1982/17. Slope stability at West's block, Cluan Tier

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Abstract

A sequence of Quaternary dolerite talus, Triassic sandstone, and Permian mudstone is exposed on the north-eastern flanks of Cluan Tier, near Westbury. Topographically the region has been divided into distinct units, basically consisting of a talus bench and a sandstone bench separated by a steeply sloping unit, and dissected lower slopes underlain by the Permian rocks. Slopes greater than 15° (27%) underlain by dolerite talus or deeply weathered Triassic rocks are potentially unstable. Guidelines for making decisions about the stability of areas have been presented and suggestions have been made as to further field inspections required to determine the instability potential of marginal areas. Initially, the most suitable areas for plantation operations are located on the topographic benches. Other areas are probably suitable depending on the outcome of field investigations and the implementation of stability guidelines. Forestry operations should be planned with respect to the potential instability of this area.

INTRODUCTION

In response to a request from Associated Pulp and Paper Mills Ltd an inspection of an area known as West's Block on the north-eastern slopes of Cluan Tier [DQ835940] was made. Minor landslipping has occurred adjacent to a logging road located at a higher altitude to the south, beneath Cluan Tier. APPM are concerned that proposed forestry activity in West's Block may have an adverse effect on the stability of the area. The area in question covers approximately 4.25 km^2 and experimental plantations are proposed. The area was inspected in the company of APPM personnel.

TOPOGRAPHY

West's Block is approximately located between the 300 m and 500 m contours on the north-eastern slopes of Cluan Tier and has a regional slope of about 10° (17%). The lower, north-eastern boundary is adjacent to the Swamp Gum Rivulet flood plain, while the higher south-western boundary lies close to the peak of Cluan Tier. The area is drained to the north-east by several small tributaries of Swamp Gum Rivulet. Well-defined streams occur approximately below the 400 m contour.

The morphology of the area is shown in Figure 1 and is based on an inspection of aerial photographs. The morphology can be subdivided into 5 distinct units, described below and arranged in order of descending altitude.

