Journal of Nepal Geological Society
Vol. 1, No. 2., 1981. 37-43

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

A. WAGNER

Swiss Association for Technical Assistance - Ministry of Local Development, Suspension Bridge Division, P. O. Box. 113, Jawalakhel, Kathmandu Nepal.

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 बारे संक्षेपमा वर्णन गरिएकोछ । लेखकको विचारमा नक्सा गर्ने यो विधी छिटो छरितो हुनुका साथै यस्ले भू–भागको स्थितिलाई राम्रो संग प्रतिबिम्बित 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 (Siddartha 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 imporved.

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 bahaviour is also a very important factor; nevertheless, its study needs datailed 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 crossection 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 propititious with occasional, rather limited landsliding and settling areas;
2. and 3. where the slates are dominant, are the most propititious for the development of soils and consequent potential instability;
4. normally little propititious 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

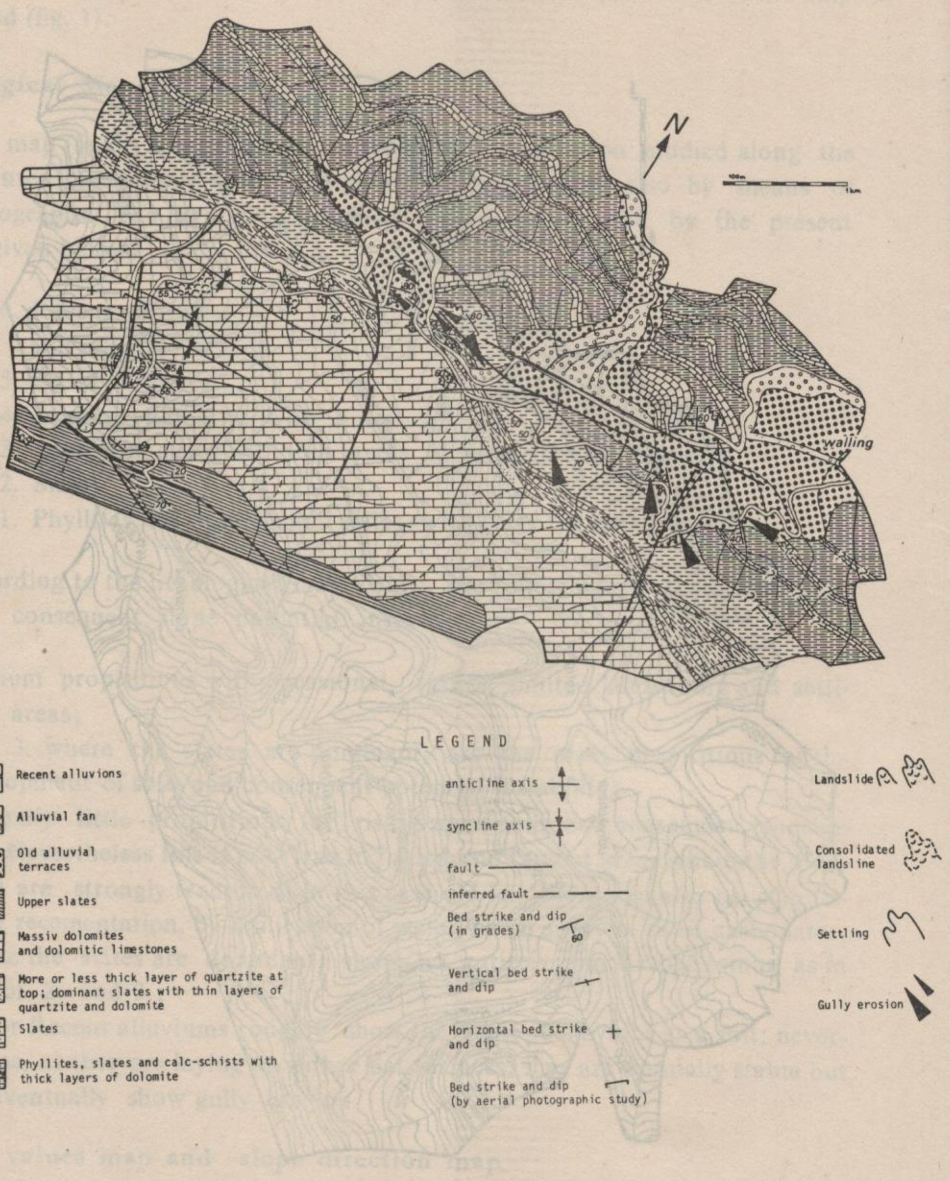

