# 7 Landslide Study Using Aerial Photographs

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Stereoscopic aerial photography allows one to obtain an overall view of the terrain as a three-dimensional image. Interpretation of such photographs gives a wide range of information on landforms, as the land's geomorphological features are visible on a larger scale than is generally possible from a ground survey. Landforms directly reflect the ongoing and past evolutionary processes related to geomorphological change. One such evolutionary process is gravitational mass movement. Aerial photographs are commonly used to detect areas of potential landslides, identifying surface expressions of present or past mass movements of slope material like main scarps, depressions, cracks, bulges, and pressure ridges.

Identifying landslide-susceptible slopes from stereoscopic interpretation of aerial photographs is usually quicker, and sometimes more effective, than field survey. However, adequate experience in the complex techniques of geomorphologic interpretation is required in order to produce good results.

## Introduction

Present-day landslides originate as a result of the same geological, especially geomorphological, and hydrological conditions that led to past landslides. Old landslides often reactivate when they are disturbed by human activities such as the construction of roads and canals. The past is the key to predicting future landslide risks. The first step in reducing human and economic losses due to landslides is to prepare landslide maps that inventory past and potential landslide distribution by locating existing and potential landslide areas (Figure 7.1). Such maps can help planners and decision-makers in planning development activities in hilly and mountainous countries, and are particularly helpful in developing countries, where it can be difficult to carry out large-scale mitigation works.

## Landslide Survey Using Aerial Photographs

Landforms directly reflect the processes related to their geomorphological evolution, i.e., the physical and chemical interactions between the earth's surface and the natural forces acting upon it which have made them the way they are. These evolutionary processes include tectonic movement; volcanic, fluvial, and colluvial processes; and gravitational mass movement, including falls, slides, flows, creep, spread and others. Stereoscopic aerial photography allows one to obtain an overall view of the terrain in a three-dimensional image. It facilitates the extraction of detailed qualitative and quantitative information about the terrain, such as slope systems, microtopography (surface features with dimensions from a few centimetres to metres), drainage systems, land use, and vegetative land cover, all of which offer clues to understanding the geology, soils, and hydrology of the area. Interpreting aerial photographs, in turn, helps the observer understand the processes occurring on the mountain slopes. Some examples of stereo aerial photographs of landslides from Japan and Nepal are presented in the Annex.

