

ROCK STRUCTURE AND SLOPE STABILITY STUDY OF WALLING AREA, CENTRAL WEST NEPAL

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सारांश

प्राकृतिक तथा कृत्रिम भू-क्षय र पाखाहरूको अस्थिरताले वातावरणिय परिवेश सन्तुलनमा ठूलो हांक दिईरहेको नेपालको पहाडी भागमा गर्भित दैविप्रकोपको ख्याल राखी जोखिम नक्सा तयार गर्नु (Risk mapping) प्राथमिकताको विषय भएको छ । लेखमा सिद्धार्थ राजमार्गमा पर्ने वालिङ्गको पश्चिम करिब १०० वर्ग किलोमिटर क्षेत्रमा चट्टान संरचना तथा स्थलाकृतिको आधारमा तयार गरिएको जोखिम नक्सा वारे संक्षेपमा वर्णन गरिएकोछ । लेखकको विचारमा नक्सा गर्ने यो विधी छिथो छरितो हुनुका साथै यसले भू-भागको स्थितिलाई राम्रो संग प्रतिविम्बित गर्दछ ।

ABSTRACT

The author emphasises the urgent need for a potential risk mapping in Nepalese hills where natural and artificially promoted erosion and slope instability are drastic and threatening the ecological balance. The author describes a potential risk mapping method based only on the relationship between the rock structure and topography.

This method is applied to an hundred square kilometers area, west of Walling which is crossed by the road Pokhara-Tansen-Butwal (Siddhartha Highway). The author finds that this method is fast and gives a good picture of the condition of the terrain.

INTRODUCTION

On wide areas the Nepalese hill slopes frequently and naturally are instable. The nature of rocks, their structure and relation to topography shaped by highly erosive streams, the subtropical climate reigning in the hills which gives rise to a strong soil development by rock weathering, are the main factors ruling this natural instability.

Human activities such as deforestation, road construction, water channeling, among others, are in their turn overburdening factors on slope stability. It is estimated that in Nepal these human activities have been responsible for 25% of the landslided area during the last twenty years. It is obvious that more and more the development of road net and other infrastructures and the drastic deforestation will continue, besides other agents, this is one of the most serious challenges to the ecological balance in this country.

It is therefore very urgent to face this situation, and a part of the strategy to stop or at least to reduce the present degradation lies in a well-tested prevision system for each new project dealing with slope stability or being in some way or other connected with it. The potential risk maps, where the natural or artificially promoted potential landslides, rockfalls, settling of gully erosion could be forecast, might be done under this prevision system. The system could provide a good background for rational planning and rules in various fields like roads, hill irrigation trails, suspension bridges and power station construction, as well as in agriculture, forests and watershed management; thus, it could be very useful in avoiding costly mistakes and high maintenance costs.

The potential risk study, west of Walling in central west Nepal, is an attempt to work out a methodology which, the author is convinced, can be further improved.

A POTENTIAL RISK STUDY

This area was studied in September 1980 during the training "Geology and Geotechniques applied to Suspension Bridge" given to Nepalese engineers and overseers of the Suspension Bridge Division (Wagner, 1980).

The factors determining the development of soils and the slope instability are:

1. the lithological nature of the rock including their depth of weathering
2. the structure of the rock
3. the topographical surface and its relation to the rock structure
4. climate, the streams, sources and seepages and degree and intensity of rain fall.
5. the soil biota.

Among these five factors, the lithological nature of the rock, its structure and its structural relation to topography are the most decisive, insofar as the slope stability is concerned and were selected for the present study for this reason.

The water behaviour is also a very important factor; nevertheless, its study needs detailed survey and can be undertaken only in a second step of a risk mapping.

The climatic factor is difficult to set into equation, but can be evaluated in general; in this area the climate is subtropical with a rainfall average of 2 meters per year (maximum in Nepal about 3 meters per year); that means a rather high potential for soil development when the nature of rock allows it. The soil biota can be taken into account only in very detailed studies.

Four basic maps are needed to prepare the potential risk maps. They are:

- topographical map
- geological map
- slope values map
- direction of slopes and water catchment map

Besides the above an instability pattern study is also required to clarify the picture.

The topographical map

Basic tool for any geological and structural study, the present topographical map of one inch to a mile scale is inadequate. A photogrammetric map of 1:50,000 would have been better. This kind of map is available in Nepal on request and

would be necessary for further studies. For the present study, the one inch map was enlarged (fig. 1).

