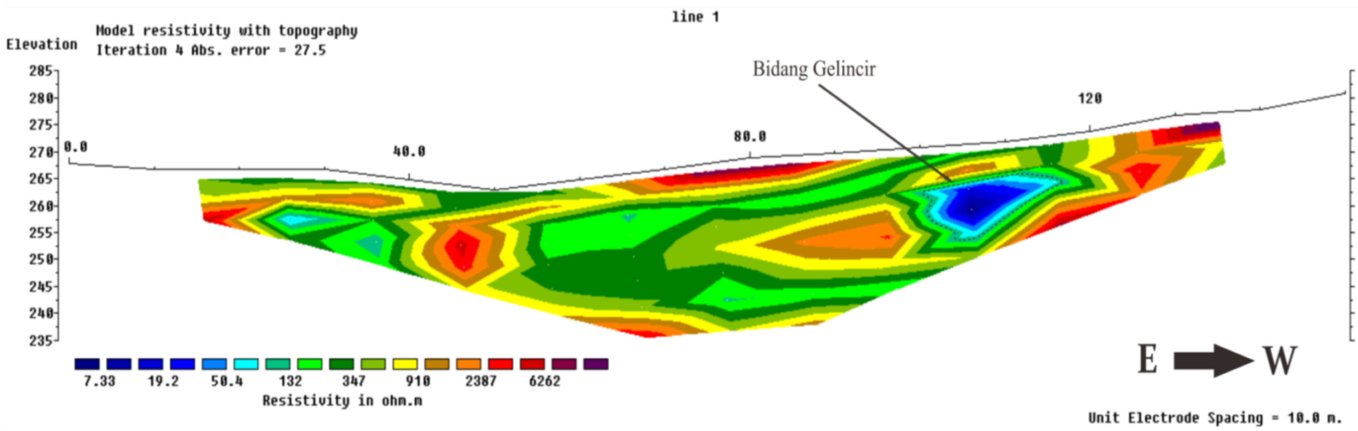

Figure 4. Interpretation 2-D results on line 1

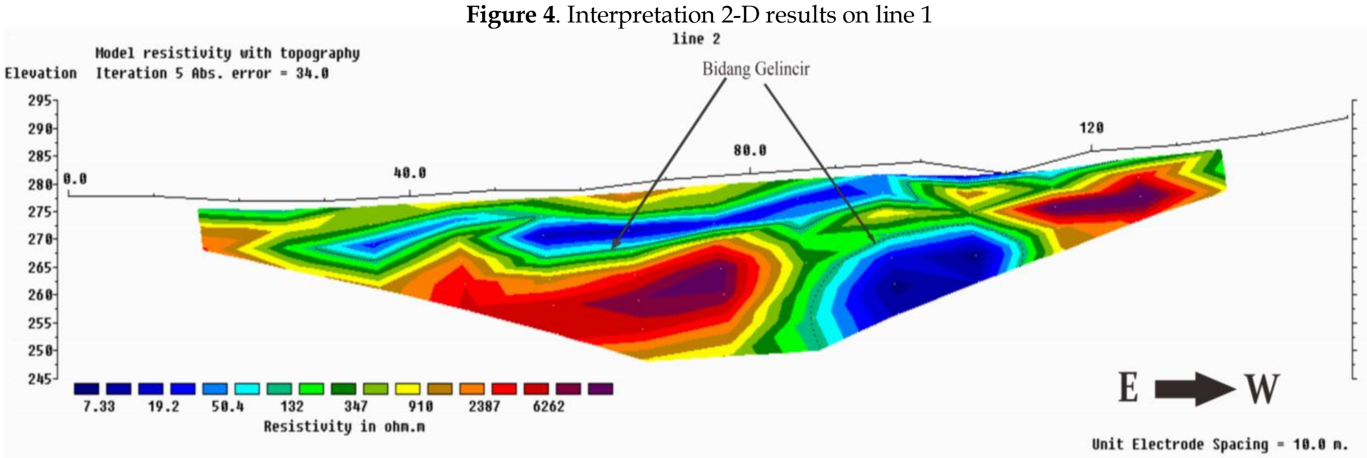

Figure 5. Interpretation 2-D results on line 2

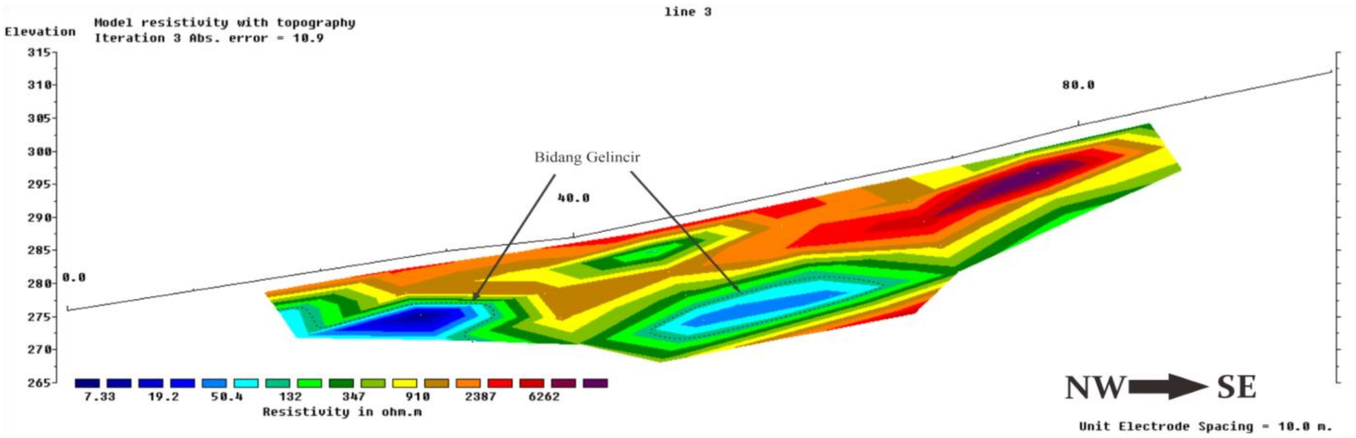

Figure 6. Interpretation 2-D results on line 3

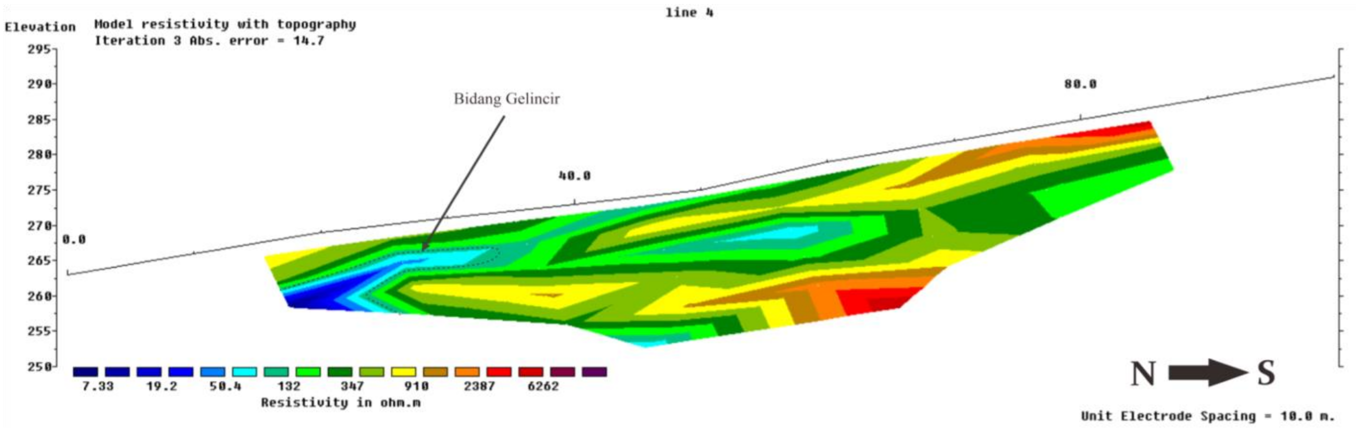

Figure 7. Interpretation 2-D results on line 4

Based on research that has been done by *sutasoma* et al, about the analysis of slope stability has been done in the hamlet of *Jawar* using the geoelectric method of resistivity of the dipole-dipole configuration, obtained 3 layers of soil namely clay (top layer), tuff (middle layer) and basalt and lava (bottom layer). The field of the avalanche area is located between the clay and tuff layers (depth 10.5 m). Based on the results of 3D data processing geoelectric resistivity, the direction of the avalanche to the southeast (Sutasoma et al., 2017).

The results of a two-dimensional cross-section on line 1 (Figure 3), line 2 (Figure 4), line 3 (Figure 5) and line 4 (Figure 6) when correlated with Telford's resistivity table in 1990 obtained a resistivity value between 7-357 Ωm. The range of resistivity values obtained can be grouped into 3 layers, namely the top layer (top soil), the middle layer (clay) and the bottom layer (lava). Low resistivity has a value of 7-110 Ωm indicated as a top soil layer consisting of weathering of rocks mixed with organic material or leaf/tree decay. Moderate resistivity has a value of 110-210 Ωm indicated as a layer of clay obtained from lava weathering products. And high resistivity has a value of 210-357 Ωm indicated as a layer of lavas.

