4th SOUTHEAST ASIAN CONFERENCE ON SOIL ENGINEERING
KUALA LUMPUR, MALAYSIA
7th – 10th April 1975

SOME ASPECTS OF LANDSLIDES IN SRI LANKA

A. S. BALASUBRAMANIAM, B.Sc., Ph.D., C.Eng., M.I.C.E., M.A.S.C.E., F.G.S.,
Asian Institute of Technology, P. O. Box 2754,
Bangkok, Thailand.

J. B. DISSANAYAKE, B.Sc., M.Sc., C.Eng., M.I.C.E.,
Superintendent Engineer,
Territorial Civil Engineering Organization, Sri Lanka.

G. P. KARUNARATNE, B.Sc., Ph.D.,
Lecturer in Civil Engineering,
University of Sri Lanka, Peradeniya Campus, Sri Lanka.

SYNOPSIS This paper summarises the preliminary studies carried out on 13 landslides that took place recently in Sri Lanka. A classification of the landslides is made. Mineralogical studies were carried out on samples of rocks and soils taken from the landslide areas. The geology of Sri Lanka is described briefly to indicate the existence of 3 well defined peneplains. Most of the rock-falls reported here are found to be at the boundaries between the highest and middle peneplains. Kaolinite and illite minerals were found in most of the landslides which are of the mudflow type. It appears that the mudflow is due to a layer of soft material (Kaolinised feldspar) getting squeezed out under overburden pressure.

1. INTRODUCTION

Landslides are a common geological phenomenon in the hilly regions of Sri Lanka. However, when one considers the potential damage that could be caused to life and property by landslides, it would probably rank second only to floods and cyclones, in its disaster potential. During the year 1972, in the two major landslides that took place at Ihala Rambukpitiya and Ragala nearly 40 lives were lost in addition to costly damage to property. Thus it appears that the problem of landslides in Sri Lanka deserves much more attention than it has hitherto received.

In this paper, an attempt will be made to present data associated with a large number of landslides that took place recently in Sri Lanka. These landslides will then be classified and the causes of their occurrence will be discussed. A detailed description of the classification of landslides will not be made here, but reference could be made to Skempton and Hutchinson (1969), Dissanayake (1973). Figure 1 illustrates a chart of the classification of landslides partly based on Skempton and Hutchinson (1969). Also, the various causes of landslides in general, have been described exclusively in Eckel (1958).

From a consideration of the various types of earth mantles in which most of the landslides in Sri Lanka have taken place it is seen that most have taken place in either residual or colluvial terrain. A brief description will therefore be made in the following section of the geology of Sri Lanka.

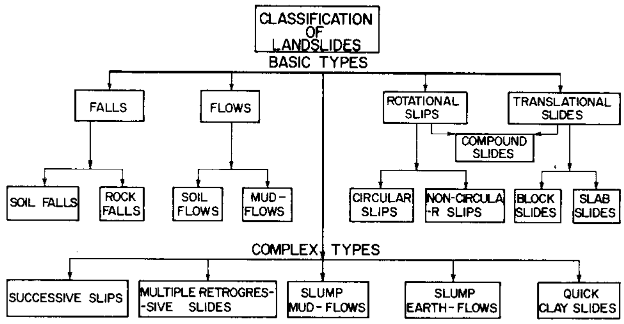

Fig. 1 Classification of landslides.

2. GEOLOGY OF SRI LANKA

Peneplains in Sri Lanka

In 1929, it was the Canadian Geologist Frank Dawson Adams, who first recognised that there were "three well marked plains of erosion or peneplains cut in the rocky frame-work of the island of Sri Lanka. A peneplain is defined as being almost a plain produced by long periods of weathering and erosion. While it is recognised that a peneplain can exist at any level, its main characteristic is that hills, ridges and plateaus belonging to it, are of the same general level. The lowest peneplain surrounds the central hill country on all sides (see Fig. 2). From the inner edge of the lowest peneplain rises the middle peneplain in a steep step of about 1000 or 1500 ft. Most of the area belonging to the middle peneplain is under 2500 ft in elevation. Rising from this middle peneplain is another steep step of about 3500 ft is the highest peneplain whose general elevation is about 5000-6000 ft, from which a few peaks rise above 7000 or 8000 ft.