The Geological Map

This map (fig. 2) was drawn on the basis of a cross-section studied along the Walling-Tansen road and other neighbouring areas and also by means of aerial photographs. The stratigraphy of the area as investigated by the present author, is given below:

6. Recent alluvium
Old alluvial terraces
5. ? Upper slates
4. Massive dolomite with limestones
3. Dominant slates with thin layers of quartzite and dolomite
2. Slates
1. Phyllites, calc-schists and slates with thick layers of dolomite

According to the lithological factor only, the following are the soil development and consequent slope potential instability;

1. medium propitious with occasional, rather limited landsliding and settling areas;
2. and 3. where the slates are dominant, are the most propitious for the development of soils and consequent potential instability;
4. normally little propitious for rising up of soils and consequent landsliding. Nevertheless this is not true in folded and faulted areas where the dolomites are strongly fractured; in this case old landslides can also be stabilized by recementation, by infiltration of water which are rich in bi-carbonates;
5. where the slates are dominant, shows an entirely similar behaviour as in case of 2. and 3.;
6. old or Recent alluviums roughly show the same behaviour as a soil; nevertheless, as they are laying on rather flat surfaces, they are normally stable but can eventually show gully erosion.

The slope values map and slope direction map

As the relationship between the slope, its direction, and the rock structure

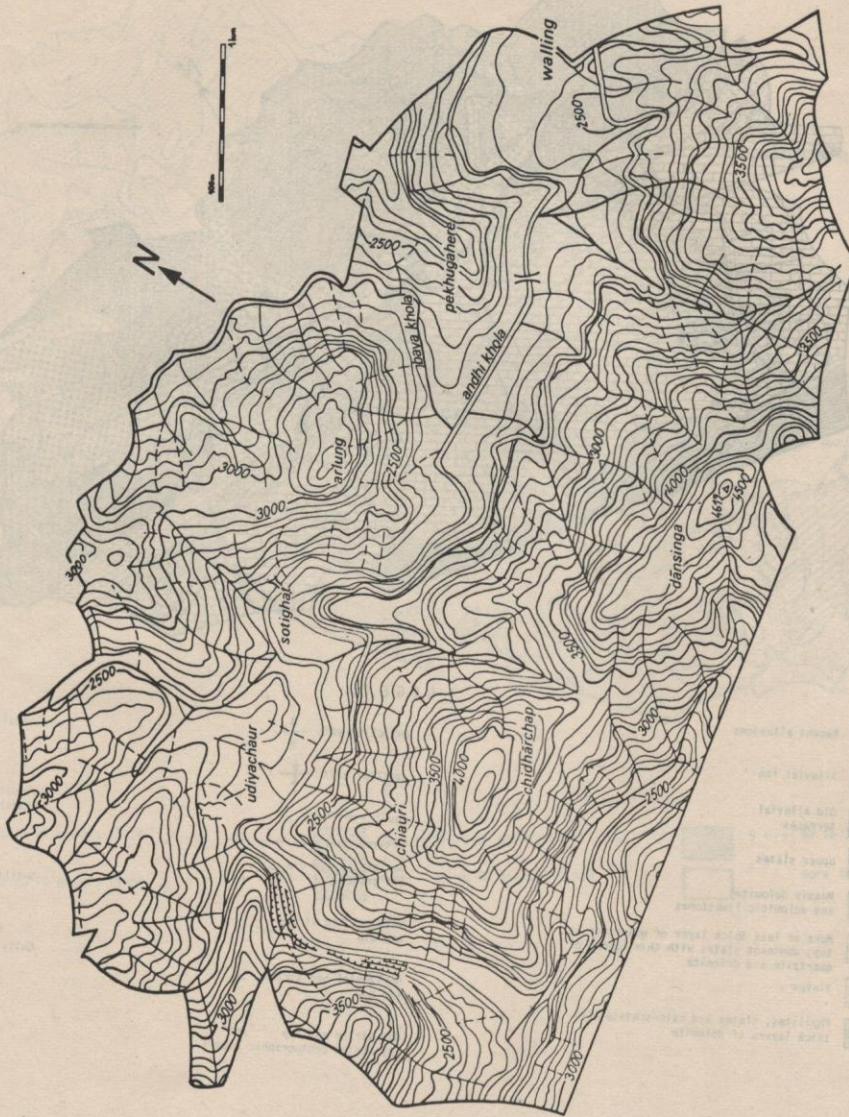
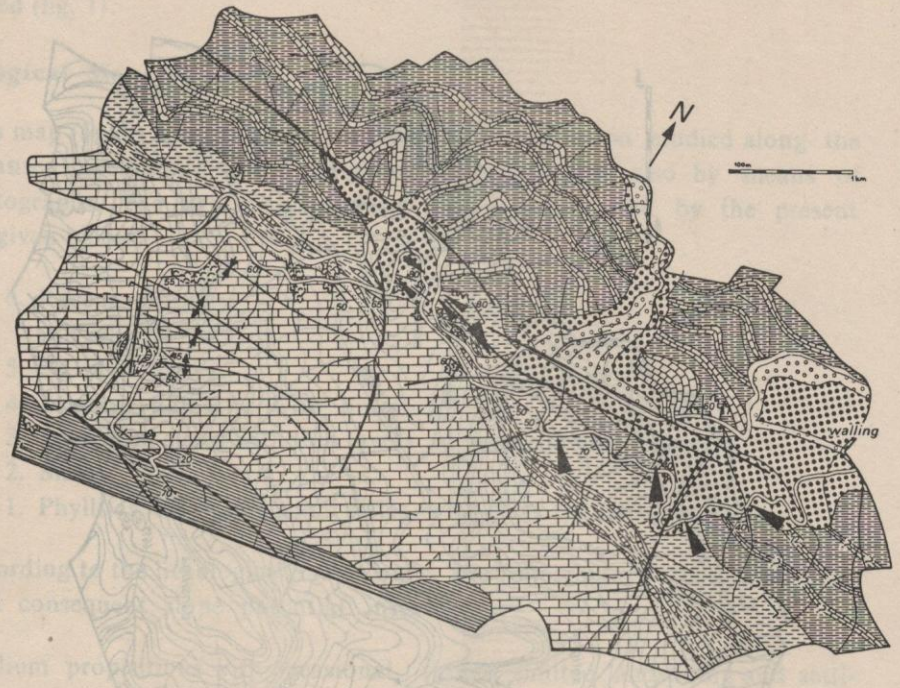










