

KILLER LANDSLIDE AT NICHOLA OYA, SRI LANKA: SOME GEOLOGICAL ASPECTS

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ABSTRACT

Since of late the occurrence of landslides has become the most common disaster in the Central Highlands of Sri Lanka particularly during periods of intense rainfall causing increasing numbers of human casualties. Human activities such as indiscriminate housing and road construction on elevated terrains in the central highland mountains usually cause instability of slopes generating minor and major landslides. However, Nichola Oya landslide can be identified essentially as a rain-induced geological disaster that caused death to seven people and much destruction to property.

The Nichola Oya landslide can be considered as a “killer” landslide due to its destructive attributes. It is a 3 km long landslide that had moved at high speed killing seven persons and causing destruction to several estate dwellings. The landslide has occurred essentially due to movement along the dip slope underlain by highly jointed gneissic rocks causing stepwise and continuous development of ponds due to damming and overflowing along its length. Field observations along the path of the landslide also suggest reactivation of several paleo-landslides due to continuous heavy rainfall, which had exceeded 200 mm within a period of about 24 hours. The Nichola Oya landslide can be considered essentially as a disastrous event caused mainly due to geological, structural and climatologic reasons.

Keywords: Killer-landslide, Intense rainfall, Reactivation, Paleo-landslides, Gneissic rocks

INTRODUCTION

The term, landslide is used to denote a wide variety of mass movements which cause downslope transport of soil and rock material under the influence of gravitational force (Varnes, 1978). Globally, landslides and other ground failures take a tremendous human and economic toll, and with climate change, bringing a sharp rise in precipitation, the threat of bigger and more frequent landslides is growing (Aleotti et al., 1999). In this context, killer landslides have assumed much importance since they cause heavy carnage and havoc causing destruction to life and property in

mountainous terrains particularly in the tropical rain-fed countries (Aleotti et al., 1999) such as Sri Lanka.

In the Central Highlands of Sri Lanka, various types of landslides occur with intense rainfall over short periods of time on steep unstable slopes (Dahanayake, 1990). In perusing records, Kandy (Sinhapitiya in 1977; Bahirawakanda in 1993), Matale (Pitakanda in 1982, 2012; Watagoda in 2012), NuwaraEliya (Katayapatana in 1986; Watawala in 1993), Ratnapura (Patulpana in 1983 ; Helauda in 1993) and Kegalle (Bulathkohupitiya-Bambarakanda-Getiyamulla in 1989) districts of Sri Lanka had

a large number of landslides. These events have occurred at locations where the downslope movement is facilitated by slopes exceeding 25° and created by folding of banded rocks or hummocky topography of loose colluvial debris on scarp slopes (Dahanayake, 1995). Also, the landslides occur in areas with high relief characterized by ridge and valley topography in meta-sedimentary rock terrains (Dahanayake, 1994). Landslides in Sri Lanka occur especially in the Central Highlands during heavy rainfall usually exceeding 200 mm in 24 hours merit serious geological examination (Dahanayake, 1995). Sri Lankan highland rocks have potential failure planes along joints as well as rock bands (foliation planes). The development of failures along the said weak planes occurs almost slowly while the rain is falling and under specific conditions of ground situation, rainfall intensity and its duration (Ellen and Wieczorek, 1989).

The reported landslide occurrences are mostly combinations of two or more landslide types (Varnes, 1978) and such landslides are massive ones with their course extending to more than 1 km in length (Dahanayake, 1995). The Nichola Oya landslide is an exceptional phenomenon with more than 3 km in length and the type of landslide is 'complex' according to the landslide classification of Varnes (Varnes, 1978). The step-wise temporary ponding due to damming and subsequent rupturing is a rare occurrence (Schuster, 1985) which however had taken place along the length and breadth of Nichola Oya landslide. Also, geological and field observations suggest that this area had previously experienced several paleo-landslide events.

The Nichola Oya killer landslide occurred during the night of 17th and 18th December, 2012. The washout debris of the landslide had caused the death of seven residents of the destroyed houses that lay on its path. Nichola Oya is one of the tributaries of Rattota River situated in Matale district, Sri Lanka. The area is well known as Bambarakiriella village.