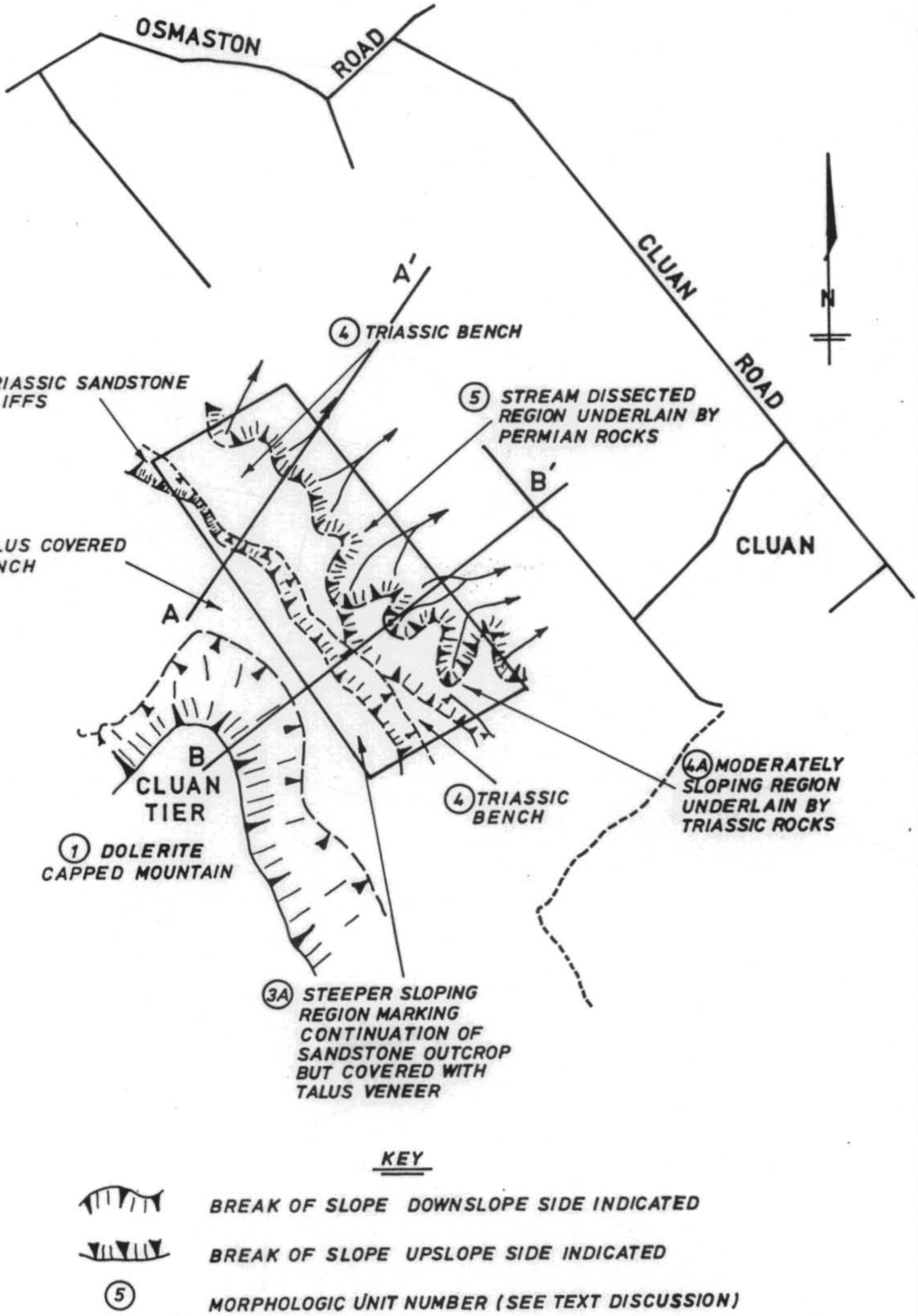
Unit 1

Cluan Tier, the main dolerite-capped peak of the region with its associated steep slopes, often covered with dolerite scree.

Unit 2

A gently sloping dolerite talus covered bench between 500 m and 750 m in width and with an overall slope of about 5° (8%).

MORPHOLOGY—WEST'S BLOCK, CLUAN TIERS



SCALE 1:50000

MAPPING BASED ON PHOTO-INTERPRETATION
PLAN 1351 RUN 5, T380-86

GEOLOGIST J. SLOANE

Fig. 1

Units 3 and 3A

An area of sandstone cliffs and steep slopes up to 20° to 25° (36% to 46%).

Units 4 and 4A

A gently sloping Triassic sandstone bench up to 700 m in width which has been partially dissected and eroded in Unit 4A to produce moderate slopes at the head of several streams.

Unit 5

An area of dissected topography where a series of streams drain towards the north-east. Moderate to steep slopes are associated with the head and side slopes of these streams, with several small spurs which have developed as drainage divides.