Fig. 1 The topographical map of Walling area



-  Recent alluvions
-  Alluvial fan
-  Old alluvial terraces
-  Upper slates
-  Massive dolomites and dolomitic limestones
-  More or less thick layer of quartzite at top; dominant slates with thin layers of quartzite and dolomite
-  Slates
-  Phyllites, slates and calc-schists with thick layers of dolomite

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









-  anticline axis
-  syncline axis
-  fault
-  inferred fault
-  Bed strike and dip (in grades)
-  Vertical bed strike and dip
-  Horizontal bed strike and dip
-  Bed strike and dip (by aerial photographic study)
-  Landslide
-  Consolidated landslide
-  Settling
-  Gully erosion

Fig. 2 The geological map of Walling area

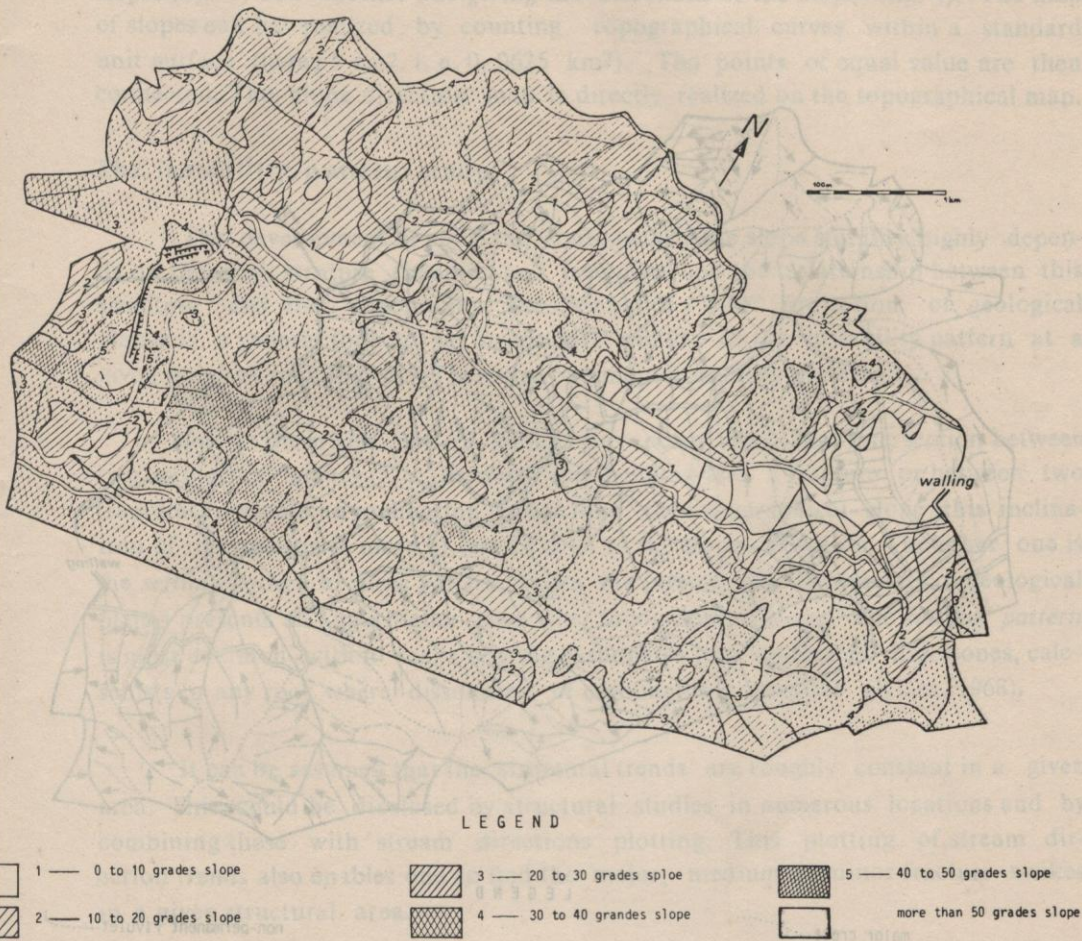
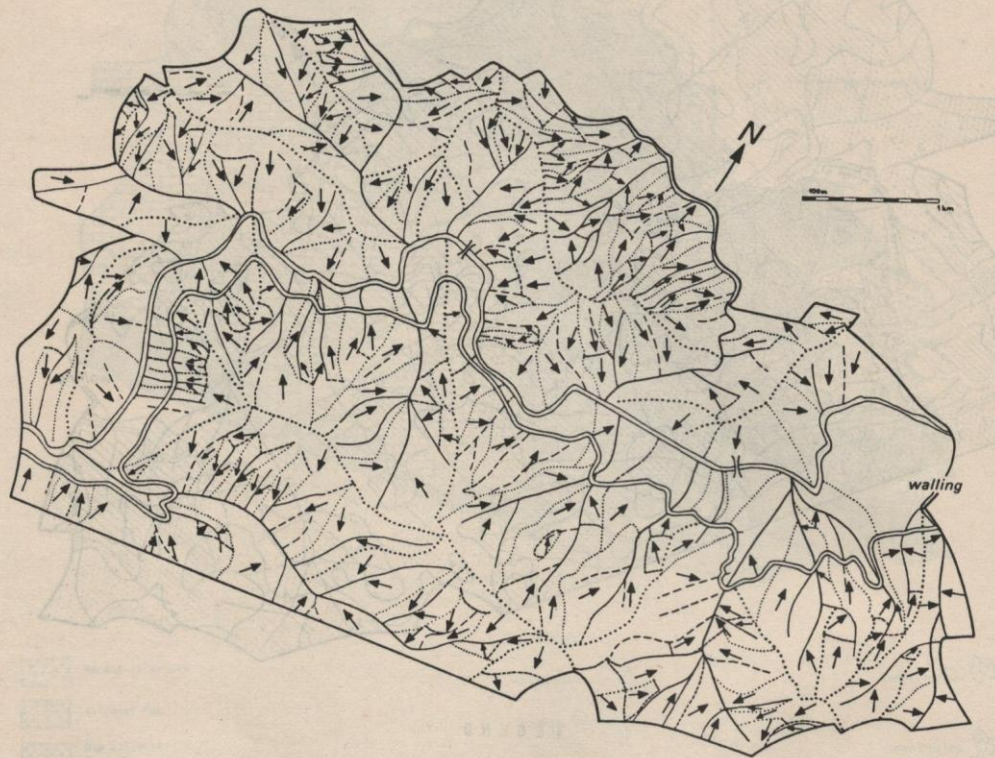