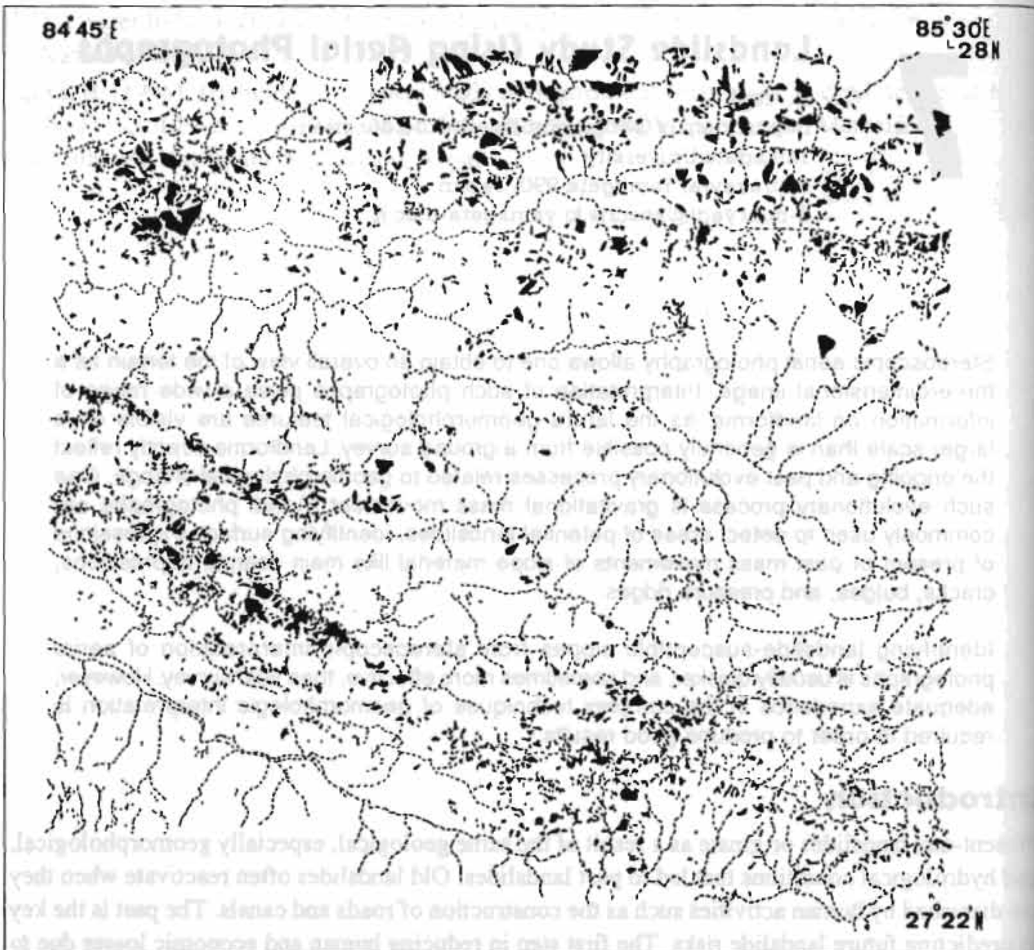


Figure 7.1: Distribution of landslides in the vicinity of the Kathmandu Valley (Yagi and Oi 1993)

Aerial photographs are commonly used to map existing landslides, detect the locations of potential landslides, and identify the surface expressions of present or past mass movements of slope material. Mapping landslides and identifying landslide-susceptible slopes from stereoscopic interpretation of aerial photographs is quicker, and sometimes more effective, than field survey. However, adequate experience in the complex techniques of geomorphologic interpretation is required in order to produce good results.

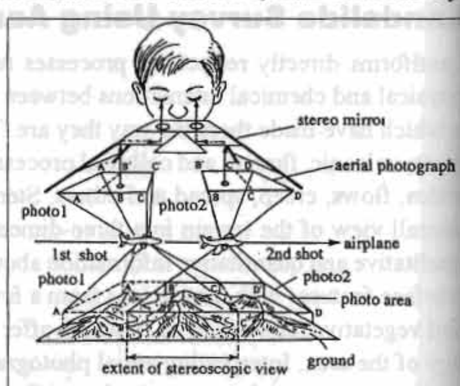


Figure 7.2: The principle of stereoscopic viewing

## Stereoscopic Aerial Photography

When conducting stereoscopic aerial photography, the aeroplane must fly in such a way that there is a 60% forward overlap between successive frames of photographs along a straight flight line and a 20% lateral overlap between adjacent flight lines (Figure 7.2). Overlapping pairs of aerial photographs create an apparent image displacement for the same object along the flight course because the projected images on the pair of aerial photographs are taken from two slightly different positions (Figure 7.3); viewed stereoscopically, this displacement produces a three-dimensional view. Relief displacement increases radially from the centre of the aerial photographs because of the central perspective projection. Hence, the image displacement of a high-relief point on two successive exposures changes; this is defined as the parallax intensity. When the two images are fused (using a stereo viewer, or by a practised observer using eye control) this parallax can provide the observer with a three-dimensional image (Figure 7.4). Interpretation and mapping of terrain features is considerably facilitated by the three-dimensional effect.

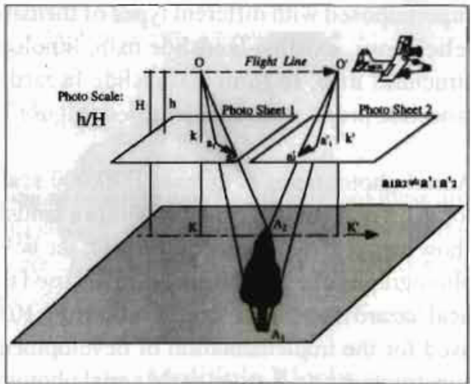


Figure 7.3: **Image displacement projected on successive aerial photo sheets** (after Ikeda et al. 1996)