Fig. 2 The geological map of Walling area

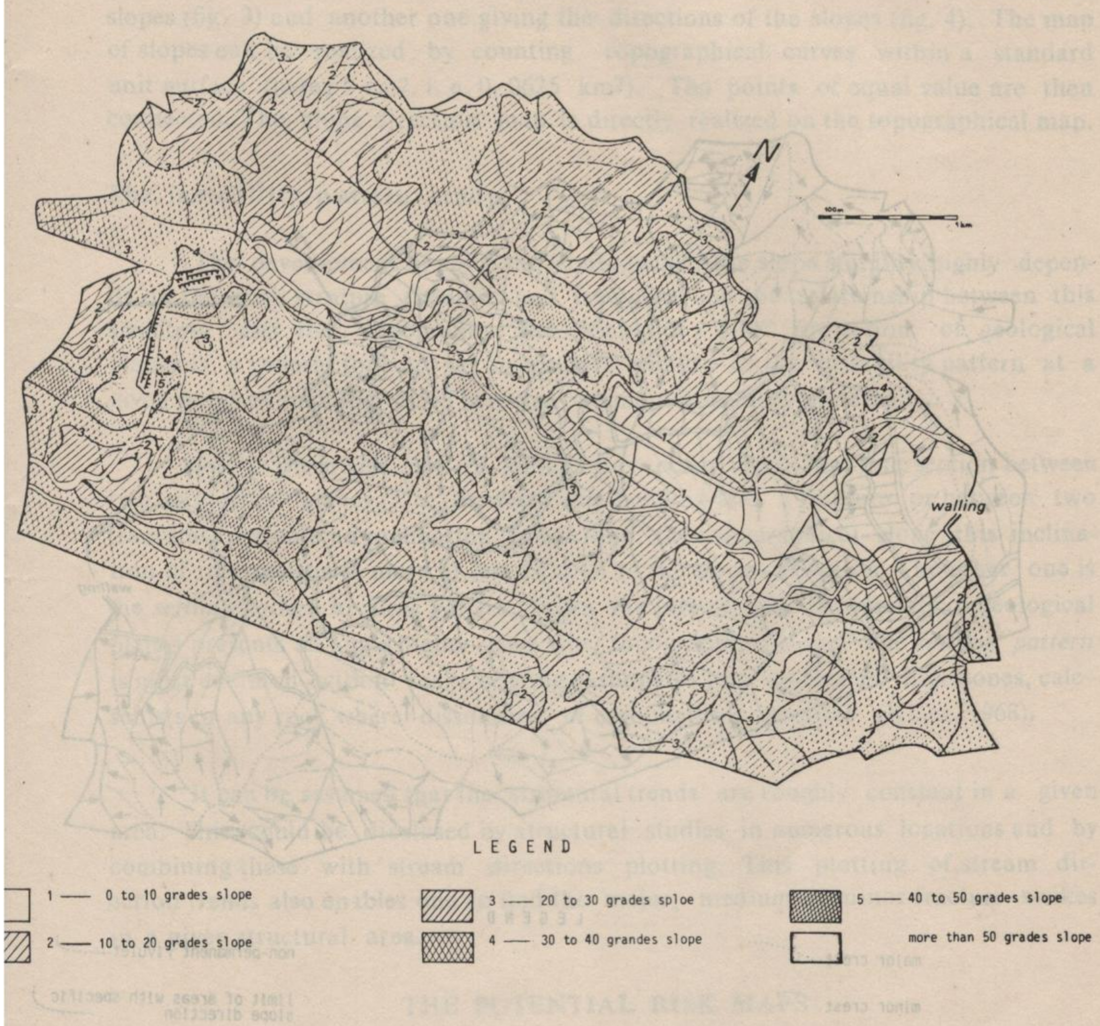

Fig. 3 The slope values map

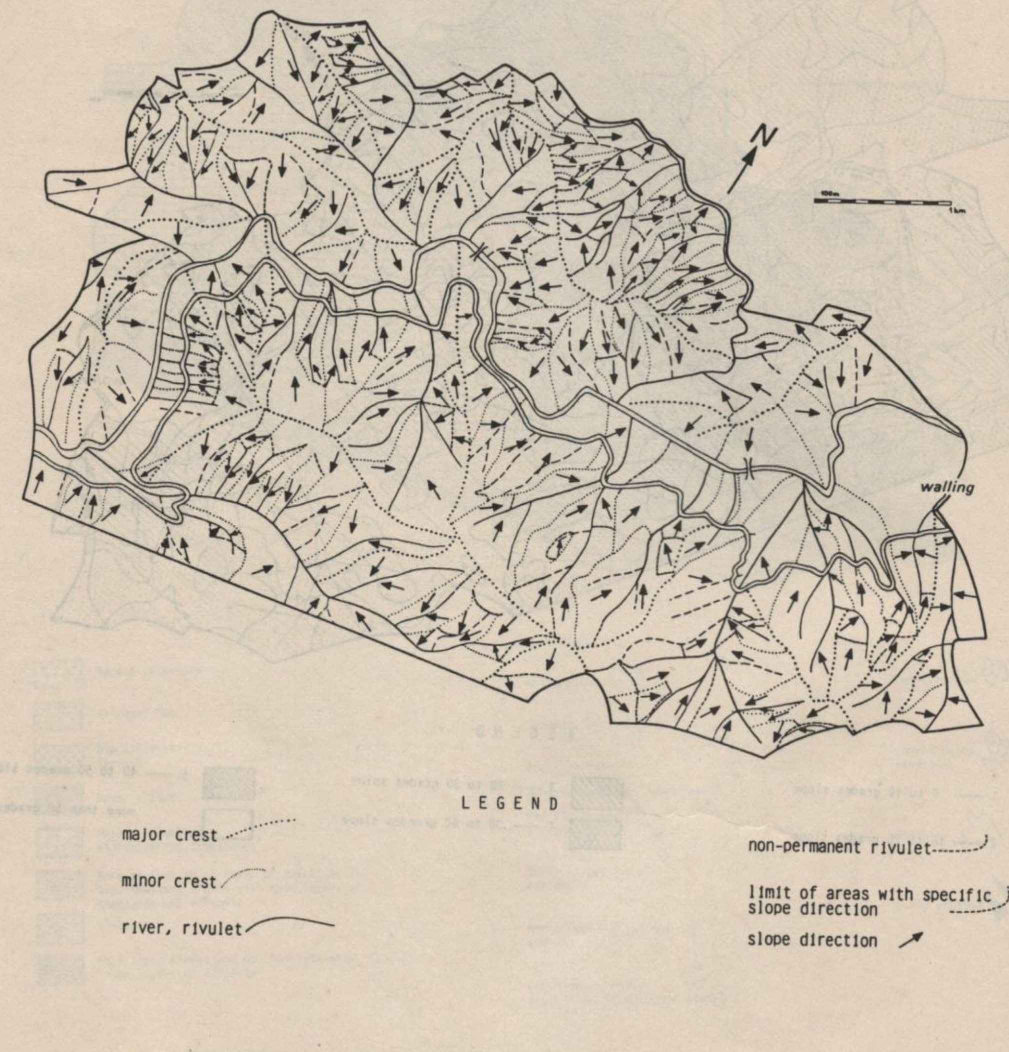

Fig. 4 The slope direction and water-catchment map

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 cm^2, i. e. 0. 0625 km^2). 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 struture (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 maxium for potential landsliding; this potential lansliding 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, feedder roads, channels and also 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