Fig. 3 The slope values map



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major crest - - - - -

minor crest - - - - -

river, rivulet ———

non-permanent rivulet - - - - -

limit of areas with specific slope direction - - - - -

slope direction ↗

Fig. 4 The slope direction and water-catchment map

are responsible for the instability pattern; it is necessary to establish one map of slopes (fig. 3) and another one giving the directions of the slopes (fig. 4). The map of slopes can be realized by counting topographical curves within a standard unit surface (here; 1 cm², i. e. 0. 0625 km²). The points of equal value are then connected. The slope direction map is directly realized on the topographical map.

The instability pattern study

The development of soils and consequently the slope stability highly depends on the rock structure (bedding and fractures) and the relationship between this structure and the topography. The "Schmidt Net" projection of geological planes is a general tool to get an accurate picture of the instability pattern at a given point of rock (fig. 5). There are two main instability patterns:

One is the *wedge pattern* which may occur when the intersection between two geological planes (i. e. between the bedding and a fracture or between two fractures) presents an inclination lower than the topographical slope; this inclination of intersection is more or less parallel to the slope direction. The other one is the *settling pattern* or *niche pattern*, where the intersection between two geological planes presents an angle higher than the topographical slope. The *settling pattern* is most common within rocks bearing carbonates like dolomites, limestones, calc-schists or any rock where dissolution of carbonates is possible (Klaus, 1968).

It can be assumed that the structural trends are roughly constant in a given area. This could be disclosed by structural studies in numerous locations and by combining these with stream directions plotting. This plotting of stream direction trends also enables one to find the major, medium or minor fracture strikes in a given structural area.

THE POTENTIAL RISK MAPS

The natural potential landsliding map

By plotting the structural pattern given by the *instability pattern study* (fig. 5) simultaneously with the *slopes and slope direction map*, one can obtain the natural potential landsliding map (fig. 6).

The intersection of the bedding, which is always a regular and continuous plane with any major fracture, if it shows a lower inclination than the slope and about the same direction in a given area, is considered as maximum for potential landsliding; this potential landsliding is also considered as maximum if the bedding plane is parallel to the slope. If this happens with two major fractures, the potential landsliding is considered medium to maximum and also when this takes place with the bedding plane and a minor fracture. If the intersection takes place between two minor fractures, the potential landsliding is considered as weak to medium.

It is obvious that the kind of rock where the potential landsliding takes place is determinant. Rocks giving little development of soil in contrast to those giving a strong one will always produce a lower landslide risk. As high it ever could be, it will never be so high with rocks giving little development of soil in comparison with rocks giving a strong one.

This map can be useful for any study needing a balance of the natural conditions such as afforestation, agriculture or watershed management.

The potential landsliding in artificial slopes and settling risk map.

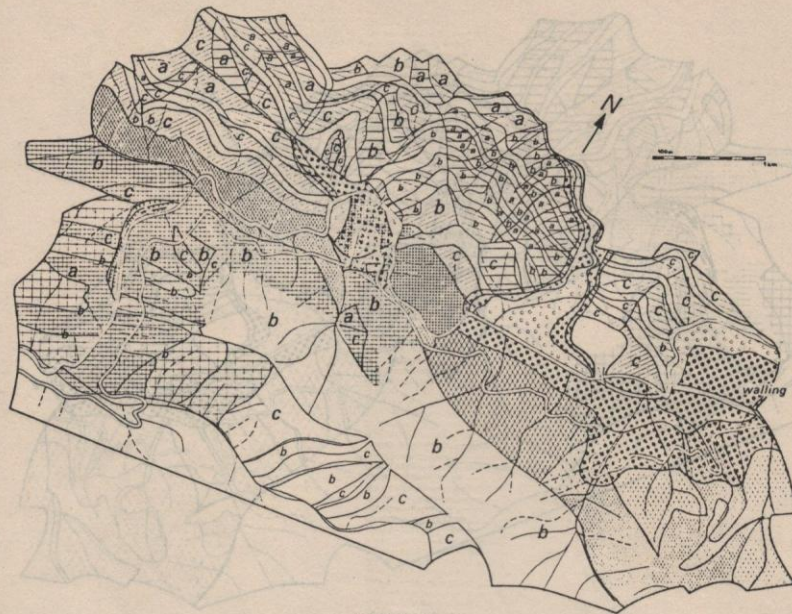
The same method is used in establishing this map, with the difference that here all the slopes are considered as vertical (cut slopes). As it can be observed on the map (fig. 7), the potential instable surface has considerably increased.