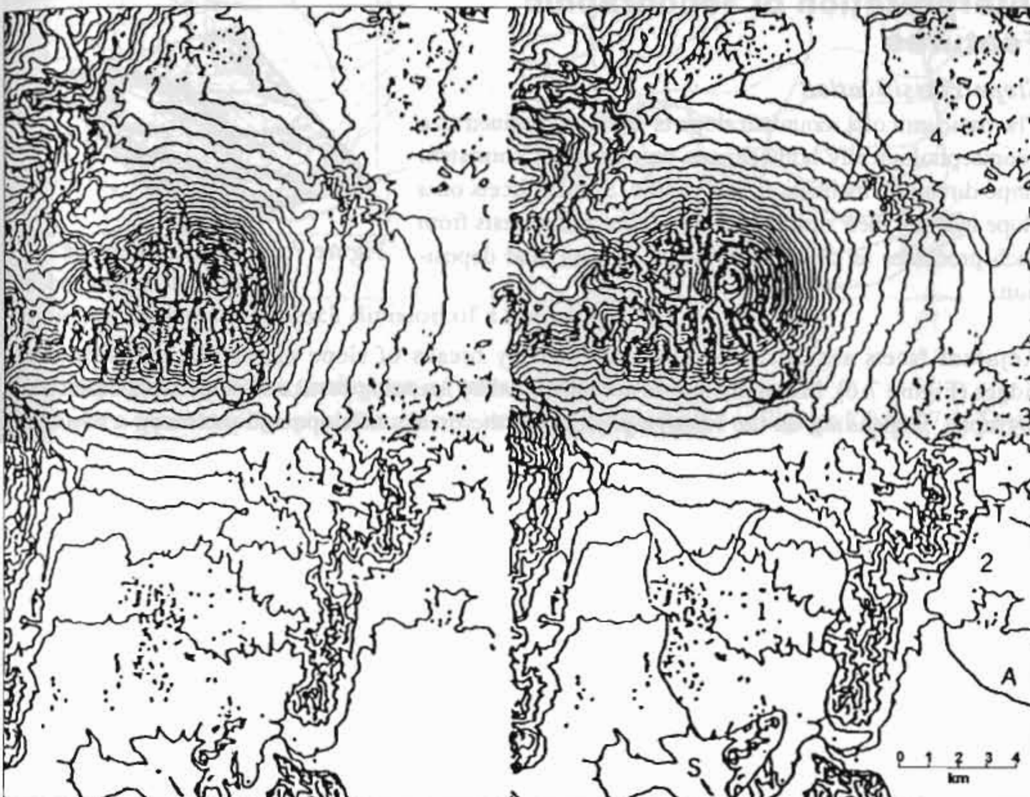


Figure 7.4: **A stereoscopic topographical map; stereoscopic fusion provides a three dimensional view**

### *Scales of photographs*

Aerial photographs at a scale of 1:20,000-1:50,000 are sufficient to detect landslide topography and to prepare a landslide distribution map covering a large area. The aerial photo interpretation map is prepared as a base map or facet map (with grouping of land elements of similar genesis). This is superimposed with different types of thematic map such as relief maps, existing landslide map, lithological map, and structural map, to form a landslide hazard map in which landslide prone areas are identified (Figure 7.5).

Aerial photographs of at least 1:20,000 scale are required for detecting landslide blocks within a landslide (areas that show separate, secondary movement, see below). Similarly, photographs of 1:20,000 are normally used to prepare practical hazard maps at a scale of 1:5,000 to 1:10,000 that can be used for the implementation of development projects at a construction site. Larger-scale aerial photographs are used for alignment surveys of new roads or other large project sites. Vertical photographs are normally used, although oblique photographs can be helpful for detailed topographic survey of specific slopes.

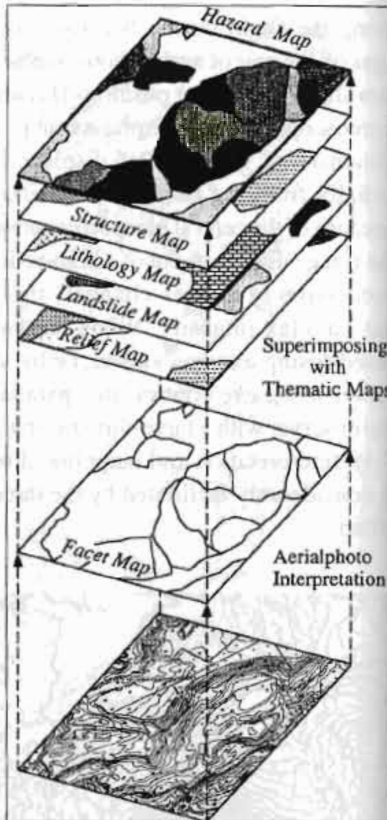

Figure 7.5: **The concept of landslide hazard mapping**

## Interpretation of Topographic Features

### *Slope classification*

The basic unit of a mountain slope is the facet, defined as a geomorphologically homogenous unit showing consistent slope direction, inclination, and profile. Similar facets on a slope indicate their similar formative ages and genesis from such processes as denudation, transportation, and deposition.

