Classification of Mass Movement

The classification proposed by Varnes (1978) is the most commonly used. It was also adopted by the Landslide Committee, Highway Research Board, Washington. It classifies landslides into falls, topples, slides, lateral spreads, and flows. Wherever two or more types of movement are involved, the slides are termed complex. Varnes (1978) has divided the material prone to landslides into two classes, i.e., rock and soil. The soil is further divided into debris and earthfall.

Falls: Falls are abrupt movements of the slope material that separate from steep slopes or cliffs. Most of the movements occur due to free falls or by rolling or bouncing. Depending upon the type of slope material involved, it may be called rockfall, debris fall, and soil or earthfall.

Topples: Topples are blocks of rock that tilt or rotate forward on a pivot or hinge and then separate from the main mass, fall on the slope, and subsequently bounce and roll down the slope. They may be rock topples, debris topples, or soil topples, depending upon the type of material involved.

Slides: These are movements caused by finite shear failure along one or more surfaces of rupture, which are visible or whose presence can be inferred. The two principal types of slide are rotational and translational.

a. Rotational: These slides refer to failures involving sliding movements on the circular or near circular surface of failure. They generally occur on slopes of homogeneous clay, shale, weathered rocks, and soil. The movements are more or less rotational on an axis parallel to the contour or the slope. Such slides are characterised by a scarp at the head which may be nearly vertical. They may be single rotational, multiple rotational, or successive rotational types.

b. Translational: These are non-rotational block slides involving mass movements on more or less planar surfaces. The movement of a translational slide is controlled by weak surfaces such as beddings, joints, foliations, faults, and shear zones. The slide materials range from unconsolidated soils to slabs of rock and debris. Block slides are translational slides in which the moving mass consists of a single unit of rock block that moves down slope.

Spreads: These failures are caused by liquefaction whereby saturated, loose, cohesionless sediments are transformed into a liquid state. Rapid ground motions, such as those caused by earthquakes, are responsible for this phenomenon.

Flows: Flows are rapid movements of material as a viscous mass where inter-granular movements predominate over shear surface movements. These can be debris flows, mudflows, or rock avalanches, depending upon the nature of the material involved in the movement.

Complex Failure: These are slides in which the failures occur due to a combination of the above types of movement.

Classification of Slope Movements (Varnes 1978)

Types of Soil Movement	Bedrock	Engineering	
		Predominantly Coarse	Predominantly Fine
Fall	Rockfall	Debris fall	Earthfall
Topples	Rock topple	Debris topple	Earth topple
Rotational Few Units	Rock slump Rock block slide	Debris slump Debris block slide	Earth slump Earth block slide
Translational Many Units	Rockslide	Debris slide	Earth slide
Lateral Spreads	Rock spread	Debris spread	Earth spread
Flows	Rock flow (deep creep)	Debris flow	Earth flow (soil creep)
Complex	Combination of two or more principal types of movements		

Some Definitions of Landslides

The Glossary of Geology (Bates and Jackson 1987) defined a landslide as "the downslope transport under gravitational influence of soil and rock material *en masse*. Usually the displaced material moves over a relatively confined zone or surface of shear."

Webster's 3rd International Dictionary gives the definition as "the usually rapid, down slope movement of a mass of rock, earth or artificial fill on a slope."

According to the Working Party on the World Landslide Inventory (1990), a landslide is "*the movement of a mass of rock, earth or debris down a slope.*" This is the informal definition recently adopted by the Working Group and suggested for use in the International Decade for Natural Disaster Reduction (1990-2000).

Landslide Features (Figure A-1)

Crown (1): The practically undisplaced material still in place and adjacent to the highest parts of the main scarp

Main Scarp (2): A steep surface on the undisturbed ground at the upper edge of the landslide, caused by movement of the slide material away from the undisturbed ground

Top (3): The highest point of contact between the displaced material (13) and the main scarp (2)

Head (4): The upper parts of the landslide along the contact between the displaced material and the main scarp (2)

Minor scarp (5): A steep surface on the displaced material of the landslide, produced by differential movements within the sliding mass

Main body (6): The part of the displaced material of the landslide that overlies the surface of rupture between the main scarp (2) and the toe of the surface of rupture (11)

Foot (7): The portion of the landslide that has moved beyond the toe of the surface of rupture (11) and overlies the original ground surface

Tip (8): The point of the toe (9) farthest from the top (3) of the landslide

Toe (9): The lower,usually curved, margin of the displaced material of a landslide, it is the furthest from the main scarp (2)

Surface of rupture (10): The projection of the main scarp (2) surface under the dis-placed material of a landslide

Toe of surface of rupture (11): The intersection (sometimes buried) between the lower part of the surface of rupture (10) of a landslide and the original ground surface