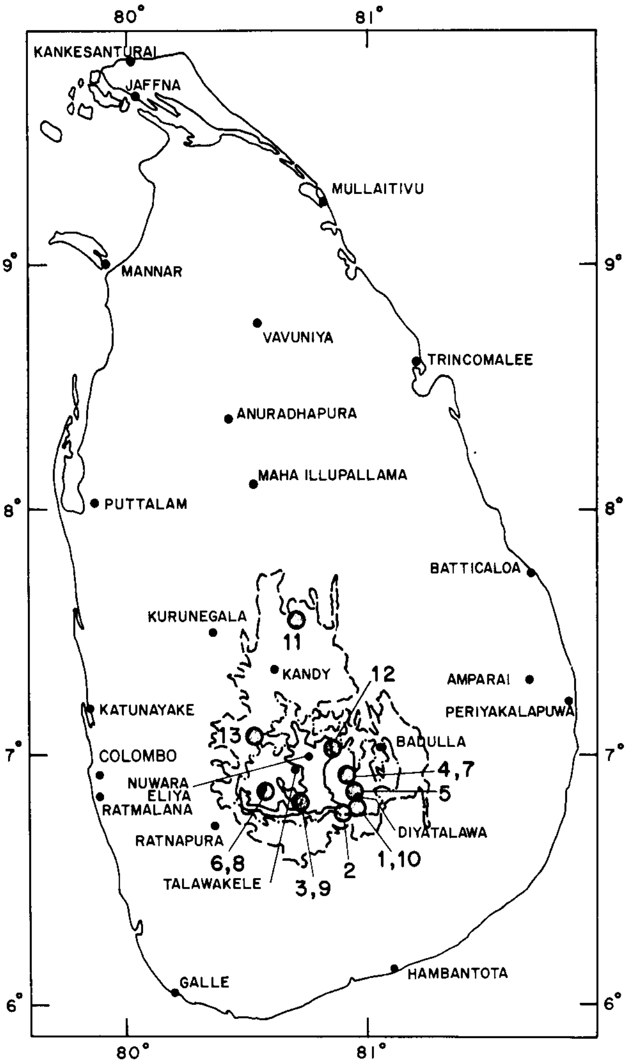

Fig. 2 Map of Sri Lanka showing peneplains and locations of landslides.

Most of the areas where landslide took place are found to belong to the regions of middle and highest peneplains. The middle peneplain is found to be separated from the lowest by a difference of nearly a 1000 ft. This escarpment, though continuous in many places is very regular and deeply indented in other places. The highest peneplain is least like a peneplain as it is a complex chain of mountains, plateaus and basins within which a general level of erosion can barely be recognised. The southern boundary of the highest peneplain is called the "Southern Wall" of the Hill Country and stretches for more than 50 miles rising from a little over 1000 ft to 5000 ft or more in some places. This almost impenetrable barrier composed largely of resistance charnockites and as a result a number of high water falls are seen to drop over its edge. The highest of the plateau regions called the "High Plains" stretches northward from the centre of the Southern wall and contains some of the highest peaks namely, Kirigalpota and Pidurutalagala and some undulating grassland areas such as Horton Plains, Moon Plains etc. which are at a general elevation of around 6500 ft (see Fig.3).

Situated east of these High Plains is the Uva Basin (sometimes) called the Welimada Plateau) which is a basin like depression surrounded by peaks such as Hakgala, Totupola, Beragala and Namunukula. Everywhere in the Uva Basin are signs of violent earth movements in the form of steep to vertical folds, recumbent folds, faults and thrusts. In both the High Plains and Uva Basin, the bedrock is composed predominantly of easily wheatherable feldspathic metamorphic rocks (Cooray, 1967).

Situated on the west of the High Plains is the Hatton Plateau which has a remarkable appearance of flatness due to horizontal attitude of the rock in most of this area. The average