Adjacent facets are discontinuous, separated by breaks of slope marked by spurs or small ridges (Figure 7.6). Mountain slopes are classified by mapping breaks of slope from aerial photographs. Depending on the relative position of the breaks of slope and the facet, a mountain slope can be classified as a

- crest slope,

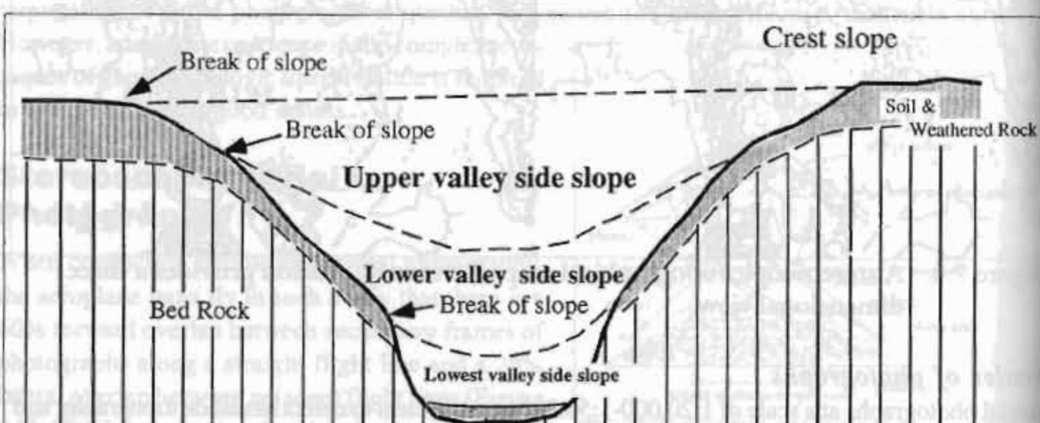

Figure 7.6: **A schematic section of valley side slopes, divided by breaks of slope**

- upper valley side slope,
- lower valley side slope, or
- lowest valley side slope (side of the valley bottom).

### *Landslide blocks*

A landslide area may consists of several blocks, each showing separate movement. Some of these are usually active (Figure 7.7). Prevention work on an active block may be sufficient to restrain the movement of a landslide area as a whole. Active blocks are characterised by microtopography with cracks, pressure ridges, breaks of slopes, and scarplets.

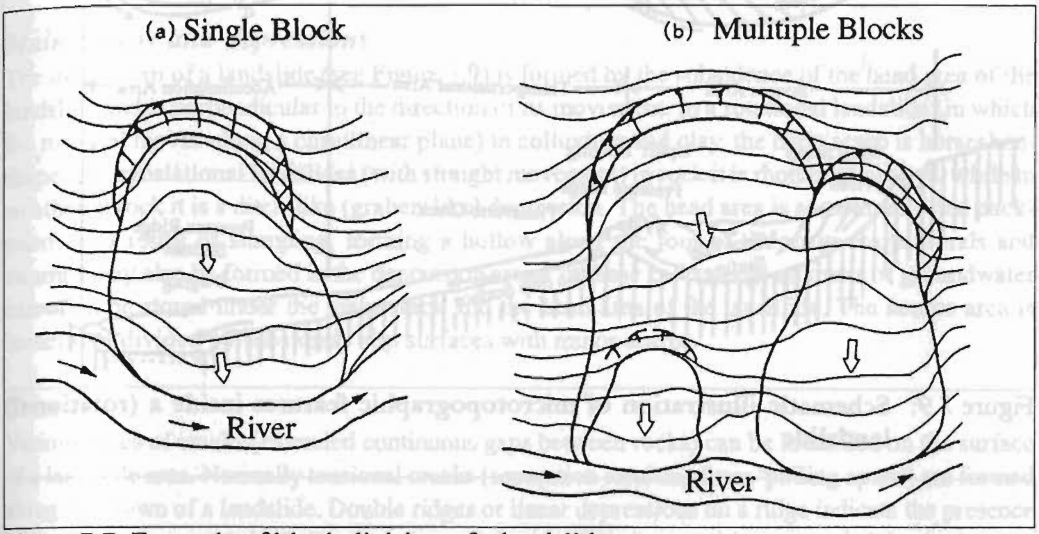


Figure 7.7: **Example of block division of a landslide**

### *Microtopography as an indicator of mass movement*

Some of the typical topographic features of a landslide are illustrated in Figures 7.8 and 7.9. These features are generally depicted on topographic maps using the symbols shown in Figure 7.10. Slope deformations related to landslides like scarps, hollows, linear depressions, cracks, bulges, and pressure ridges are detected through aerial photography and can be used to gain an understanding of past and future mass slope movement. Microtopography, i.e., ruptures or deformation of slope surfaces with dimensions of a few centimetres to a metre or more, can be examined from aerial photographs at larger scale. These micro-topographic features are convincing signs for identifying moving blocks, their direction of movement and precursors of landsliding (Figure 7.9). The larger geographical features (or homogeneous