The potential settling was also plotted in the same way as for the potential landsliding, with the difference that this pattern occurs, when the intersection line inclination between two geologic planes is higher than the slope; for this reason, the potential settling can only be natural and becomes a possible potential landsliding risk in the vertically cut slopes.

This kind of risk map can be very useful for laying out of roads, feeder roads, channels and a's for suspension bridges, when applied in less wide areas.

The potential gully erosion map

The rock structure can be responsible for gully erosion when the bedding or any dominant fracture strike is more or less parallel to the slope direction. This

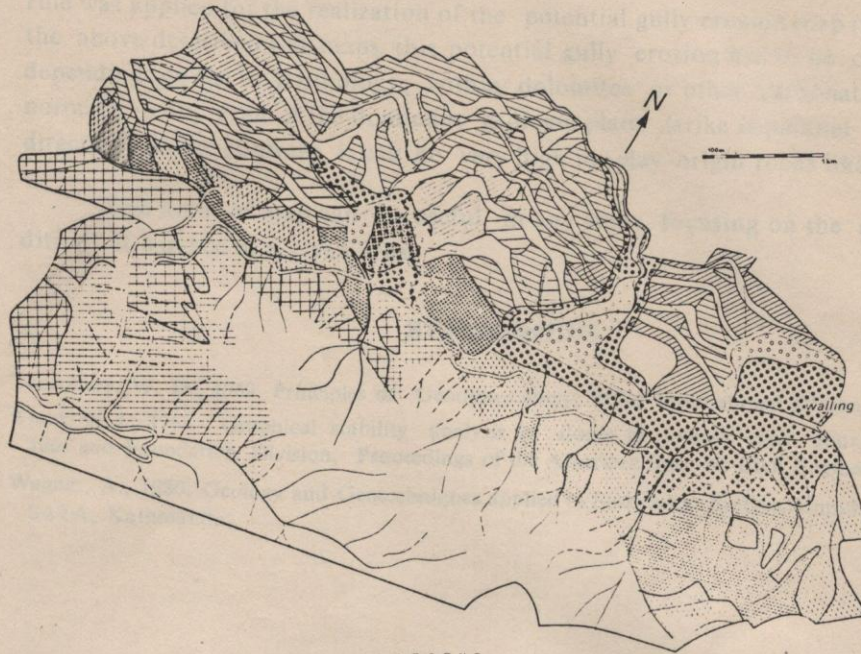


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LANDSLIDING POTENTIAL RISKS IN ARTIFICIALLY CUT VERTICAL SLOPES

MASSIVE DOLOMITE		PHYLITES, CALC-SCHISTS AND SLATES		SLATES DOMINANT	
According to lithological factor only:	According to the relationship between rock structure and topography:	According to lithological factor only:	According to the relationship between rock structure and topography:	According to lithological factor only:	According to the relationship between rock structure and topography:
NORMALLY NONE	NONE TO WEAK	NORMALLY MEDIUM	WEAK	NORMALLY STRONG	WEAK TO MEDIUM
Exceptions: in tectonized and/or folded areas where the rock is strongly fractured risks can be locally medium to very strong	WEAK LOCALLY MEDIUM LOCALLY STRONG TO VERY STRONG	Exceptions: in tectonized and/or folded areas or in locations where slates are dominant risk can be medium to very strong	LOCALLY MEDIUM LOCALLY STRONG TO VERY STRONG	No exception VERY STRONG IN TECTONIZED AND/OR FOLDED AREAS	MEDIUM TO STRONG STRONG TO VERY STRONG
NATURAL SETTLING POTENTIAL RISKS		NATURAL SETTLING POTENTIAL RISKS		NATURAL SETTLING POTENTIAL RISKS INEXISTANT	
According to lithological factor only:	According to the rock structure:	According to lithological factor only:	According to the rock structure:	ALLUVIONS	
NORMALLY MEDIUM TO STRONG	A WEAK B WEAK TO MEDIUM C MEDIUM TO STRONG	NORMALLY WEAK EXCEPT WHERE CALC-SCHISTS ARE DOMINANT	A WEAK B WEAK TO MEDIUM C MEDIUM TO STRONG	According to the granulometric factor only: VERY WEAK LANDSLIDING POTENTIAL RISKS FOR THE HIGH FRICTION ANGLE ϕ	
SLATES, PHYLITE and CALC-SCHISTS in strongly tectonized areas		DOLOMITE LAYERS interbedded with phylites, calc-schists and slates		Recent alluvions	
STRONG TO VERY STRONG LANDSLIDING AND SETTLING POTENTIAL RISKS		LANDSLIDING POTENTIAL RISKS IN ARTIFICIALLY CUT SLOPES NORMALLY WEAK		Old alluvial terraces	
		NATURAL SETTLING POTENTIAL RISKS		Old alluvial terrace on phylites, calc-schists slates and dolomite layers	
		According to lithological factor only:		Old alluvial terraces on slates	
		WEAK TO LOCALLY STRONG		Old alluvial terraces on slates, phylites and calc-schists strongly tectonized	
		WEAK WEAK TO MEDIUM MEDIUM TO STRONG		Landslide structural control by underlying rock only when alluvium layer is thin	