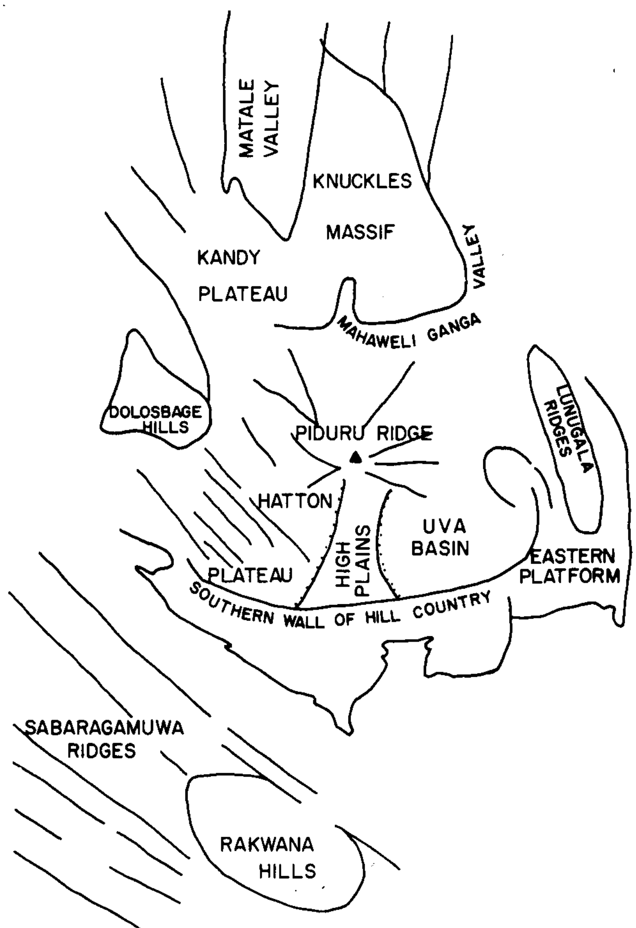

Fig. 3 Physiographic regions of the hill country.

elevation of the Hatton Plateau is nearly 4000 ft and the rivers in this area are seen to flow in gorges such as Kotmale Oya. Separated from the rest of the central highlands are massifs which also form a part of the highest peneplain. North-east of the Kandy Plateau is the Knuckles Massif which includes peaks such as Gombaniya and Knuckles. The eastern boundary of this massif overlooks the middle peneplain, which is well defined in this region. To the South-West of the Central Highlands is situated the Rakwana Massif which is bounded on the north by an escarpment similar to the Southern Wall of the hill country. Rakwana Massif comprises of a few high plains such as the Handapana Ella Plains and the Tangamale Plains and a few peaks such as Beralagala, Gongala and Suriyakanda.

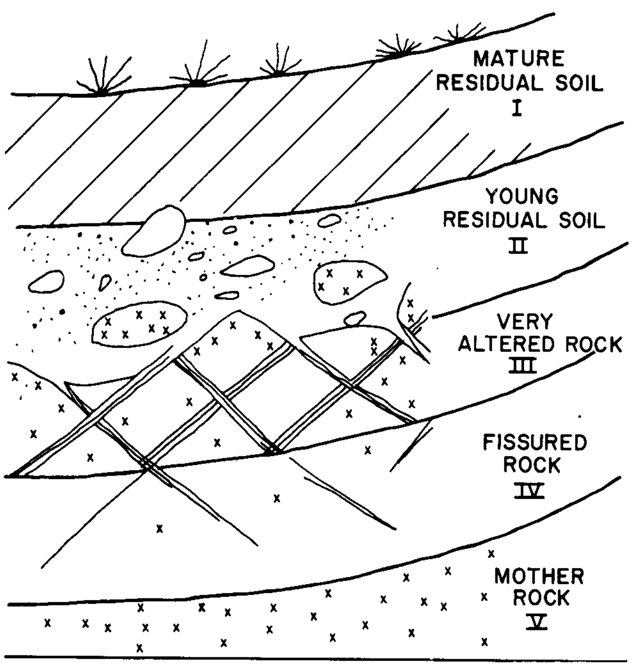

Fig. 4 Cross-section of typical residual terrain.

Different Types of Earth Mantles

The different types of earth mantles in Sri Lanka can be divided into (a) Transported Sediments, (b) Residual Soils, (c) Colluvial Terrain and (d) Mixed Hill Slopes. In the hill country of Sri Lanka, large extents of transported sediments have not so far been discovered. Attention will therefore be confined to the other three types of earth mantles.

Residual Soils: These are normally derived from the in-situ weathering of igneous and metamorphic rocks and are found in many parts of the central hills of Sri Lanka. The complete profile of a residual terrain has been represented [Deere and Patton (1972), Barata (1969)] as having five layers (see Fig. 4), while layer I is referred to as the upper zone, layer II, the intermediate zone, layer III and IV taken together constitute the partially weathered zone.

The upper zone which has undergone the most advanced weathering contains soil minerals as quarts, micas, clay minerals and iron oxide.

The clay minerals are largely members of the Kaolinite group and Illites. Varying amounts of both biotite and muscovite micas are present along with similar hydrous micas such as Vermiculite. The soils of this zone come fairly close to being homogeneous and contain little or no evidence of the structure of the parent rock from which it was derived.

