SEEING EARTH THE SCIENTIFIC WAY

Kapila Dahanayake

Large scale geological processes have resulted in the differentiation of the earth. Melting processes in the earth's mantle lead to the formation of igneous rocks. Some of these rocks cool deep in the earth. Others form volcanoes and extrusive lava flows. Weathering processes break down the surface rocks and the resultant material is transported by water, wind, ice to sites of deposition where they eventually become sedimentary rocks. As a result of deep burial, deformation and heating, the sedimentary rocks are metamorphosed. Some of the metamorphic rocks may be heated to their melting points forming new magmatic intrusions; igneous rocks also may be metamorphosed. All three kinds of rocks can be weathered and broken down into the raw materials of sedimentary rocks.

Needless to mention - that physical and chemical processes occurring in and outside the earth can not only cause havoc to man but also prove to be beneficial for his existence. The igneous activity could result in the development of earthquakes, massive lava flows and destabilization of large segments of the earth which cause destruction to human life and property and disturb the ecological balance. The surficial processes of weathering, erosion and sedimentation could also like-wise create natural hazards such as landslides, floods and coastal and other erosion phenomena.

However, both internal and external geological processes also can generate or uncover massive mineral and metal deposits, develop thick soil profiles and river valley deposits suitable for agriculture, thereby supporting the existence of man. We intend to discuss two examples : one of destruction and the other of construction in today's programme. e.g. (a) Landslides (b) A phosphate Deposit.

LANDSLIDES IN THE CENTRAL HIGHLANDS OF SRI LANKA

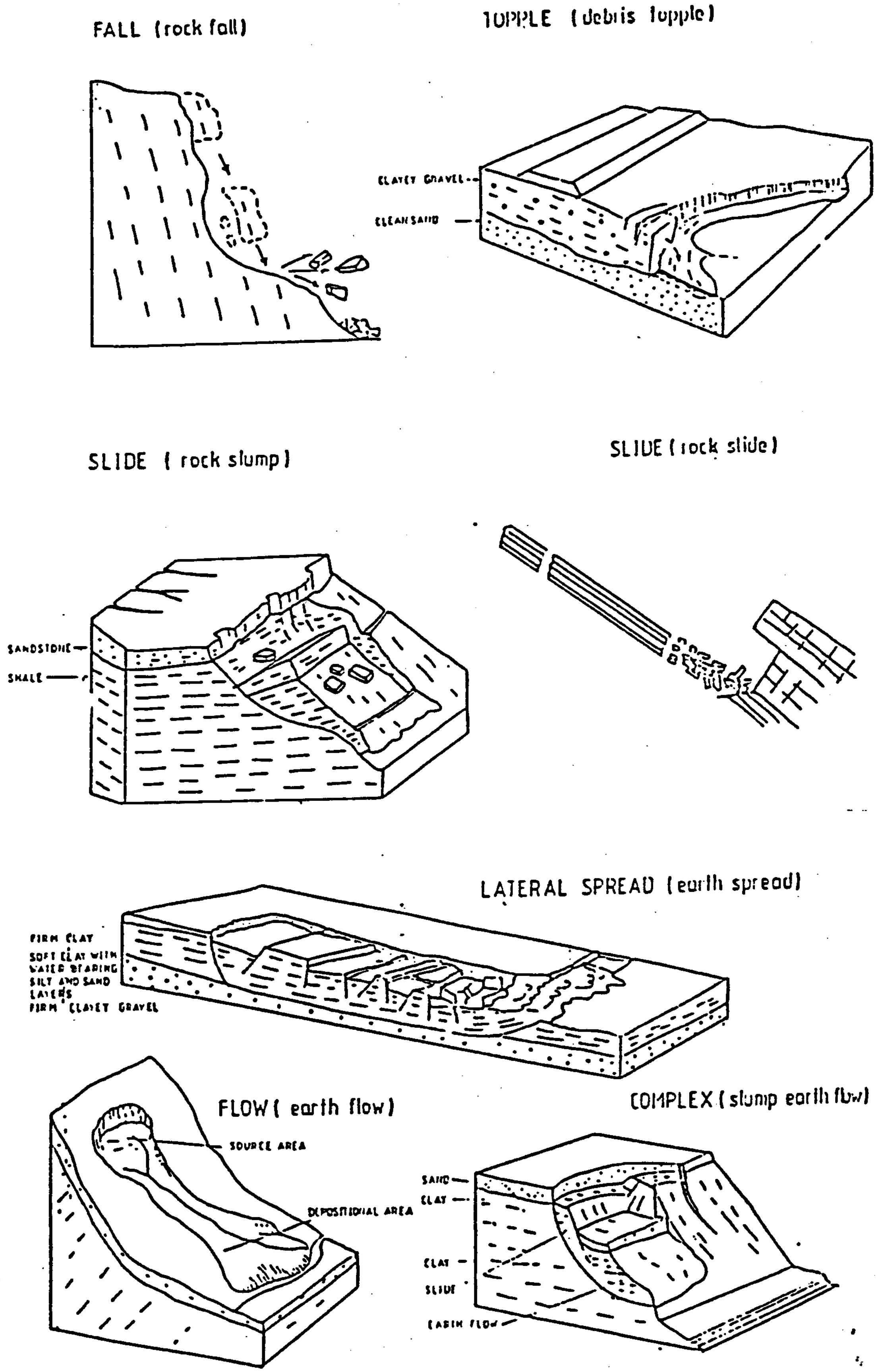
Landslides involve a wide variety of mass movements which cause downslope transport of soil and rock material under gravitational influence. In the central highlands of Sri Lanka the downward movement is facilitated by slopes exceeding 25 degrees which have been created by the underlying structure of the rocks or by the nature of overlying colluvial material. The underlying rocks are mostly Precambrian metasedimentary rocks in which the bedding or banding has been clearly preserved. The folded metasedimentary sequences of quartzite, marble, charnockite, calc- and granitic gneiss, hornblende biotite gneiss and granulites when subjected to intense tropical weathering have given rise to steeply sloping ridges and hillocks susceptible to landslides.