Interpretation of 2D geoelectric data obtained the limit of the field of the gelincir between the top layer (top soil) with a resistivity value of 7-110 Ωm and the middle layer (clay) with a value of 110-210 Ωm. The top soil layer is indicated as an easy layer to landslide, because the material is weathered or not compact. The top soil layer has a small permability, so the water that enters due to rain cannot seep into the lower layer. The amount of water that enters also increases the load mass in the top soil layer, so there is an avalanche in the layer (Brahmantyo & Yulianto, 2014).

Story: layer 1 has a depth between 258-264 meters (6 meters), layer 2 has a depth between 266-279 meters (13 meters), layer 3 has a depth between 270-276 meters (6 meters), and layer 4 has a depth between 262-266 meters (4 meters). The area that has the highest level of landslide vulnerability is in the line 1 area. The most vulnerable track is on track 1. The track has the thickest top soil, the vegetation cover is slightly/only in the form of plants with shallow roots/banana trees and the soil is very weathered. The field of the research area is located at an average depth of 7.25 meters.

Conclusion

Based on the results of 2D interpretation is a high resistivity value of 210-357 Ωm is a layer of Lavas rock, rock structures that have moderate resistivity 110-210 Ωm are clay layers, rock structures that have low resistivity 7-110 Ωm are soil layers. The field of gelincir in the research area is between top soil (low resistivity) and clay (moderate resistivity) with a low resistivity value of 7-110 Ωm at an average depth of 7.25 meters. Further research needs to be done soil sampling to be tested at the soil mechanics laboratory to find out the physical and mechanical properties of the soil, so that it can be used for soil movement modeling.

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