The intermediate zone is formed by the incomplete weathering of the parent rock. As the weathering is not complete, the soils reflect some of the characteristics of the original rock. Sometimes, the material in the Intermediate Zone, which is soil intexture, but which still retain the appearance and structure of the parent rock, is termed "Saprolite". The predominant minerals found in Saprolites are clay minerals, quartz, partially weathered feldspars and mica. Large areas of partially kaolinised feldspars are often present. However, the most important characteristics of the soils of the intermediate zone is their content of various types of mica. Most of the original crystalline rock contain large amounts of mica. Since these micas do not weather as readily as the feldspars, the soils contain large amounts of unweathered or slightly weathered mica mainly of the Muscovite and Biotite varieties. It is very difficult to make accurate determination of the liquid limit in these soils as they tend to slide in the Casagrande cup instead of flow as specified in the test. Even in the plastic limit test the threads are so spongy that they cannot be easily rolled.

Colluvial Terrain: These terrains occur at the foot of rock scarps, of steep mixed hill slopes and are generally composed of mixtures of rock boulders and soil masses which fall or roll off from the rock scarps. Colluvial hill slopes generally have a "neck" of steep inclination in contact with the scarp and just below it. The neck is continued downwards by a "loin" of smaller inclination. Any weathered material that falls off the scarp is directly received by the "neck" which is as a result a more recent accumulation than the "loin". As these colluvial deposits tend to increase in thickness with time they tend to become unstable mainly during periods of heavy precipitation.

They receive their water in two ways; (a) rainfall uniformly over the surface of the slope and (b) direct ingress of water into the contact with the scarp. By this process, the colluvial material can get softened through saturation and due to the high pore pressures that develop in these regions during periods of exceptionally heavy precipitation, sudden failures could occur in these terrain.

Mixed Hill Slopes: These are terrains in which earthy mantles co-exist with out crops of bedrock. One may also consider earthy slopes with stones and boulders enclosed in the soil or laid on its surface, as mixed hill slopes. The boulders may be of colluvial origin or of residual origin. When mixed hill slopes of this nature are subjected to periods of excessive rainfall, the boulders get detached from their original positions and rolling boulders will result.

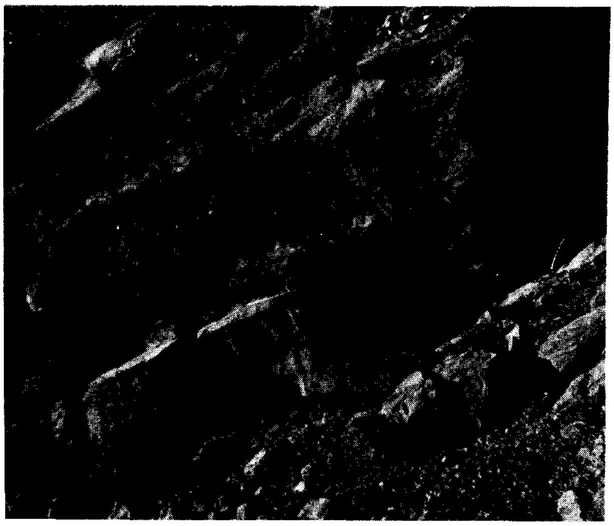

Fig. 5 Advancement of weathering along the joints of rocks.

3. DETAIL OF LANDSLIDES

Altogether 13 landslides have been reported here and they are classified as (a) Falls, (b) Flows, (c) Rotational and Translational Slides and (d) Complex landslides. The locations of these landslides are numbered in Fig. 2. Numbers 1-3 can be classified as Falls, 4-6 as Flows, 7-10 as Slides and 11-13 as Complex Land Slides.

Falls

The landslide No. 1 is the rockfall at Viharagala, Haputale. The road from Balangoda to Haputale gradually climbs the steep scarp that separates the highest peneplain from the middle peneplain. Viharagala which is situated between Beragala and Haputale has an elevation of nearly 4000 ft above mean sea level and is near the top of the scarp. At this point several rockfalls have taken place over the years. The slope below the road level at this point is colluvial in nature and is clearly the result of numerous rockfalls in the past. It is seen (see Fig. 5) that weathering has advanced along the joints and fissures in the parent rock mass and as a result, the rock is at present separated into unweathered block of rock, with weathered material lying between them, the sizes of the blocks depending on the original distribution of joints and fissures. During periods of intense rainfall precipitation, when the weathered soil between the blocks of rock gets saturated and thereby softened, some of the blocks of rock can no longer be contained in their positions and a rockfall results.

The second landslide reported is the rockfall at Beragala, Haputale where the township is situated immediately below what is termed the Beragala Peak, which is one of the several peaks that rise from the Southern Wall. A small perennial stream that originates from Beragala Peak flows through the townships and the terrain above the town clearly falls into the category of colluvial terrain and the earth mantle has boulders embedded in it which are very likely the result of previous rockfalls. The soil mantle would have been in a loose state of compaction and the heavy ingress of water into it would have softened the terrain. Due to this softening the boulders could no longer be contained in their original position causing a rock fall.