METHODOLOGY

Initially, the study area was perused in satellite images to demarcate the exact location, extent and distribution of the Nichola Oya landslide. Its structural and geological control was examined and studied in detail. Observations were made along the landslide axis from the head to its toe and on the adjacent hillocks of the right and left flanks. Main emphasis was laid on the influence of structure and geology in the recognition of the landslide and its path.

The landslide path was traced and marked on the 1:10,000 topographic maps. This document was used as the base map for field work and especially in the preparation of the geological maps. Several field visits were conducted soon after the occurrence and in the subsequent weeks to decipher the causes leading to the landslide event. Preliminary observations were carried out during the first reconnaissance visit. Subsequent field visits were conducted to record geological measurements on foliation and joint planes along the landslide path. Also, observations were made on the axis/path as well as on either flank of the landslide for evidence on paleo-landslides. The flanks of the recent landslide were perused for evidence of any occurrences of soil profiles and land use patterns. Consequently, the geological map along the landslide axis was produced covering this landslide area. Then, a 3-d model for the landslide area was developed based on geomorphological and geological observations. Also, a rose diagram was prepared using the joint plane orientations to identify the more prominent joint orientations.

Also, daily rainfall data records were collected from the rain gauge station of NBRO (National Building Research Organization) at Rattota with a view to better understanding their influence on Nichola Oya landslide.

RESULTS

According to the rain gauge station records of NBRO (National Building Research

Organization) at Rattota, a daily rainfall

ridge that lies at a maximum elevation of 1450 m above mean sea level (MSL). The body of this landslide is more than 3km in length (Figure 2). The toe is near the Nichola Oya tea factory with a width of 80 meters. Also, the head region of the landslide is overgrown with thick vegetation and shows uneven ridges and valley morphology with irregular networks of streams (Figure 2). The slope angles from head, body to toe varies from 75°, 60° to 40° respectively.

The stream depth of the body region extends to more than 30 meters towards the toe area. Also,

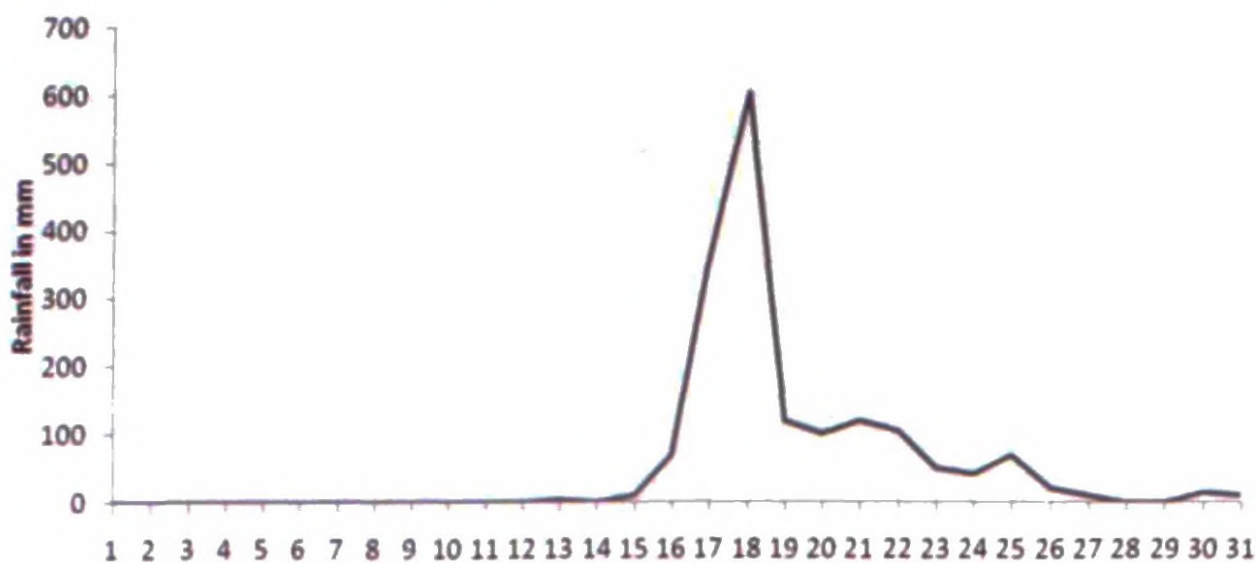


Fig.1 Rainfall intensity of Rattota region during December 2012.