In a landslide, one can recognize a head region, body region and a toe. Landslides can be classified according to type of movement as falls, topples, slides, lateral spreads and flows (see Fig.1).

Fall: mass travels as a free fall and as rolling of rock and soil may form the head region of a landslide.

Fig 1 - Classification of Landslides

(modified after Hays, 1981)



Topple: overturning movement which can result in a fall or slide- may form the head region of a landslide.

Slides: two types recognized as rotational and translational slides- first being due to slumping on a scarp slope and the second type due to movement predominantly on a dip slope (bedding plane or along bands in metamorphic rocks)- may form the head of body of a landslide.

Flows: mud flows (for fine grained material) and rock or debris flow for coarse particles such as boulders. Movement resembles that of viscous fluids- may form the head, body or the toe of a landslide.

In Sri Lanka, isolated rock falls and rock slumps occurring on the scarp slope are common, Rock slides and lateral spread are also noticed. However, most reported occurrences are a combination of two or more types referred to above and such landslides are massive ones extending more than 1 km in length. Such massive landslides assume importance when they occur in populated areas causing human and material losses.

CASE HISTORIES OF LANDSLIDES

Landslide at Gonaadika Estate, Sinhapitiya, Gampola

This landslide occurred on 22nd October 1977 in the early morning killing 26 people. The landslide, about 800 m in length, can be regarded as a rock slump- rock flow originating from an oblique scarp slope. The rocks were thinly banded and these were gneisses rich in feldspar. The rocks were characterized by three systems of joints out of which two were very closely spaced.

On-the-spot investigatins revealed that prior to the slide, continuous rains occurred for nearly seven days. The line rooms in which people lived showed springs of water sprouting from the muddy floors. It was noted that the pre-slide slopes had been disturbed by cutting of deep drains towards the tail of the present slide.

It was concluded that man had been responsible to some extent in disturbing the stability of an earlier slide. The cutting of drains at the toe of the earlier slide had activated the flow of the slide. The slide was facilitated at the head portion by the scarp slope characterized by weak jointed rocks. With continuous percolation of ground and rain water on such weak jointed rocks, the scarp wall had failed. The resultant debris flow consisting of large boulders essentially had devastated the human dwellings downslope burying most of the inmates alive.

Pitakanda Landslide, Pitakanda Estate, Matale

This landslide occurred at about 2.00 a.m. on 2nd December, 1982 killing 11 people and destroying more than 10 human dwellings. The landslide, more than 1 km. in length can be regarded as a combination of earth flow-rock, slide-lateral spread and rock flow. The slide had occurred mainly on the dip slope underlain by garnetiferous gneisses which were weakened by three systems of joints out of which two were closely spaced.