Fig. 7 The potential landsliding in artificial slopes and settling risk



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MASSIVE DOLOMITE		PHYLLITES, CALC-SCHISTS AND SLATES		SLATES DOMINANT	
According to the lithological factor only: NORMALLY NONE or ONLY LOCAL and combined with dissolution between the geologic planes. Stronger in tectonized and/or folded areas	According to the relationship between the rock structure, its lithology and topography: NONE OR VERY WEAK MEDIUM STRONG in tectonized and/or folded areas	According to the lithological factor only: NORMALLY WEAK TO MEDIUM locally stronger and sometime combined with dissolution between the geologic planes or in tect. areas. Can be very strong in locations where slates are dominant.	According to the relationship between the rock structure, its lithology and topography: WEAK MEDIUM STRONG	According to the lithological factor only: NORMALLY STRONG Very strong in tectonized and/or folded areas	According to the relationship between the rock structure, its lithology and topography: WEAK TO MEDIUM MEDIUM TO STRONG STRONG TO VERY STRONG
		DOLOMITE LAYERS interbedded with phyllites, calc-schists and slates		ALLUVIONS	
		According to lithological factor only: NORMALLY NONE or ONLY LOCAL and combined with dissolution between the geological planes. SLATES, PHYLLITES and CALC-SCHISTS in STRONGLY TECTONIZED AREAS STRONG TO VERY STRONG gully erosion potential risks		Recently Very WEAK Recent alluvions Old alluvial terraces Old alluvial terraces on phyllites, calc-schists, slates and dolomite layers Old alluvial terraces on slates Old alluvial terraces on slates, phyllites and calc-schists strongly tectonized.	
				The gully potential risks depends greatly on the variable old alluvions compactness. There is no gully erosion control by the underlying rock structure except when the alluvion layer is very thin. The paddy fields are a stabilizing factor against stream erosion.	

Fig. 8 The potential gully erosion map

rule was applied for the realization of the potential gully erosion map (fig. 8). As to the above described risk maps, this potential gully erosion has to be considered as depending on the rock lithology; within dolomites or other carbonate rocks it is normally weak, even if the dominant geologic plane strike is parallel to the slope direction; on the contrary, it can be very high in clay-origin rocks like slates.

This kind of map can be useful in any study focusing on the natural conditions of balance in a given area.

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ABSTRACT

To evaluate the geomorphological and geotechnical conditions of the Kathmandu block in the west of the Main Central Thrust, a detailed study was made along the Kathmandu valley. The study was carried out in the Kathmandu valley, which is bounded to the north by the Main Central Thrust, to the south by the Kathmandu valley, and to the east by the Kathmandu valley. The study was carried out in the Kathmandu valley, which is bounded to the north by the Main Central Thrust, to the south by the Kathmandu valley, and to the east by the Kathmandu valley.

INTRODUCTION

The Kathmandu block is delineated to the east by the Main Central Thrust, to the west by the Kathmandu valley, to the north by the Main Central Thrust, and to the south by the Kathmandu valley. Two tectonic zones were taken, one following the Main Central Thrust and the other Kathmandu-Mingling Thrust. A detailed study of the geology of Nepal