precipitation of 100 mm had been recorded during the period on 15th/16th December 2012. This figure had drastically increased to 600 mm (Figure 1) within 24 hours on 17th December 2012 showing extraordinary heavy and torrential

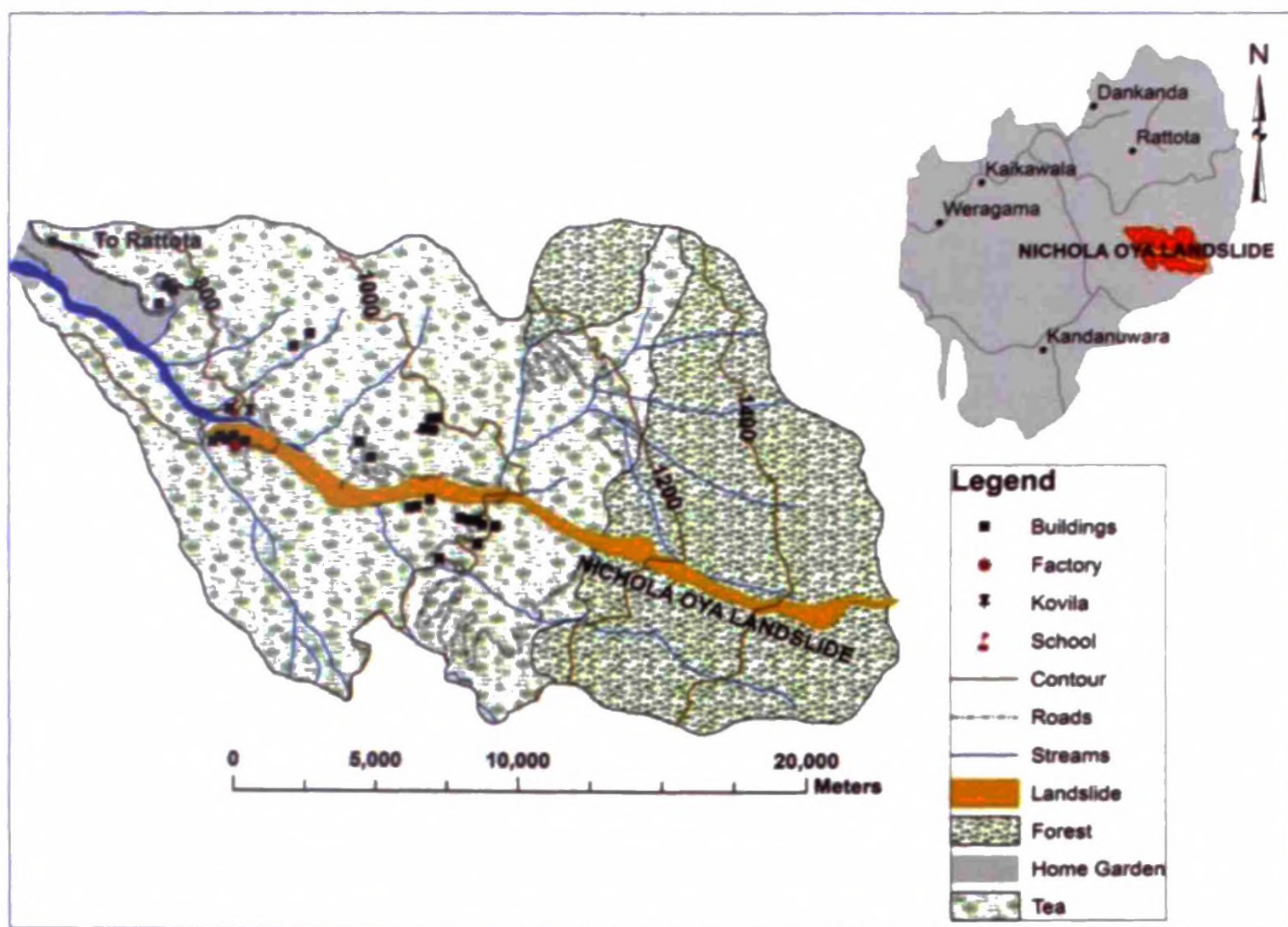


Fig.2 Path of the Nichola Oya landslide and land-use pattern on fertile colluvial sediments/soils characteristic of paleo-landslides.

rainfall that had characterized the Nichola Oya killer landslide as well as many other such catastrophic events in the Central Highlands during the past .

The head of the landslide of Nichola Oya occurs on a dip slope surface of the Bambarakiriella

field evidence as shown by consecutive and the progressive recession of slopes visible in the upper regions of the landslide suggests that width, depth and also the length of Nichola Oya have increased gradually with several consecutive landslide events of the past. Geologically, the area under the landslide

consists of charnockitic biotite gneiss, quartzite, granitic gneiss and marble (Figure 3) whereas the head region is dipping towards slope direction with the value of 50° . The rocks are characterized mainly by three joint systems with steep dips (Figure 4).

The strike direction of one joint set (J_2) is parallel to the direction of slide and the strike direction of other two joint sets (J_1, J_3) are parallel to the strike of the bed rock (Table 1). These three create blocks of rock masses that lie in abundance on either flank of the landslide. These three joint systems are also evident on blocks of rocks that form part of the collapse materials of debris flow. Effects of these joints on landslide are manifested on either flank of the landslide flow (Figure 4). Also, the joint intensities are characteristically very high in quartzite. But, joint apertures wise charnockitic gneiss has characteristically high apertures sometimes exceeding 5 cm (Table 1).

According to the Geology map of Dambulla-Pallegama (Geological Survey and Mines Bureau of Sri Lanka Sheet no 11, 1998), close to

the toe area of the landslide there is a shear zone which is also identified in aerial photographs.

Field observations around landslide area indicate an upper thin residual soil at steep slope with varying overburdens and a lower gentle slope composed of paleo-landslide deposits of variable thickness (Figure 5). The materials on the slide are rich in sandy clayey soil and angular rock fragments (colluvial sediments). Also, large size of rock boulders can be seen in the toe of present landslide which are deposited after severe devastation to the inhabitants with their dwellings of this village.

DISCUSSION

Underground soil saturation by water infiltration due to intense rainfall received within a short period of time appears to be the triggering factor for the Nichola Oya landslide. This is due to water saturation, between joints of bedrock as well as pore spaces of soil, which would increase pore water pressure (Ellen and Wieczorek, 1989). That is exceeding the maximum underground geological conditions to