Surface of separation (12): The part of the original ground surface overlain by the foot (7) of the landslide

Displaced material (13): Material displaced from its original position on the slope by movement in the landslide

Zone of depletion (14): The area of the landslide within which the displaced material (13) lies below the original ground surface

Zone of accumulation (15): The area of the landslide within which the displaced material lies above the original ground surface

Depletion (16): The volume bounded by the main scarp (2), the depleted mass (17), and the original ground surface (Cruden 1980)

Depleted mass (17): Part of the displaced material which overlies the rupture surface (10) but underlies the original ground surface

Accumulation (18): The volume of the displaced material (13) which lies above the original ground surface (Cruden 1991)

Flank (19): The side of the landslide. Compass directions are preferable for describing the slide but, if left and right are used, they refer to the slide viewed from the crown

Landslide Dimensions

L_r = The length of the rupture surface: the distance from the toe of the surface of rupture to the crown

L_d = Length of the displaced mass: the distance from the tip to the top

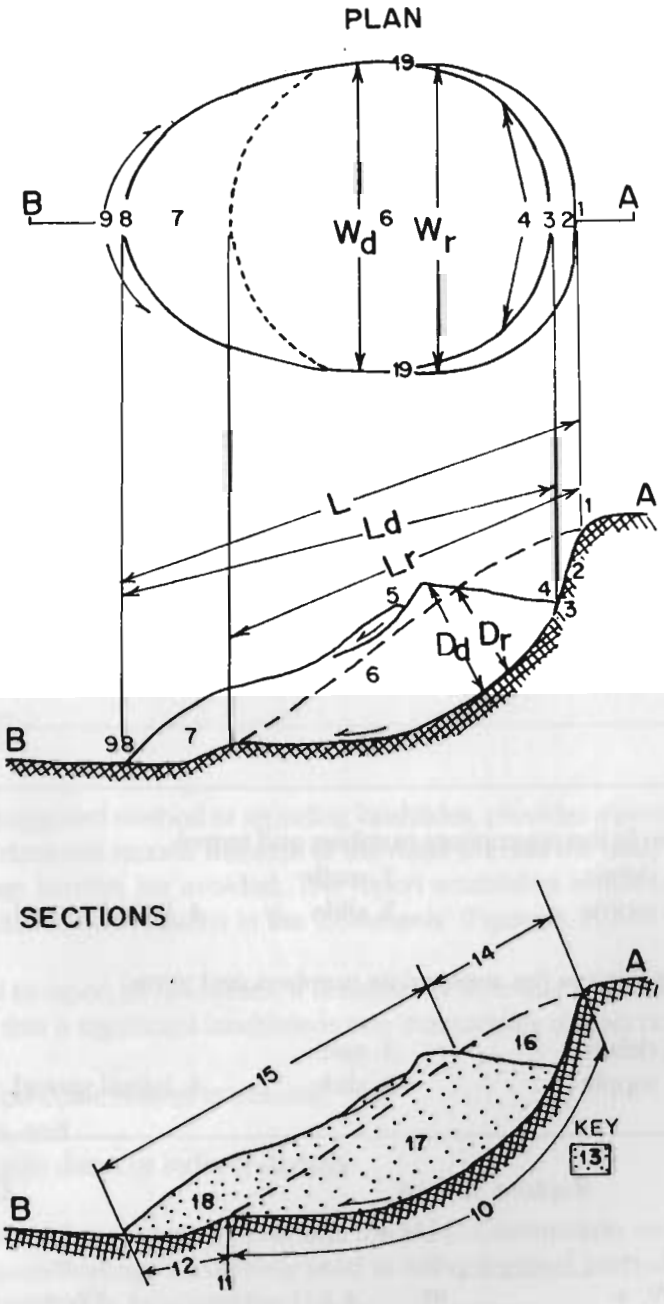
L = Total length: the distance from the tip of the landslide to its crown

W_r = Width of the rupture surface: the maximum width between the flanks of the landslide, perpendicular to the length, L_r

W_d = Width of the displaced mass: the maximum breadth of the displaced mass perpendicular to the length, L_d

D_r = The depth of the rupture surface: the maximum depth of the rupture surface below the original ground surface measured perpendicular to the original ground surface

Figure A-1: Suggested nomenclature for landslides. Cross-hatching indicates undisturbed ground, stipping shows the extent of displaced material (13) (IAEG Commission on Landslides 1990)



LANDSLIDE REPORT

Day month year

Date of Report / / /

Landslide Locality: _____ National Inventory Number: _____

Reporter's Name: _____

Affiliation: _____

Address: _____

_____

_____

Phone: _____

_____

Day month year

Date of Report / / /

_____

Type: First movement (circle the appropriate numbers and terms)

1. rock 2. debris 3. earth
1. fall 2. topple 3. slide 4. lateral spread 5. flow

Second movement (circule the appropriate numbers and terms)