On the spot investigations revealed that there were continous rains for more than 5 days and on the day in question a very high rainfall had been recorded at the Pitakanda Estate meteorological station. The estate workers and the personnel of the factory of Pitakanda Estate reported the appearance of springs on the floors of the line rooms and the factory floor prior to the landslide.

Field investigations revealed that the stream which flowed along the slide had remained dammed or ponded for a few hours upstream and suddenly the massive quantity of water that accumulated on the temporary lake up-stream had given way carrying with it large blocks of rocks and soil debris devastating the line rooms downslope and killing some of the inmates of the rooms by burying them alive in the debris.

The elderly people of the area reported earlier slides which had occurred more than 100 years ago on the same spot. Such slides apparently had been in equilibrium until their destabilization which occurred with the massive flow of water and debris.

Patulpana Landslide, Ratnapura-Pelmadulla Road, Ratnapura

This slide occurred on 8th June 1982 at 11.30 a.m., killing 9 people and destroying three houses. The landslide can be categorised as a rock-slump-mud and rock flow. The landslide was 1.5 km long and the slide occurred adjacent to a gully which had become overly activated during heavy rains. The underlying rocks were feldspar-rich gneisses and the kaolinization was evident all along the 1.5 km length of the slide. The rock was characterized by three systems of joints which were widespread in the rocks.

At the site of the Patulpana landslide which occurred after 5 days of continuous rain, no evidence of an earlier slide was visible. The slide had resulted from failure along the prominent joint systems. The failure seems to have resulted from expansion of clayey material along joint planes which had given rise to separated blocks of rock. Such evidence was found at the head region of the slide where large blocks of rock had separated along the master joint planes. Throughout the length of the slide, the overlying soil-vegetation cover showed cracks separated by definite intervals suggesting failure along the underlying fracture system.

Katayapatana Landslide, Maturata

This landslide occurred on 6th January 1986 at 10.30 p.m. and 13 people were killed and 3 houses were destroyed. The landslide was about 1 km long and can be categorized as a rock slump-mud and debris flow. The Katayapatana area is located in a zone characterized by multitudes of ancient slides. The underlying rocks were feldspar rich gneisses which showed two prominent systems of joints. The unstable debris material can run into a few meters in depth and a considerable number of houses in the area has been constructed on such stable slopes. Cracks were noticed on the walls of many such houses.

The landslide which had occurred after about a week of intense rains resulted from destabilization of earlier slides which had buttressed against banks of streams downslope and were in equilibrium. Due to increased lateral erosion at the streams downslope during incessant rains, resulting in undercutting the slopes and removal of buttressing material, the area had begun to destabilize resulting in the failure of weak rocks along major joint planes.

CAUSES OF LANDSLIDES

The causes of landslides studied can be listed as follows:

(a) Unusually high rainfall (16 inches in 5 hours at Pitakanda, Matale). Incessant rains for a few days resulting in increasing pore pressure in the debris material and expansion of clays within joint planes of underlying rocks.

(b) Failure of weak rocks characterized by multiple facture systems and feldspar-rich compositions. The latter on weathering produce kaolin which lubricates movement of overlying rock and debris material. Underlying association of easily soluble crystalline limestone (marble) will further aggravate the stability of overlying slopes causing movement.

(c) Destabilization of ancient landslides, which are in equilibrium by man-made activities such as road construction, drain construction, denudation of lands, etc.

MEASURES FOR PREVENTION OF LANDSLIDES AND REDUCTION OF DAMAGES

(a) Suitable afforestation on unstable slopes with sound landuse and drainage controls to be carried out with the collaboration of geologists, soil scientists, agriculturists and engineers.

(b) Recognition and monitoring of signals of landslides such as subsidence, appearance of springs on the floors of houses and development of cracks on surface soils and walls of houses, slanting of tall trees and buildings, etc.

(c) Evacuation of people from very dangerous zones identified in areas with histories of frequent landslides and perennial springs and streams. Such areas show scars of repeated scarp retreats at the head regions of landslides recognized easily by the hummocky nature of the topography.

(d) Rehabilitation of less dangerous zones by stabilizing the area with the use of engineering practices such as removal of unstable material, proper drainage of water by the construction of trenches, tunnels, horizontal and vertical drains etc.

(e) Creation of an awareness of the signals and causes of landslides among the people living in less dangerous hazard-prone terrains and arrangement for timely evacuation in cases of necessity.