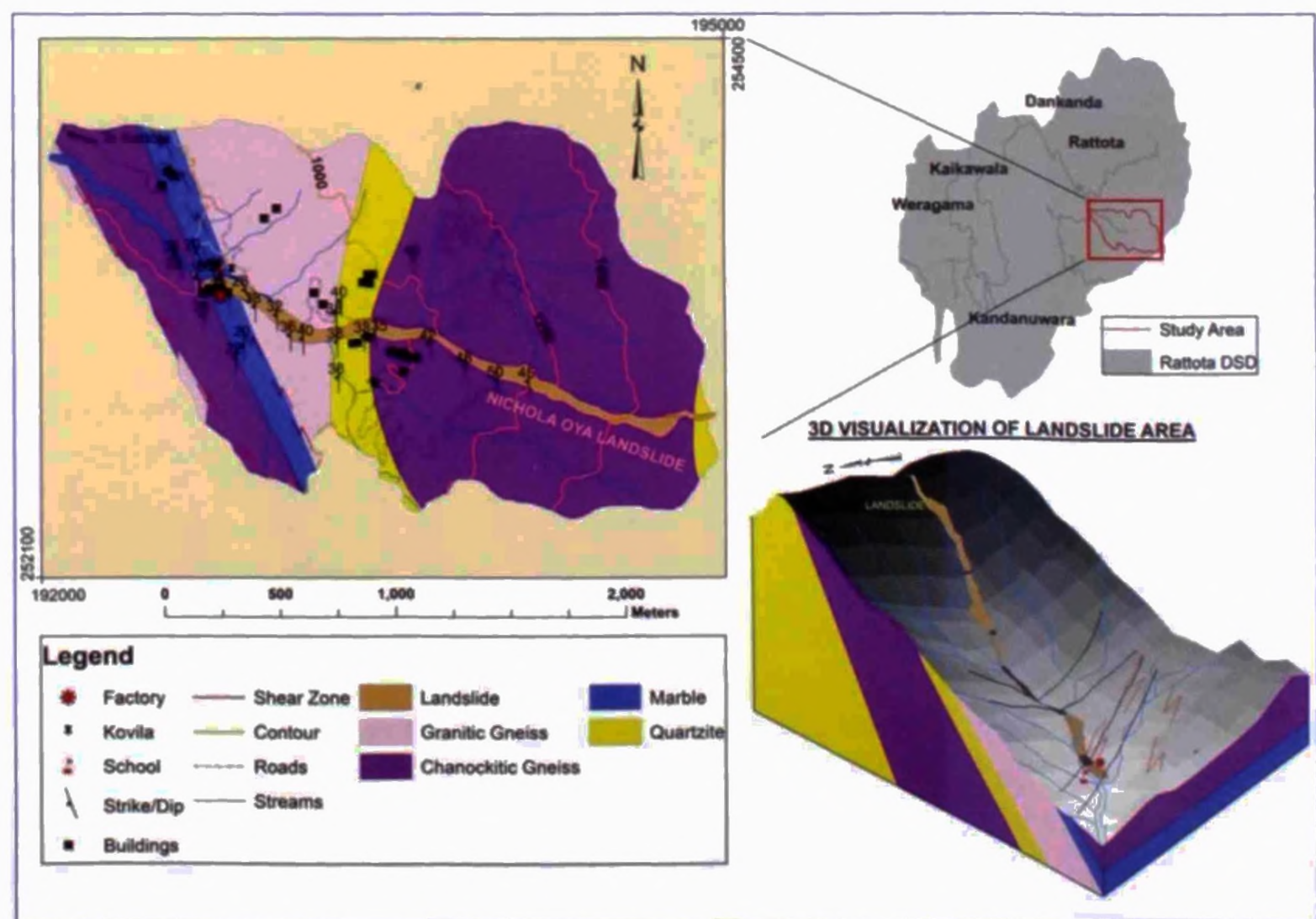


Fig 3 Geology along the Nichola Oya landslide path.