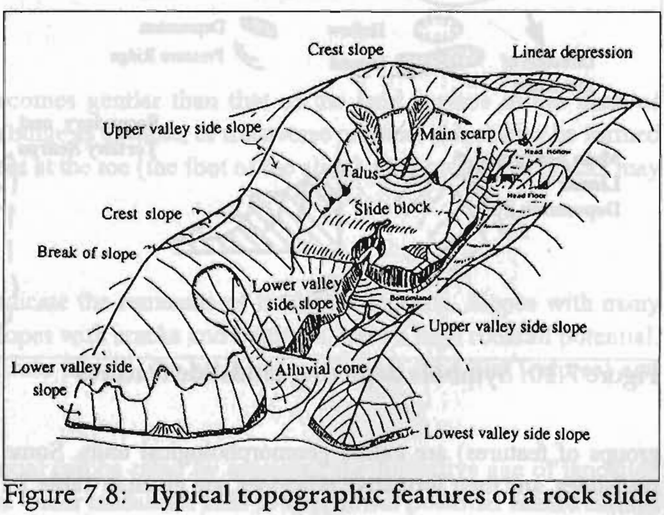


Figure 7.8: **Typical topographic features of a rock slide**

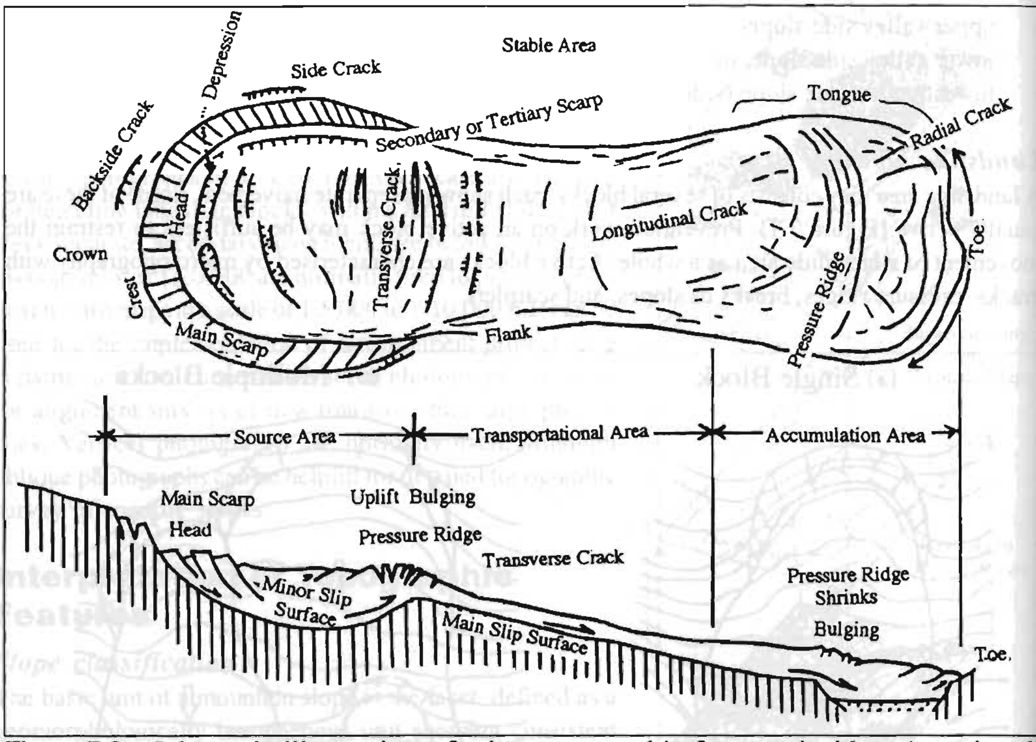


Figure 7.9: **Schematic illustration of microtopographic features inside a (rotational) landslide**