The third landslide was the rockfall on the Balangoda Bogawantalawa road. This particular road crosses the Southern Wall of the hill country and the present slide took place in November 1972 during a period of fairly high rainfall precipitation. Samples of rock collected from the site were found to be a feldspathic quartzite with traces of graphite. There were closely spaced weak planes which imparted a schistose character to certain areas of the rock. The feldspar has weathered and Kaolinised and traces of mica were found along the weak planes which would have helped the unweathered portion of the dipping rock to slide along the weathered surface which had absorbed water from the rainfall precipitation. This type of rockfall is difficult to control as the rock has broken up into small rectangular blocks of quartz not much bigger than rubble sizes.

Flows

Mudflow at Kahagolla, Diyatalawa: Situated roughly half-way between Haputale (elevation 4750 ft) and Bandarawela (elevation 4020 ft) is one of the landslide (Landslide No. 4) that has remained active for possibly the longest period of record and is situated at Kahagolla. It first occured in the year 1958 and has remained active during the periods of heavy rainfall precipitation up to the present day. An area contiguous to the old mudflow was affected during the heavy rains of November 1972. A bridge situated in the area of the flow was washed away in 1960 and a Bailey bridge has served the purpose since then (see Fig. 6). At present there are signs of this Bailey Bridge too getting shifted out of alignment.

The affected area is over 15 acres in extent and prior to the slide it has been a portion of a flourishing tea estate. Two perennial streams enter the mudflow area and flow through the affected area over its entire length. These streams form into stagnant pools where the terrain is reasonably flat (see Fig. 6(a). The rear scarp of the mudflow at Kahagolla is not at all impressive and is of the order of 1 to 2 metres. The movement in the upper part of the slide area is virtually a vertical displacement of the nature of a subsidence while towards the lower part of the flow the material is seen to heave with relatively high horizontal displacements.

Disturbed samples of soil taken from the slip area when tested revealed 4 pc clay, 43 pc silt and the balance 53 pc sand. The liquid limit was 68.5 pc, plastic limit 46.5 pc and the plasticity index 22.0 pc. Differential

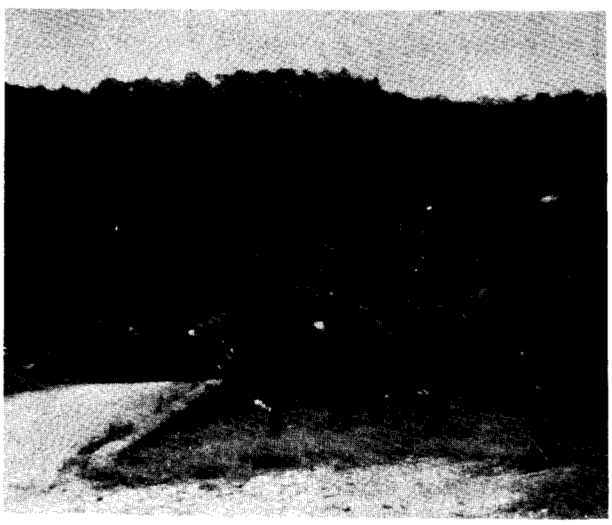

Fig. 6 Landslide at Kahagolla, Diyatalawa.

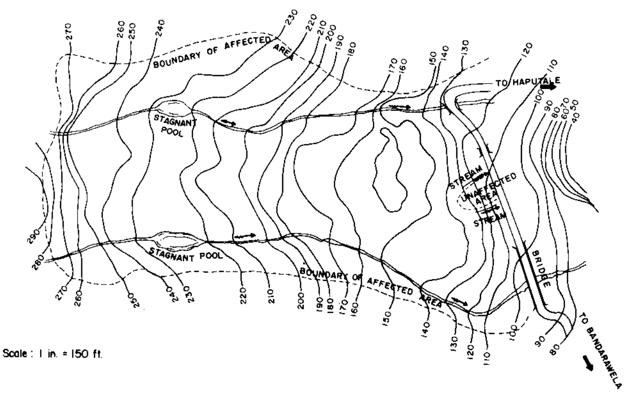

Fig. 6a Contour plan of Kahagolla landslide area

thermal analysis and X-ray diffraction tests revealed the presence of kaolinite and illite clay minerals. Even though the cause of the landslide has not been conclusively established, it appears that the mudflow is due to a layer of soft material (in this instance kaolinised feldspar) getting squeezed out under the overburden pressure of the soil mantle. Due to the surface cracks that have appeared in the affected area, a further ingress of water has been promoted thereby resulting in the softening of more material. The parent rock in the vicinity composed predominantly of feldspar and quartz.