1. rock 2. debris 3. earth
1. fall 2. topple 3. slide 4. lateral spread 5. flow

_____

Geometry:

	Rupture Surface		Displaced Mass	
Length	L_r =	_____ m	L_d =	_____ m
Width	W_r =	_____ m	W_d =	_____ m
Depth	D_r =	_____ m	D_d =	_____ m

_____

Damage: Value

Currency _____

Casualties _____

Reference:

1. _____

_____

_____

2. _____

_____

_____

3. _____

_____

_____

Comments: _____

_____

_____

_____

_____

The Landslide Report, a suggested method of reporting landslides, provides a permanent record of details that cannot be coded in the database record. Because of the need to code the data, complex descriptive details which may face language barriers are avoided. The report establishes minimum data requirements while permitting additional, detailed observations in the 'comments' (Figure A-2).

Because it is not practical to report all landslides, it is necessary to create a working definition of a significant landslide. It is proposed that a significant landslide is one that satisfies at least one of the following criteria:

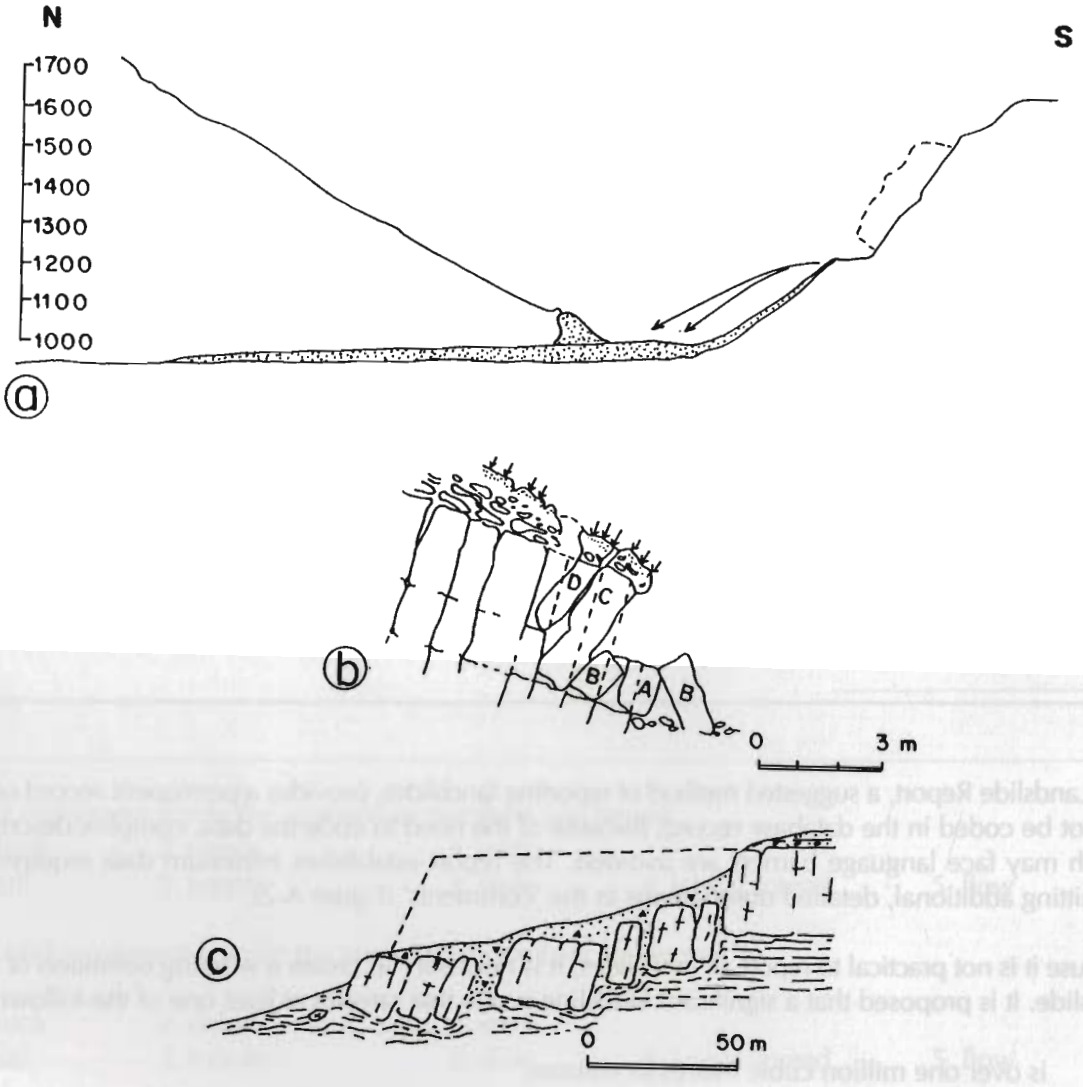
1) is over one million cubic metres in volume,
2) causes casualties, and
3) causes considerable direct or indirect damage.