References

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EPPAWALA PHOSPHATE DEPOSIT

Sri Lanka at present imports a very large percentage of its fertilizer needs at a cost of nearly 60 million US $ per year. Between 15 to 20% of fertilizers used in the country are phosphates-rock phosphates or triple super phosphates. In 1985, 34,396 metric tons of rock phosphate and 41600 metric tons of triple superphosphate were imported. The local production of rock phosphate was 17,000 metric tons in 1985 (source-Review of fertilizer Secretariat of Sri Lanka - year 1985).

Triple superphosphate (TSP) with a Phosphorus (P) availability of about 45% is used mainly for paddy whereas imported rock phosphate (IRP) with Phosphorus availability of about 12% was used largely for coconut and rubber. Local rock phosphate (LRP) which has P availabilities varying from 2 to 6 was utilized mainly for tea (see Table 1).

Table 1 - FERTILIZER CONSUMPTION BY CROP SECTORS (in 1985) (Source - Sri Lanka National Fertilizer Secretariat Report 1985)

	PADDY	TEA	RUBBER	COCONUT
TSP	27973	29	nil	196
IRP	25	7640	9146	11618
LRP	4	9618	1355	525

The need to import phosphate fertilizer has arisen due to the poor availability of P in the phosphate deposits found in the country. Although many processes have been developed to increase the P availability, no detailed systematic study has been carried out to determine the mineralogical and chemical distribution of the major phosphate deposit discovered at Eppawala more than 15 years ago.

The Eppawala phosphate deposit is located at Eppawala near Anuradhapura in the North Central Province and is lying at about 200 km from Colombo, capital of Sri Lanka. The deposit occurs as hillocks of about 50 to 100 m local relief. These hillocks are underlain by marble formations which occur interbanded in successions of quartzites, charnockites and different types of gneisses (Fig. 2).

Such metasedimentary rock associations are common in the Highland Series rocks of the Sri Lanka Precambrian. At least two other apatite deposits though of much lesser extent and different compositions have been located by the geologists attached to the Institute of Fundamental Studies and the University of Peradeniya.

These apatite occurrences are found concentrated in the weathered or leached zone of the hillocks extending to depths of 30 to 100m. The leached zones overlie rocks identified as apatite marble. The work already done on the deposit reveals variable compositions within the leached zone of the deposit and also among apatite crystals released from the parent marble rock (Fig. 3).

Fig. 2 Sri Lanka Showing the location of the major geological units and the Eppawala Phosphate Deposit

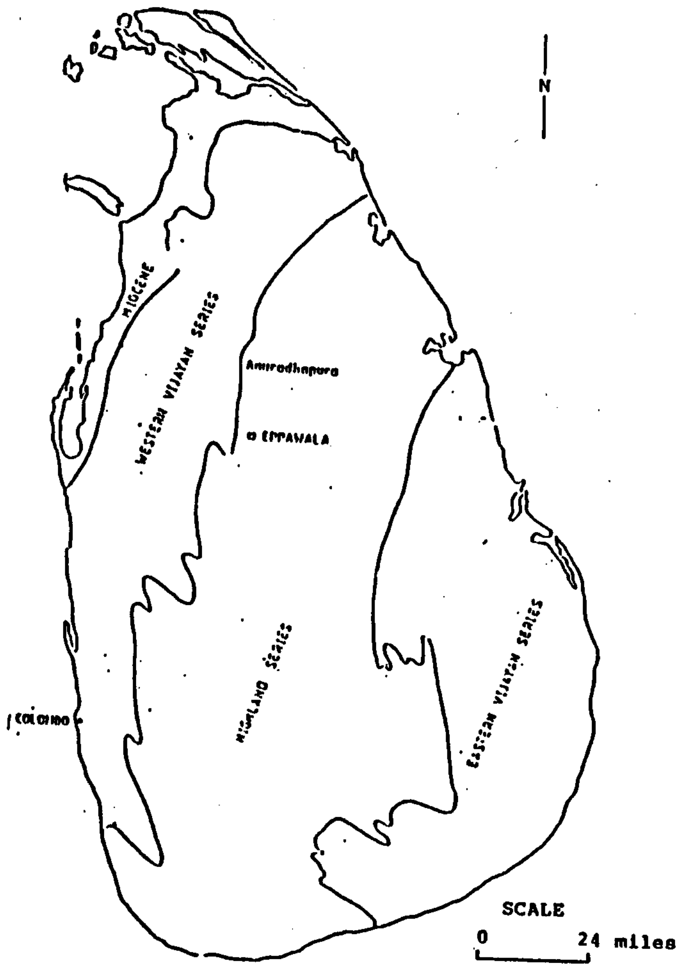

Fig. 3 The weathering profile on the apatite marble formation showing the Phosphate Deposit at Eppawala