The other two mudflows are (i) the mudflow at Kandekumbura, Welimada (Landslide No. 5) and (ii) the mudflow on Hatton-Maskeliya Dalhousie Road (Landslide No. 6). Kaolinite and Illite clay minerals are found on samples of soils taken from these two slip areas. Details of these landslides could be found in Dissanayake (1973).

Slides

Slide at Boralanda, Welimada (Landslide No. 7): Welimada has already been mentioned is a township within the Uva basin which is bounded on the west by the High Plains and on the south by the Southern Wall of the hill country. The slide at Boralanda has occurred almost halfway between Welimada and Diyatalawa. The slide took place in December 1971, during a period of high rainfall precipitation. The slide has taken place in residual terrain but due to the presence of competent parent rock a few feet below the road level it has interfered with the formation of a circular slip surface and has introduced a translational element into the slide movement. This slide could be classified as a compound slide which have a part rotational and a part translational movement. During the construction of the highway from Diyatalawa to Welimada a certain amount of lateral support had been removed at the slide area due to a cutting made for a raod platform. The subsequent effect of weathering combined with the adverse effect of heavy rainfall has triggered this slide during the rainy season of 1971 (see Fig. 7).

Fig. 7 Landslide at Boralanda.

Disturbed samples of the soil from the slip area when tested revealed a clay content of 7 pc, 33 pc of silt and the balance 61 pc sand. Mineralogical investigation confirmed the presence of Kaolinite, Illite and Muscovite. The slides at Mousakalle, Maskeliya (Landslide No. 8) the one at Balangoda-Bogawantalawa road (Landslide No. 9) and at Haputale (Landslide No. 10) will not be discussed here. Details of these slides could be found in Dissanayake (1973).

Complex Landslides

Slump-mudflow on Rattota-Gammaduwa Road (Landslide No. 11): On the Rattota-Gammaduwa Road in Matale District, a landslide of above average magnitude occurred in January 1971, during a period of usually heavy rainfall. During the slide an 85 m length of highway was completely destroyed. As the initial stages of the slide took place during the night there are no eye witnesses to the initial stage but many inhabitants of the area have seen the latter stages of the slide. The length of the slide was approximately 560 metres and the volume of the material that has been assessed to have taken part in the slide is around 200,000 cu metres (see Fig. 8).

The upper part of the slide took place in a tea estate above the Rottota-Gammaduwa Road and in this region large downward displacements of the soil had taken place. The portion of the slide below the road, in land where a mixed vegetation of coconut and jak trees were existing, had taken the form of a flow until a stream was reached which carried away most of the debris. The severity of the flow in this region has been such that there was not a single tree or tree trunk left in the path of the flow. This landslide could be identified in the category of slump-mudflow.

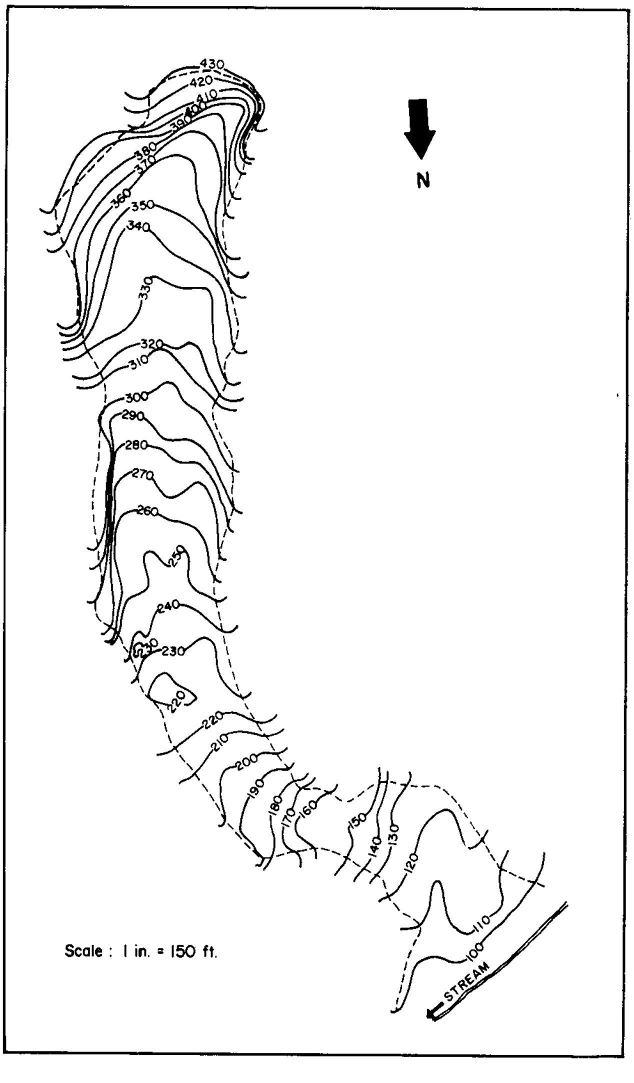

Fig. 8 Contour plan of Slump mud-flow on Rattota Gammaduwa Road.