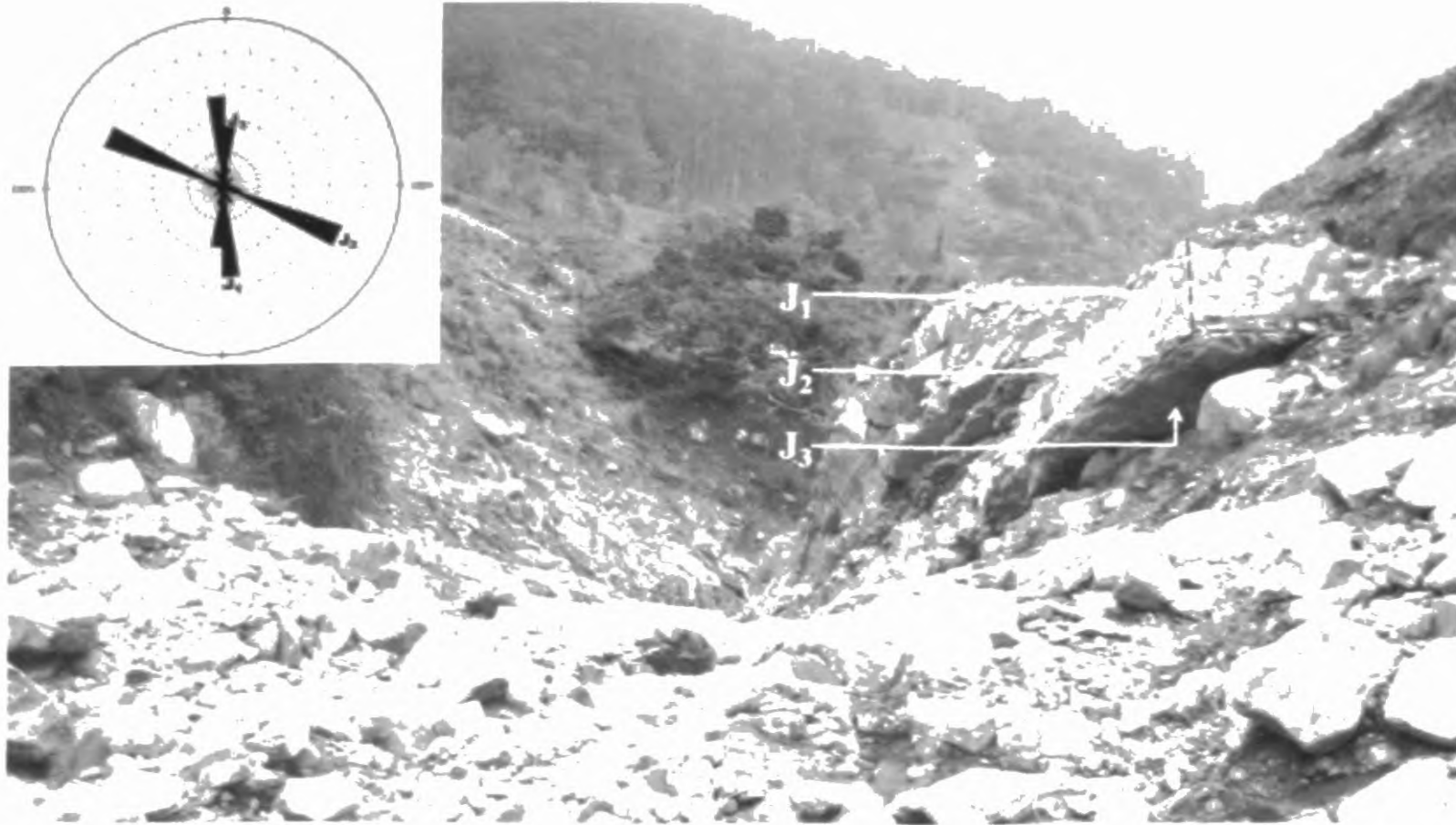


Fig. 4 Three prominent joint systems (J_1 , J_2 and J_3) of gneissic bedrock on the path of the landslide originated in the mountainous region- Rose diagram indicates orientation of joints.

accommodate pore water content could cause instability of the slope. With extraordinary high rainfall exceeding maximum limit of underground saturation could facilitate increase of pore water pressure (Ellen and Wieczorek, 1989). This appears to be the main reason for the occurrence of this killer landslide. On the other hand, presence of paleo-landslide debris also provides sufficient pore spaces to saturate

the water due to their loosely compact texture (Dahanayake, 1990). As a result, existing colluvial boulders would get lubricated and sliding is facilitated.

The debris sliding along the dip slope is a phenomenon not reported in other recorded landslides of the Central Highlands of Sri Lanka. Nichola Oya landslide occurs mostly



Fig. 5 (A)-Exposed paleo-landslide sediment layers, (B)-landslide sediment layers deposited by the December 18, 2012 Nichola Oya event. This is the location where Nichola Oya estate bridge existed before the event.

along the dip slope. The three joint sets create blocks of rock with a driving force along joint planes (the sliding planes) parallel to the foliation plane. Also, these joint sets facilitate intense weathering of bedrock over lengthy periods developing loose sandy and clayey soil as a thick overburden. Furthermore, more feldspar rich, highly weathering susceptible mineralogical composition of charnockitic gneiss rock with relatively thick feldspathic bands provides for the development of a thick overburden in the uppermost parts of the head region of the landslide. Such compositions possess a high vulnerability to sliding with the increase of pore water pressure during rainy periods.