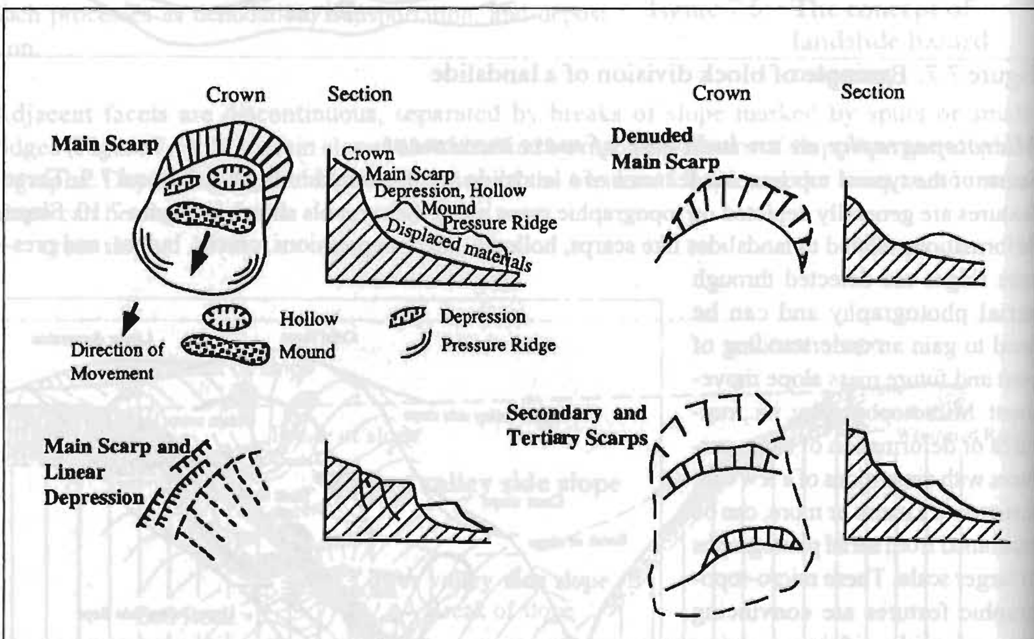


Figure 7.10: **Symbols depicting landslide features**

groups of features) are called geomorphological units. Some geomorphological units relating to landslides, and their formative processes, are given in Table 7.1.

**Table 7.1: Origins of some geomorphological units relating to landslides**

| Geomorphological unit | Formative process | |
|---|---|---|
| | Type of movement | Type of stress |
| Tensional crack | Slide | Tension |
| Compressional crack | Bulge, thrust | Compression |
| Main scarp | Slump, glide | Tension |
| Detached scarp | Glide | Tension |
| Rhomboid depression | Glide | Tension |
| Block | Slide | Tension |
| Pressure ridge | Slump, glide, or bulge | Compression |
| Debris-flow ridge | Flow | Tension |
| Debris-flow cone | Flow | Compression |

### *Main scarps and depressions*

The main scarp of a landslide (see Figure 7.9) is formed by the subsidence of the head area of the landslide and is perpendicular to the direction of its movement. In a rotational landslide (in which the material moves along a curvilinear plane) in colluvium and clay, the main scarp is horseshoe-shaped; in translational landslides (with straight movement) in rock it is rhomboid-shaped, while in weathered rock it is a ditch-like (graben-like) depression. The head area is sometimes tilted backwards as a result of slumping, forming a hollow along the foot of the main scarp. Ponds and swamps may also be formed in the depression areas; in these cases, large amounts of groundwater can often be stored under the main crack and the head area of the landslide. The source area is sometimes divided by subsidiary slip surfaces with minor scarps.

### *Cracks*

Various types of cracks (extended continuous gaps between rocks) can be identified on the surface of a landslide area. Normally tensional cracks (separation resulting from 'pulling apart') are formed along the crown of a landslide. Double ridges or linear depressions on a ridge indicate the presence of large and deep-seated tensional cracks, and they are precursors of deep-seated slides in the case of rock slide or creep. Transverse tension cracks with vertical displacements will appear in a source area. Transverse open cracks will develop on an upwarping sliding mass in a transition zone between the source and transportational areas. (At the local scale upwarping is the uplifting of a tract of land as a result of the impact of one of several possible effects like cryostatic processes or seismic uplift.) Radial cracks may occur in an accumulation area as a result of the lateral spreading of transported materials. Diagonal tension shear cracks may be observed along the flanks.

### *Bulges and pressure ridges*

If the slope of the slip surface becomes gentler than that of the land surface in the zone of accumulation, the sliding mass may bulge as a whole, or transverse pressure ridges may be formed as a result of the compressional stress at the toe (the foot of the slide). Compressional cracks may form in the bulge.