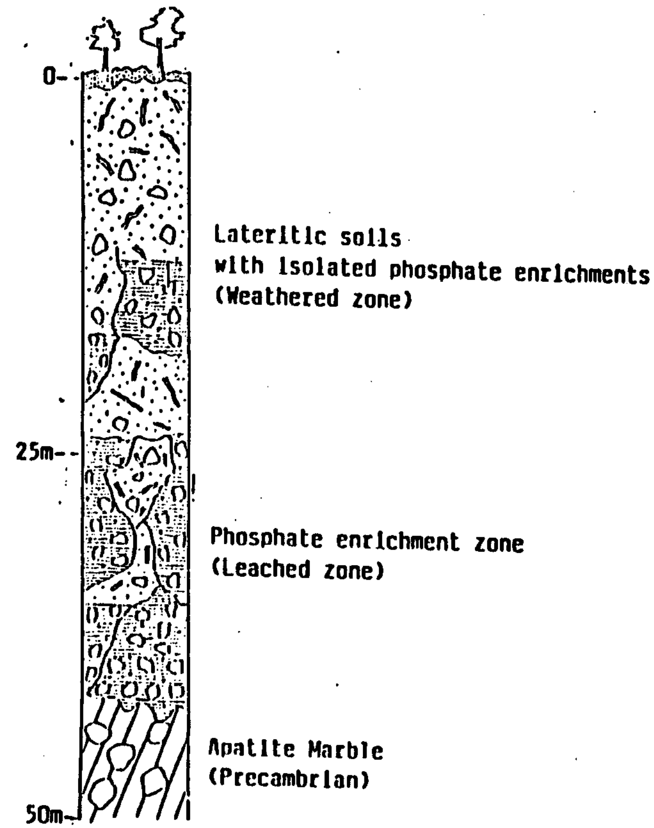

Table 2 - CHEMICAL ANALYSIS OF APATITE CRYSTALS AND SAMPLES COLLECTED FROM THE LEACHED ZONE- EPPAWALA APATITE DEPOSIT (in wt %)

	Apatite crystals	Phosphate Deposit (from leached zone)
SiO_2	0.22 to 5.0	0.21 to 7.7
TiO_2	-	0.14 to 1.6
Al_2O_3	-	1.10 to 44.0
Fe_2O_3	0.05 to 0.5	2.27 to 16.8
FeO	-	0.09 to 1.77
MgO	0.01 to 0.17	0.10 to 0.29
CaO	50.5 to 55.95	7.2 to 53.03
Na_2O	-	0.08 to 0.19
K_2O	-	0.22 to 0.44
P_2O_5	32.0 to 40.75	19.9 to 37.30
Cl	2.16 to 2.29	0.88 to 1.04
F	1.54 to 1.78	-

The Eppawala apatite deposit has been estimated to consist of a reserve of 40 million metric tons of rock phosphate (Jayawarden, 1976) and is presently exploited by the State Mining and Mineral Development Corporation of Sri Lanka. The material is crushed and ground to -80 mesh size and is made available for use as a fertilizer after mixing with other ingredients. At the current rate of exploitation, viz. on the average of about 15000 metric tons per year, the Eppawala deposit could be utilized for more than 100 years.

The phosphate deposit consists of P_2O_5 contents varying from 18 to 40% which makes Eppawala deposit one of the important apatite deposits of its type in the world. However, the paucity of knowledge on the exact distribution of P_2O_5 within the deposit has led to haphazard exploitation which is currently being done by merely bulldozing the leached zone indiscriminately. A systematic exploitation would not only be economical in the long run but also would lead to optimum utilization of this important ore. Such optimal use could only be achieved if a detailed geological and geochemical study of the deposit is undertaken with a view to delineate various mineralogical and chemical assemblage zones particularly on the leached zone. The need of such a study is well exemplified by the varying compositions observed at Eppawala both in single crystals and in the leached zone (see Table 1). Preliminary investigations show the existence of at least three apatite types (one primary and two secondary) of variable solubility at the Eppawala deposit.