The Nichola Oya landslide has moved down very fast causing much destruction due to the relatively high slope angle (60°) of particularly in its body region. Also, the rupturing of temporally created ponds has given rise to enhanced destruction. The presence of a shear zone along the lower reaches of the landslide might also support this phenomenon. There is a possibility of active interminable neo-tectonic activity along such regional shear zones (Vitanage, 1972).

The field observations show that this killer landslide phenomenon has not been facilitated by human activities. Thus, this landslide can be considered as an event mainly due to geological, structural and climatologic reasons.

CONCLUSIONS

Nichola Oya killer landslide phenomenon is an exceptional event that has occurred along the dip slope in the Central Highlands of Sri Lanka. The presence of paleo-landslide debris has facilitated the occurrence of this landslide supported by intense rainfall. Most probably, the short

recurrence interval of exceptionally high rainfall had facilitated the occurrence of this landslide.

Large quantities of loose debris materials are seen associated on the flanks of the landslide. Therefore, attention should be paid to this aspect of the landslide which could aggravate the impact during future recurrence.

Also, further studies should be carried out on this landslide, especially regarding the possible neo tectonic activities associated perhaps with the shear zone located along this landslide.

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APPENDIX

Appendix Table 1 Orientations of the rock layers and joint planes

| Location ID | Coordinates | | Lithology | Orientation of foliation plane | Orientation of joint planes | Joint intensity (m ⁻¹) | Joint aperture (cm) |
|-------------|-------------|--------|---------------------|--------------------------------|---------------------------------------|------------------------------------|---------------------|
| | N | E | | | | | |
| Ni181212-L1 | 192802 | 253617 | charnockitic gneiss | N10°W/30°SW | N67°W/90° N09°E/47°NW | 2 1 | 0.5 0.5 |
| Ni181212-L2 | 192803 | 253508 | charnockitic gneiss | N07°W/20°SW | N54°E/90° N78°W/90° N12°W/90° | - 1 - | 1 - - |
| Ni181212-L3 | 192719 | 253553 | charnockitic gneiss | N08°W/22°SW | N56°W/90° N67°W/90° N08°E/49°NW | 2 - 2 | 1 0.5 - |
| Ni181212-L4 | 192711 | 253609 | Marble | N05°W/26°SW | N89°W/90°/ N36°E/90° | 1 - | - - |
| Ni181212-L5 | 192914 | 253472 | Marble | N12°W/20°SW | N63°W/90° N06°E/44°NW | - 1 | - - |
| Ni181212-L6 | 192887 | 253477 | charnockitic gneiss | N09°W/20°SW | N27°E/90° N64°W/90° N01°W/76°SW | 1 3 - | 4 1 2 |
| Ni201212-L1 | 192902 | 253500 | Marble | N05°W/22°SW | N66°W/90° | - | - |
| Ni201212-L2 | 193009 | 253451 | charnockitic gneiss | N02°W/25°SW | N63°W/90° N01°E/40°NW | 2 1 | - 1 |
| Ni201212-L3 | 193583 | 253261 | Granitic gneiss | N20°W/38°SW | N07°W/78°SW N38°W/90° | 1 2 | 0.5 0.5 |
| Ni201212-L4 | 193536 | 253253 | Granitic gneiss | N10°W/32°SW | N62°W/90° | 1 | 1 |
| Ni201212-L5 | 193439 | 253226 | Granitic gneiss | NS/36°W | N45°W/90° N03°W/79°SW N72°E/90° | 3 + 2 | - - 0.5 |
| Ni201212-L6 | 193271 | 253240 | Granitic gneiss | NS/40°W | N82°W/90° N09°W/73°SW N45°E/90° | 3 3 1 | 0.5 1 - |
| Ni201212-L7 | 193415 | 253352 | Granitic gneiss | NS/40°W | N64°W/90° N08°W/79°SW | - 1 | - - |
| Ni201212-L8 | 193415 | 253352 | Granitic gneiss | NS/38°W | N26°W/90° N49°E/90° | - - | 0.5 - |
| Ni211212-L1 | 193437 | 253409 | Quartzite | N03°E/37°NW | N51°W/90° N09°W/73°SW N15°E/90° | 4 6 2 | - - - |