### *Other features*

Slopes with an irregular surface indicate the remnants of landslide deposits. Slopes with many boulders or overhangs, and steep slopes with cracks and boulders, have a high rockfall potential. Slopes with leaking water can indicate piping (the presence of sloping tube-like features) and erosion inside the material.

The relative landslide hazard potential can be rated by assessing the formative age of landslide slopes from the extent of dissection. Older landslides tend to have lower potential hazard ratings than newer ones, since they have clearly already successfully withstood earthquakes, heavy rains, and other natural phenomena.

## Reference

Ikeda, Y., Shimazaki, K.; Yamazaki, H. (1996) *A Primer on Active Faults in Japan.* Tokyo: University of Tokyo Press

Yagi, H.; Oi, H. (1993) 'Hazard Mapping on Large-scale Landslides in Lower Nepal Himalaya', Proc. 7th International Conference and Field Workshop on Landslides, Bratislava

## Appendix

### *Aerial Photographs*

Pairs of six aerial photographs are presented in Figures 7.A1 to 7.A6. When viewed stereoscopically these photographs show some examples of landslides as seen in aerial photographs. Figures 7.A1-7.A3 show typical landslides in Japan, the remainder are from Nepal. Landslide areas and divisions of landslide blocks are delineated in Figures 7.A4 and 7.A5.

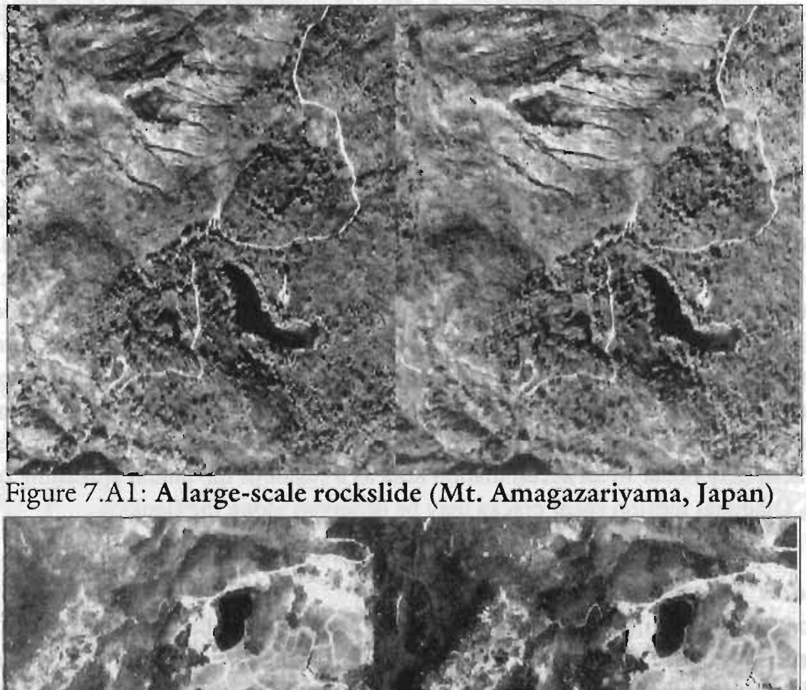

Figure 7.A1: **A large-scale rockslide (Mt. Amagazariyama, Japan)**

Figure 7.A2: **Translational landslide in an unconsolidated sediment zone (Matsunoyama Hot Spring, Japan)**

Figure 7.A3: **Multiple landslide in an unconsolidated sediment zone (Saikawa Hill, Japan)**

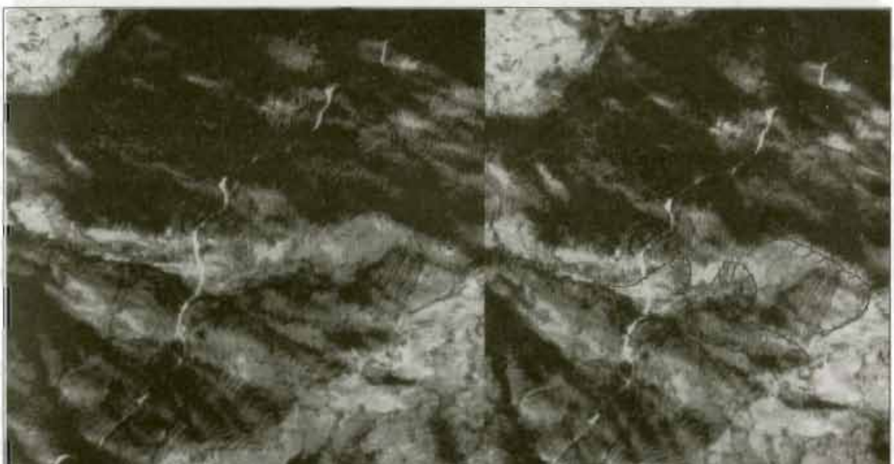

Figure 7.A4: **Landslide in a fractured schistose zone (Kathmandu-Trisuli Road, 19-km, central Nepal)**