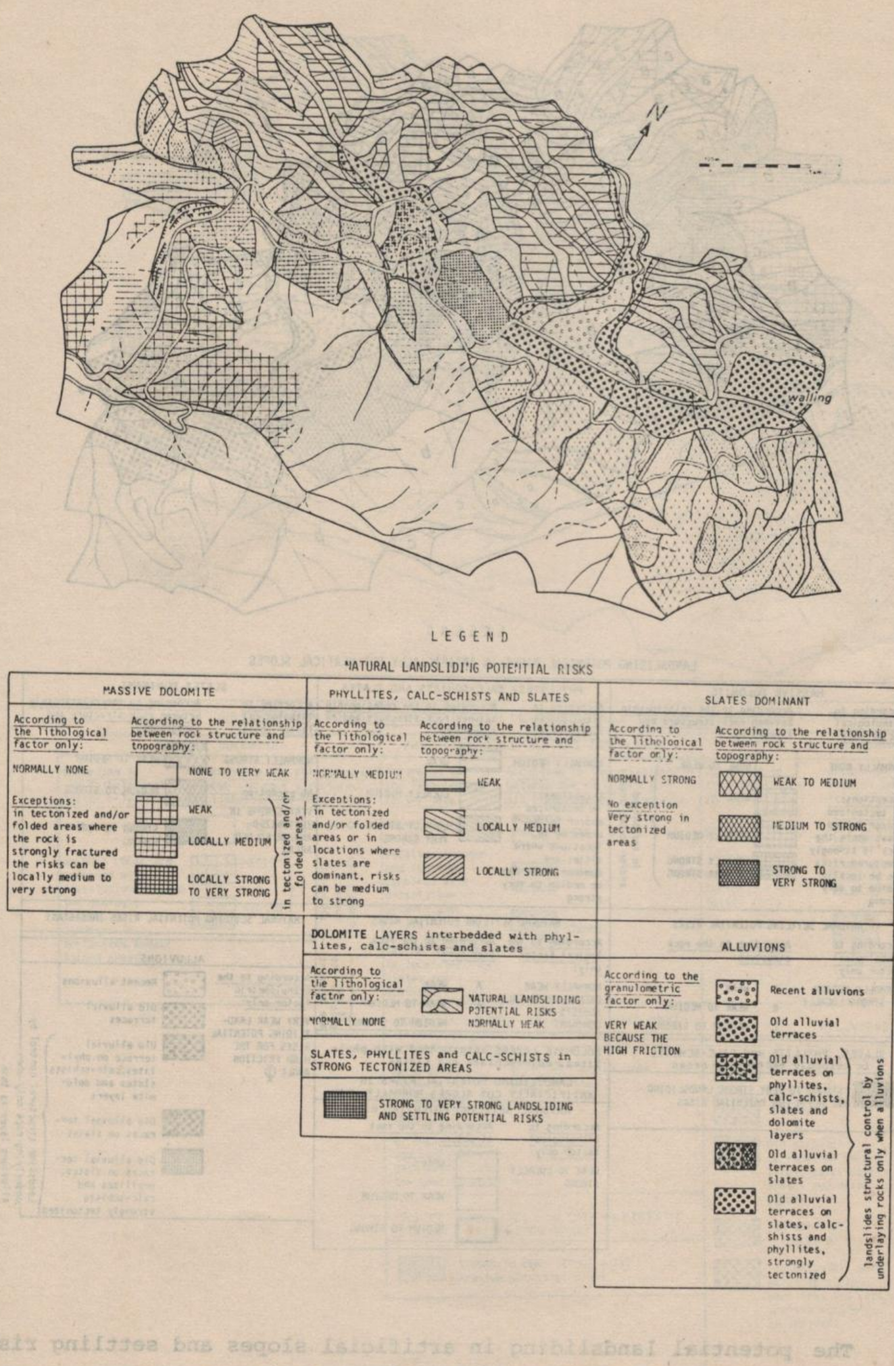

Fig. 6 The natural potential landsliding map

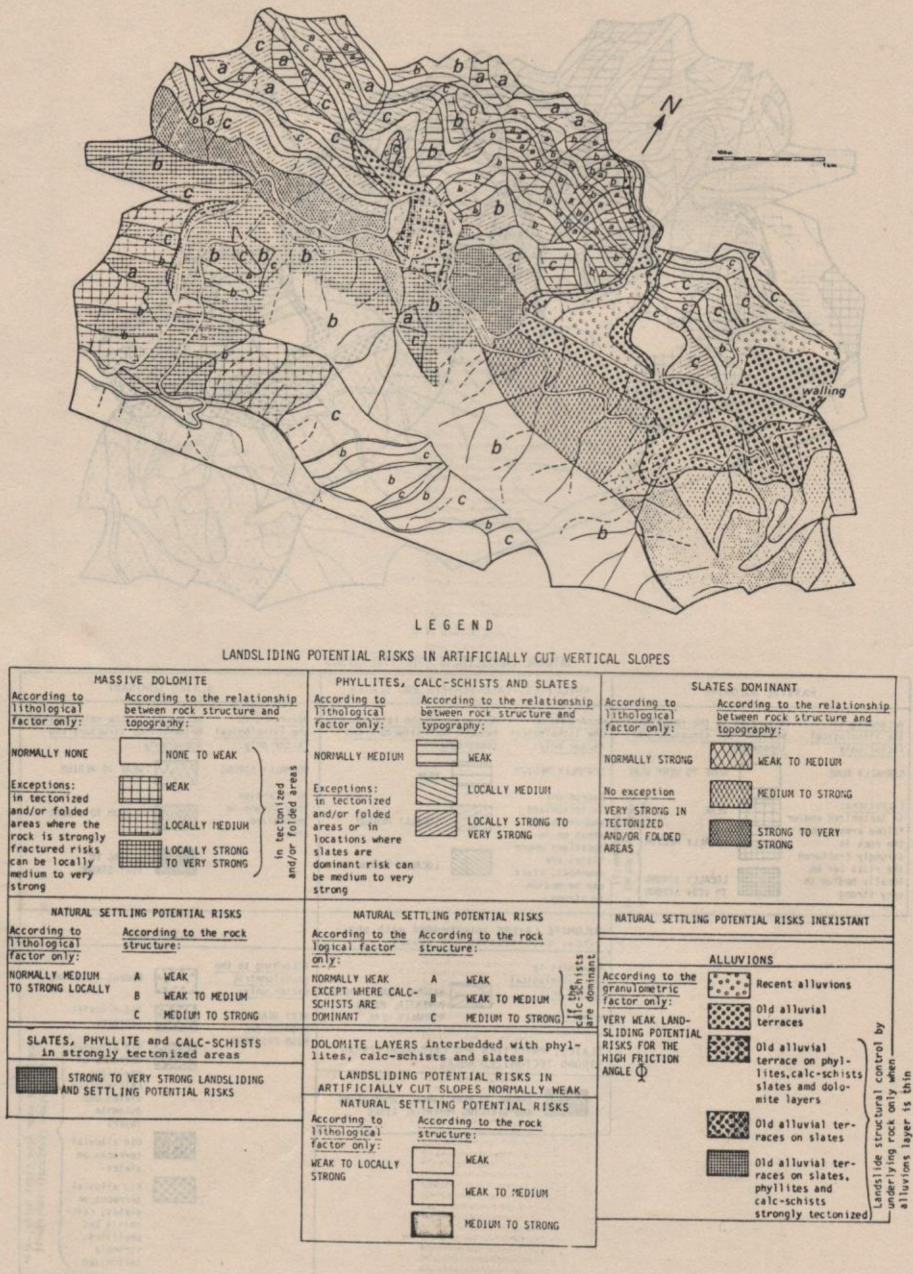

Fig. 7 The potential landsliding in artificial slopes and settling risk m

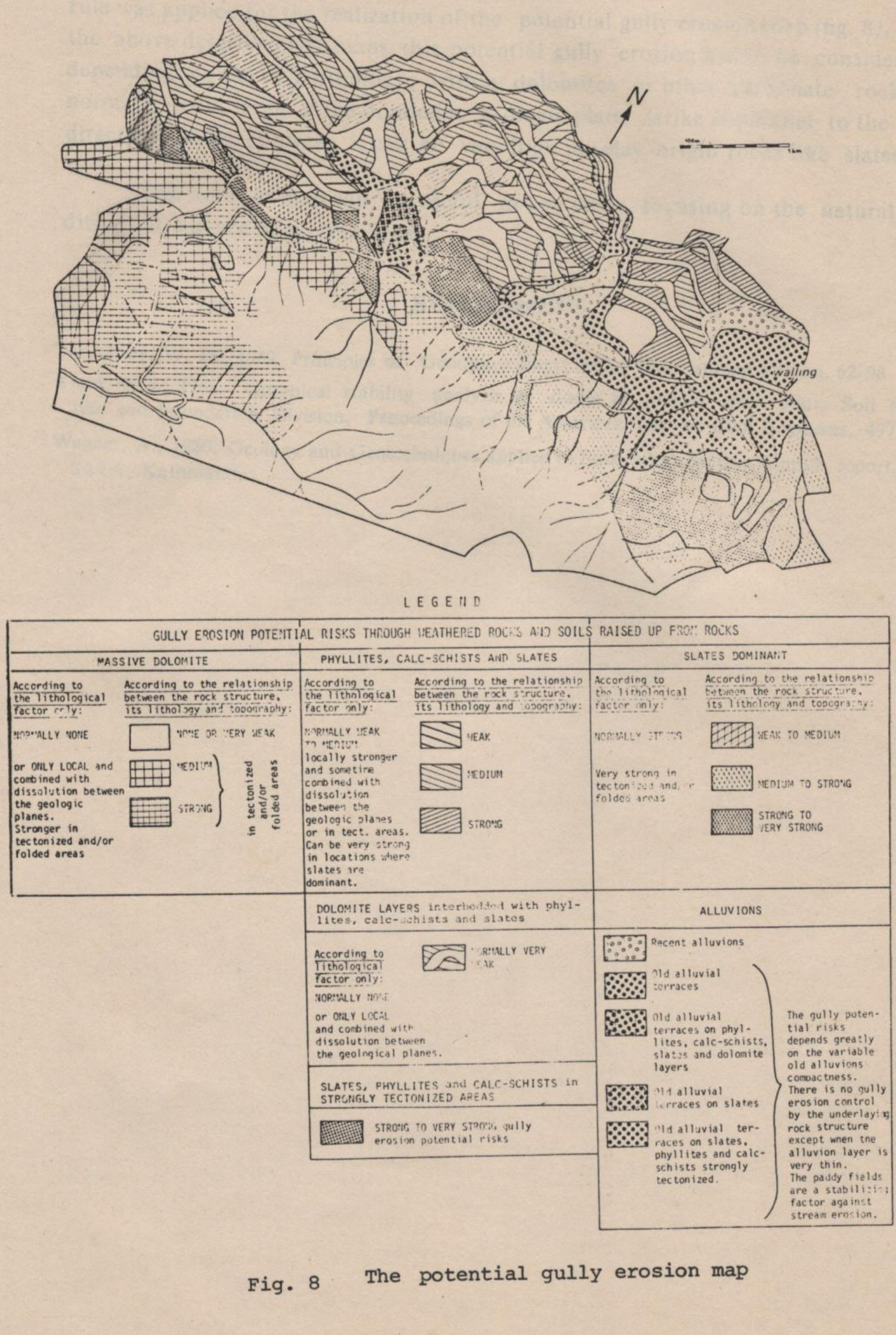

Fig. 8 The potential gully erosion map

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.

REFERENCES

Thornbury, W. D., 1969. Principles of Geomorphology. Wiley International Edition, 62-98

Klaus, W. J., 1968. Graphical stability analysis of slopes in jointed rock. Jour. Soil Machanics and Foundation Division, Proceedings of the American Soc. of Civil Engineers, 497-527

Wagner, A., 1980. Geology and Geotechniques applied to Suspension Bridges. Unpub. report, SBD-SATA, Kathmandu.