Table contd to the next page

| Location ID | Coordinates | | Lithology | Orientation of foliation plane | Orientation of Joint planes | Joint intensity (m ⁻¹) | Joint aperture (cm) |
|-------------|-------------|--------|---------------------------------------|--------------------------------|-----------------------------|------------------------------------|---------------------|
| | N | E | | | | | |
| Ni181212-L1 | 192802 | 253617 | chanockitic gneiss Granitic gneiss | N10°W/30°SW | N67°W/90° | 2 | 0.5 |
| Ni211212-L2 | 193215 | 253255 | | N05°E/38°NW | N66°W/90° | 4 | - |
| | | | | | N01°W/71°SW | 5 | 0.5 |
| | | | | | N68°E/90° | 6 | 0.5 |
| Ni211212-L3 | 193158 | 253345 | Quartzite | NS/33°W | N74°W/90° | - | - |
| | | | | | N04°W/71°SW | 4 | - |
| Ni211212-L4 | 193063 | 253381 | Quartzite | NS/35°W | N04°W/75°SW | 6 | - |
| | | | | | N69°W/90° | 4 | 1 |
| | | | | | N13°E/90° | 2 | - |
| Ni211212-L5 | 194112 | 253058 | Quartzite | N08°E/38°NW | N07°W/74°SW | 6 | - |
| | | | | | N12°E/90° | 6 | - |
| | | | | | N69°W/90° | 4 | - |
| Ni211212-L6 | 194248 | 253054 | Quartzite | N02°E/48°NW | N04°E/39°NW | 2 | - |
| | | | | | N73°W/90° | 8 | 1 |
| Ni211212-L7 | 193976 | 253121 | Quartzite | N04°E/50°NW | N84°E/90° | 6 | - |
| | | | | | N61°W/90° | 5 | - |
| | | | | | N02°W/72°SW | - | - |
| Ni211212-L8 | 193822 | 253217 | chanockitic gneiss | NS/45°W | N68°W/90° | - | 3 |
| | | | | | N06°W/78°SW | 3 | 2 |
| Ni211212-L9 | 193754 | 253593 | Quartzite | NS/52°W | N68°W/90° | 8 | - |
| | | | | | N07°E/45°NW | 5 | - |
| | | | | | N13°W/90° | 4 | 1 |
| Ni241212-L1 | 193422 | 253071 | chanockitic gneiss | N03°W/44°SW | N62°W/90° | 2 | 2 |
| | | | | | N04°E/41°NW | 1 | 3 |
| | | | | | N28°W/90° | 1 | 1 |
| Ni241212-L2 | 193422 | 253071 | chanockitic gneiss | N14°E/40°NW | N03°W/74°SW | - | 10 |
| | | | | | N66°W/90° | 1 | 1 |
| | | | | | N23°W/90° | - | 0.5 |
| Ni241212-L3 | 193012 | 253207 | chanockitic gneiss | NS/47°W | N67°W/90° | 3 | 1 |
| | | | | | N02°W/75°SW | 3 | 2 |
| Ni241212-L4 | 192978 | 253160 | chanockitic gneiss | NS/50°W | N65°W/90° | 3 | - |
| Ni241212-L5 | 192838 | 253342 | chanockitic gneiss | NS/41°W | N08°E/43°NW | 3 | 1 |
| Ni241212-L6 | 192850 | 253360 | chanockitic gneiss | NS/40°W | N63°W/90° | - | 8 |
| | | | | | N05°E/45°NW | 2 | - |
| Ni241212-L7 | 192876 | 253390 | chanockitic gneiss | N02°W/39°SW | N65°W/90° | - | 6 |
| | | | | | N06°E/40°NW | 2 | - |