Disturbed samples of the soil taken from the slip area when tested revealed that the clay content was 5 pc, silt 35 pc and the balance 60 pc sand. Mineralogical investigation carried out indicated the presence of Biotite mica (see Figs. 9 and 10). The fact that the intermediate zone between the fully weathered soil on top and the unweathered rock at the bottom was having high concentration of micaceous soils when looked in combination with the parent rock dipping towards the free surface of the slope gives a clue for the failure of the slope. The immediate cause which triggered the landslide was however, the intense rainfall precipitation that preceeded the movement. This rain water has played the dual role of lubricating the micaceous interface between the soil and the rock and also of increasing the instability due to the high wet density of the soil. The high seepage pressure of the groundwater would have also assisted in the failure. While the slump-mudflow on Rattota-Gammaduwa road took place over several days, the slide at Ragala (Landslide No. 12) which was very similar took only a few minutes. In the landslide at Ragala the initial slump took place in steep colluvial terrain and the quantity of colluvial material that got displaced flowed rapidly along the stream bed taking a toll of nineteen human lives. The rapidity of movement of the slide at Ragala, was comparable to that of an avalanche and most of the damage of life and property had been caused by the boulders that had been embedded in the earth mantle. This failure took place on either side of a small perennial stream which was during the time of the slide carrying a much larger flow due to intermittent rainfall which had taken place over several preceeding days.

4. STRENGTH PARAMETERS AND STABILITY ANALYSIS

Most of the landslides reported in this paper has taken place in either residual or colluvial terrain, where the failure surface is non planar and irregular. Detailed analysis of the stability of natural slopes in these terrain have not been carried out yet. However, undisturbed samples of soil taken from similar terrain when tested in the laboratory under saturated condition revealed strength parameters of the order c_u = 10 psi, ϕ_u = 17° and c' = 1-2 psi and ϕ = 29° - 32°. Artificial slopes cut on these terrains with the above strength parameters and a factor of safety of F = 1.5 have failed under conditions of full saturation and heavy rainfall Existing data on the stability analysis of failures in cut slopes seem to indicate a value of c' = 0 and ϕ' = 20°. Thus it appears that there is a reduction in the strength parameters due to softening of the soil during moisture absorption. The absorption characteristics of laboratory compacted samples were studied. It was found that samples of soil compacted at its