The report uses terminology from Varnes (1978) and the IAEG Commission on Landslides and Other Mass Movements (1990). This terminology is currently used in many regional and national inventories, including those in Canada, Czechoslovakia, Italy, and the U.S.A.

The Landslide Report is arranged to permit ready coding for computer processing. Consequently, observations are either numeric or of mutually exclusive categories that can be classified numerically. Each category is represented by a number so that information is transcribable on to the electronic database.

References in the Report and descriptive comments will not be transferred to the Landslide Record. However, a separate file of references will be created and represented by numbers in the Record. The comments need not be transferred to the Record but should remain on file with the Landslide Report. Landslide Reports should be maintained in National Centres for public reference.

Figure A-2: Section through typical slope movements (International Geotech. Society 1990)



The specifications of the measurements of an individual landslide in the Report, which include the position, the date, the type,the geometry, and the volume,are described here.

Position

The position of each landslide is to be mapped by its latitude and longitude to the nearest second. This provides a reference point for subsequent mapping and research. On landslides that extend over more than one second, the crown of the landslide should be taken as the reference point. The elevation of the tip of the

landslide, the toe of the surface of rupture, and the highest point of the crown above mean sea level should be recorded to the nearest 10m.

Date

The date of occurrence should be recorded. Difficulties arise when the movement is not fast. When the movement is progressive and takes place over an extended period of time, the 'date of occurrence' is when the most rapid displacement took place. If this is not known, the day when displacement last took place should be recorded.

Type

The most widely-used classification is Varnes (1978). Varnes' classification is based on two criteria: the type of movement and the material involved. Material is classified as either bedrock or engineering soil. Soils are divided into debris or earth. The latter is fine-grained material in which at least 50 per cent consists of sand, silt, and clay-sized particles. There are five main types of movement: falls, topples, slides, spreads, and flows. A sixth group includes all complex failures in which one of the five main types of movement is followed by another. Some movements may exhibit more than two types of movement in sequence. Most movements are complex. Varnes (1978) suggested the construction of names for the movements which reflected their complexity.

Consider the Elm landslide in which the displaced rock mass fell, shattered, and flowed as debris. This was a rockfall-debris flow (Varnes 1978, p.21). The complex type of movement can be accommodated in the report by describing a second type of movement which follows the first. To aid in the definition of movement type, a brief description is given of each, according to Varnes (1978).

In falls, a mass is detached from a steep slope along a surface on which little or no shear displacement takes place. Materials descend mostly through the air either by free fall, saltation, or rolling.

Topples involve the forward rotation of the displaced mass about an axis at or near its base. Topples may precede or follow falls or slides and are sometimes evident as detached blocks perched precariously on a valley wall.

Slides are movements of a more or less coherent mass along one or more well-defined surfaces of rupture.

In spreads, the dominant mode of movement is lateral extension, accommodated by either shear or tensile fractures.

Flows include a wide range of movements with significant variations in velocity and water content which exhibit spatially continuous deformations. Flows often begin as either slides, falls, or topples on steep slopes which rapidly disintegrate with the loss of cohesion of the displaced material.

Geometry

The length, width, and depth of the rupture surface can often be estimated when parts of the surface of rupture are obscured. They are shown by a subscripted r. The length, width, and thickness of the mass of displaced material are measured directly and are denoted with a subscripted d.

The maximum length of the rupture surface, L_r, is measured from the toe of the surface of rupture to the crown. The other length measure, L_d, is taken from the tip of the displaced material to its top. The total length, L, is measured from the tip to the crown (Varnes 1978). The maximum widths of the surface of rupture, W_r, and the displaced mass, W_d, are measured across the original ground surface in directions perpendicular to the lengths L_r and L_d. Depth is the most difficult dimension to estimate. The maximum depth of the surface of rupture, D_r, should be estimated from the original ground surface in a direction perpendicular to it. The thickness of the displaced material, D_d, is measured perpendicular to the surface of the displaced material.

Volume

The volume of the displaced mass in cubic metres should be given to three significant digits. In the Landslide Record, n represents the order of magnitude of the volume. When the displaced mass does not have regular dimensions, the volume can be estimated by fitting a geometric figure. For instance, considering the displaced mass as half an ellipsoid might be appropriate for a rotational slide. In this case, the volume is computed by using the major axes of half an ellipsoid:

$$V = \frac{1}{2}\, n^{\frac{4}{3}}\, \frac{1}{2}\, L_d\, D_d\, \frac{1}{2}\, W_d = \frac{1}{6}\, L_d\, D_d\, W_d \quad (1)$$