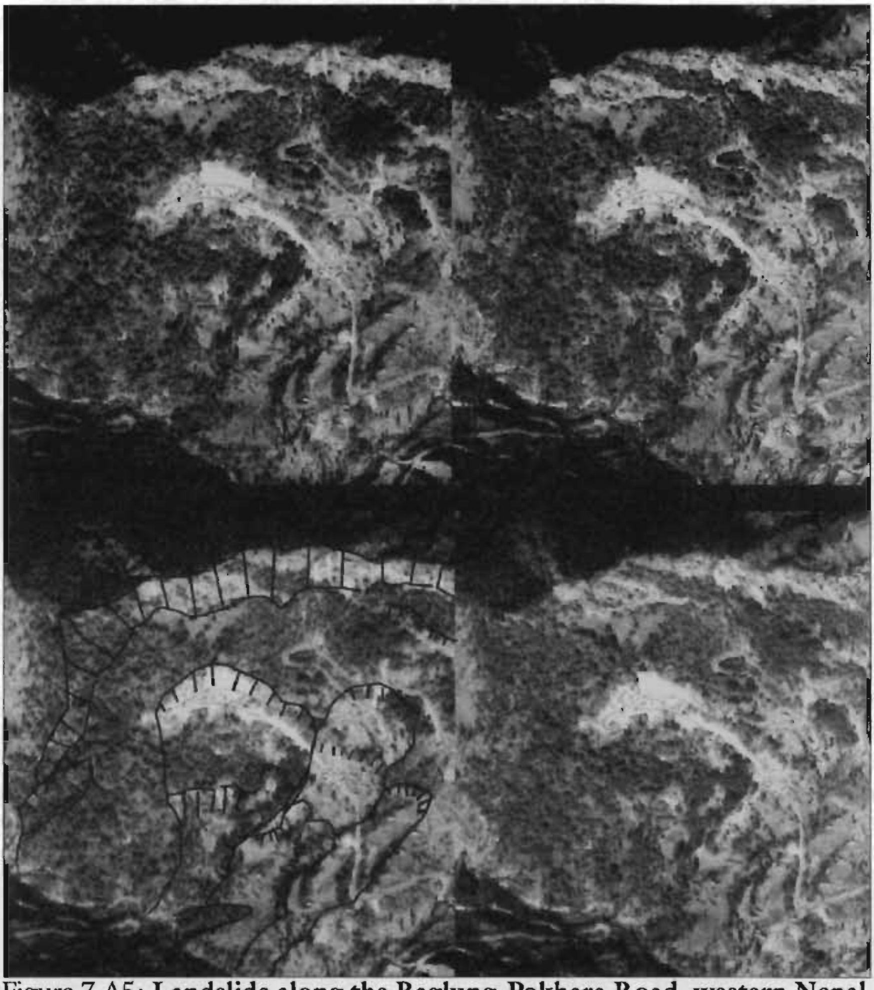

Figure 7.A5: Landslide along the Baglung-Pokhara Road, western Nepal

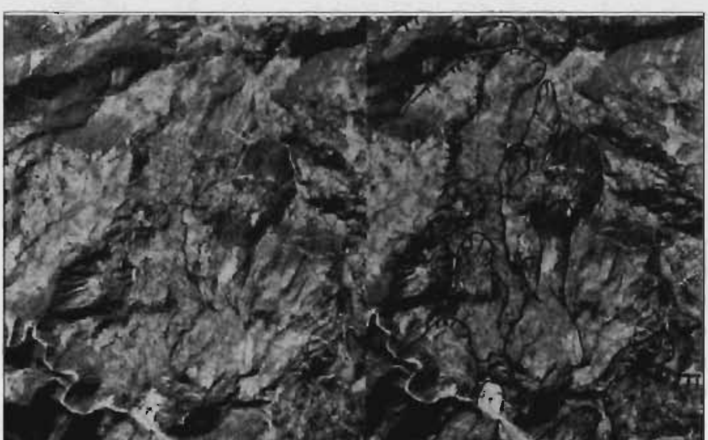

Figure 7.A6: Landslide south of Charikot, central Nepal