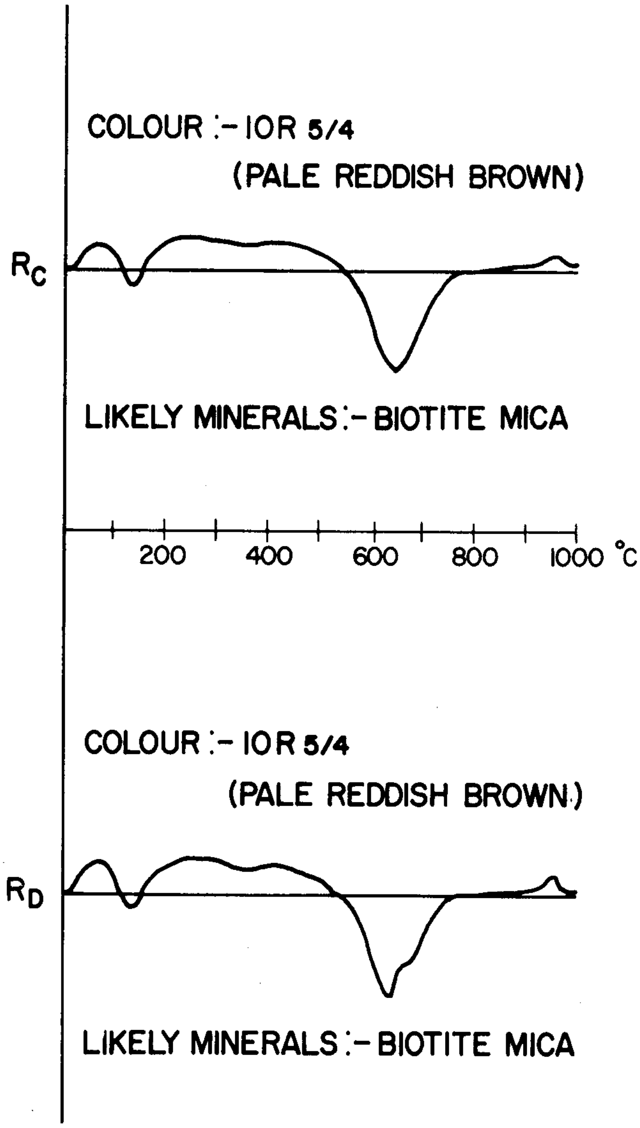

Fig. 9 DTA curve of samples taken from slump mud-flow at Rattota Gammaduwa Road.

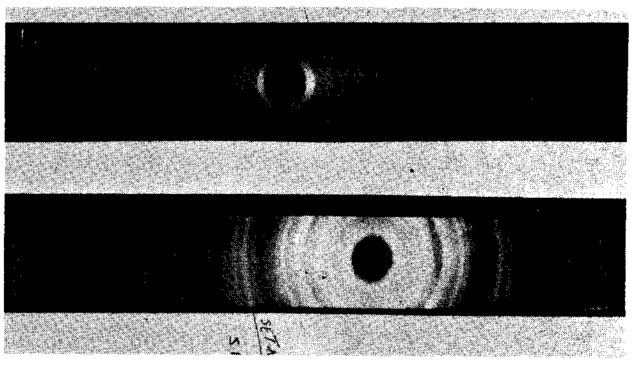

Fig.10 X-ray diffraction patterns of samples taken from slump mud-flow at Rattota Gammaduwa Road.

optimum density when immersed in a container of water, have a high degree of absorption and disintegrated and crumbled to pieces within hours. However, samples of these soils when stabilized with 3 pc of lime or cement and then compacted near the optimum moisture content had very small water absorption and remained intact over a period of one month. The rate of absorption was negligible after 24 hours. These work are still in progress and will be published elsewhere.

5. CONCLUSIONS

The paper summaries the preliminary studies carried out on 13 landslides that took place recently in Sri Lanka. The landslides were classified as falls, flows and complex landslides. Most of the falls reported here are rockfalls and are found to be at the boundaries between the highest and the middle peneplains. Samples of rock taken from these locations were found to be feldspathic quartzite with traces of graphite. Closely spaced weak planes imparting a schistose character to certain areas of the rock are also noted. Mineralogical studies reveal the presence of Kaolinite and Illite minerals in most of the landslides which are of the mudflow type. It appears that the mudflow is due to a layer of soft material (Kaolinised feldspar) getting squeezed out under overburden pressure. The most devastating type of landslide encountered is the slump mudflow taking place in a colluvial terrain which possesses the rapidly of an avalanche. A high concentration of micaceous soils are found in these slip materials.

6. ACKNOWLEDGEMENTS

The authors wish to thank Prof. A. Thurairajah, Dr. B.L. Tennekoon and the Soil Mechanics Laboratory Staff, University of Sri Lanka, Peradeniya Campus for their valuable assistance and support in carrying out the work presented in this paper. The manuscript of this paper was prepared at the Asian Institute of Technology, Bangkok. Thanks are due to Prof. Za-Chieh Moh, Drs. Edward W. Brand, A. Kazi and Mrs. Vatinee Chern.

REFERENCES

BARRATA, F.E. Landslides in the Tropical Region of Rid de Janeiro, Proc. 7th Int. Conf. on Soil Mech. and Founds. Eng., Vol. II, 1969, pp. 507-516.

COORAY, P.G. An Introduction to the Geology of Ceylon, National Museums of Ceylon Publication, 1967.

DEERE, D.V. and F.D. PATTON. Slope Stability in Residual Soils, Proc. 4th Pan-American Conf. on Soil Mech. and Found. Eng., Vol. 1, 1972, pp. 87-170.

DISSANAYAKE, J.B. Some Aspects of Landslides in Sri Lanka, M. Sc. Thesis, University of Sri Lanka, Peradeniya Campus, 1973.

EEKEL, E.B. Landslides and Engineering Practice, Prepared by The Committee on Landslide Investigations, Highway Research Board, U.S.A., 1958.

SKEMPTON, A.W. and HUTCHINSON, J. Stability of Natural Slopes and Embankment Foundations, Proc. 7th Int. Conf. on Soil Mech. and Found. Eng., Vol. 3, 1969, pp. 291-340.