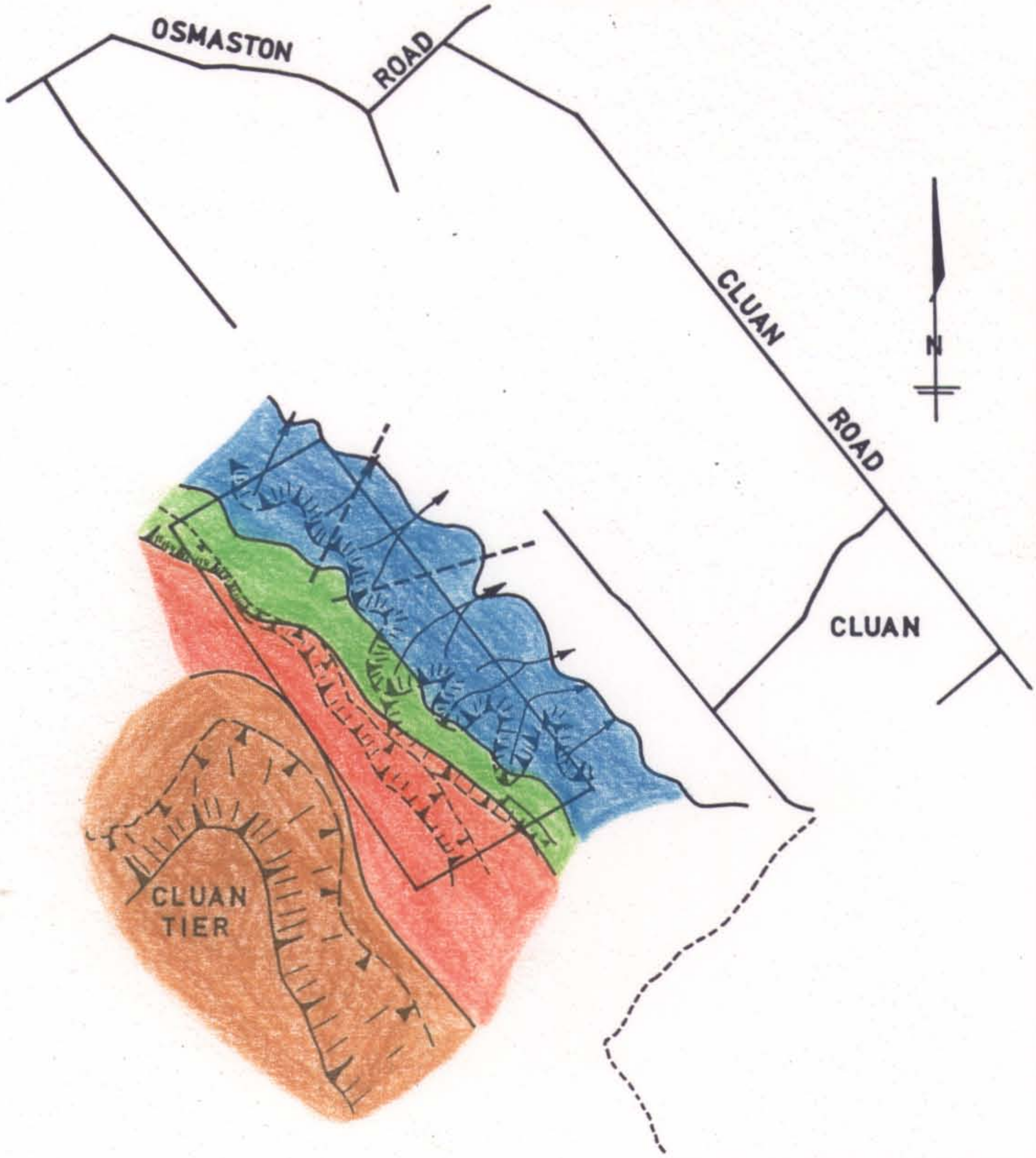
GEOLOGY

The topography of the region closely reflects the underlying geology (figs. 2, 3). Morphologic unit 1 is underlain by *in situ* Jurassic dolerite, a remnant of an intrusive sill which has subsequently been exhumed by erosion and now caps the Cluan Tier peak. Underlying the dolerite is sandstone of Triassic age. The sedimentary rock can be clearly seen exposed in cliffs near the western corner of the area. This resistant band of sandstone undoubtedly underlies steeper slopes to the south-east in Unit 3A. It is considered that the talus covered bench (Unit 2) is a structural feature related to the top of the Triassic sandstone which has horizontal to subhorizontal bedding. Triassic sandstone and siltstone also underlies the topographic bench (Unit 4) and steeper slopes (Unit 4A). The Triassic sediments can be readily identified in the field as they are composed largely of medium sand-sized quartz grains. Where exposed the sandstone is often friable and has weathered to a clayey sand. The main West's Block access road passes below the Triassic sandstone cliffs (Unit 3) and traverses the Triassic bench (Unit 4). Triassic rocks are exposed in several road cuttings in this area.

Conformably underlying the Triassic sandstone is mudstone of the Upper Permian Bogan Gap Group (Barton *et al.*, 1970). This mudstone crops out on the lower slopes and largely underlies the stream dissected Unit 5. The Permian rocks have horizontal to subhorizontal bedding and are generally much harder and less friable than the Triassic sandstone. Jointing is well developed in the Permian rocks and the rock breaks easily into roughly square blocks, enabling easy quarrying. The harder nature of the mudstone renders it suitable for road surfacing. Soils developed on the Permian mudstone are thin, with bedrock often less than one metre from the surface. Soils are generally stony and less susceptible to instability than the deeper clayey sands and sandy clays developed on the Triassic sediments.

The youngest rock of the region is dolerite talus of Quaternary age. A veneer of dolerite talus of varying thickness overlies part of the Jurassic dolerite and Triassic sandstone. The talus is also variable in composition, consisting of angular dolerite boulders up to several metres in diameter in a matrix of silty clay in varying proportions. The presence of dolerite boulders in underlying talus cannot be totally assumed from the surface occurrence of such boulders. Often a surface veneer of boulders is present which may have its origin as a lag deposit produced by removal of the silty clay matrix by erosion. The surface boulder veneer may also be

GEOLOGY–WESTS BLOCK CLUAN TIERS
(OVERLAID ON MORPHOLOGY)



MAPPING BASED ON 1 63360 SERIES QUAMBY SHEET 1970

KEY

- *QUATERNARY DOLERITE TALUS*
- *TRIASSIC SANDSTONE*
- *UPPER PERMIAN MUDSTONE (BOGAN GAP GROUP)*
- *JURASSIC DOLERITE*
- *FAULT*

SCALE 1:50000

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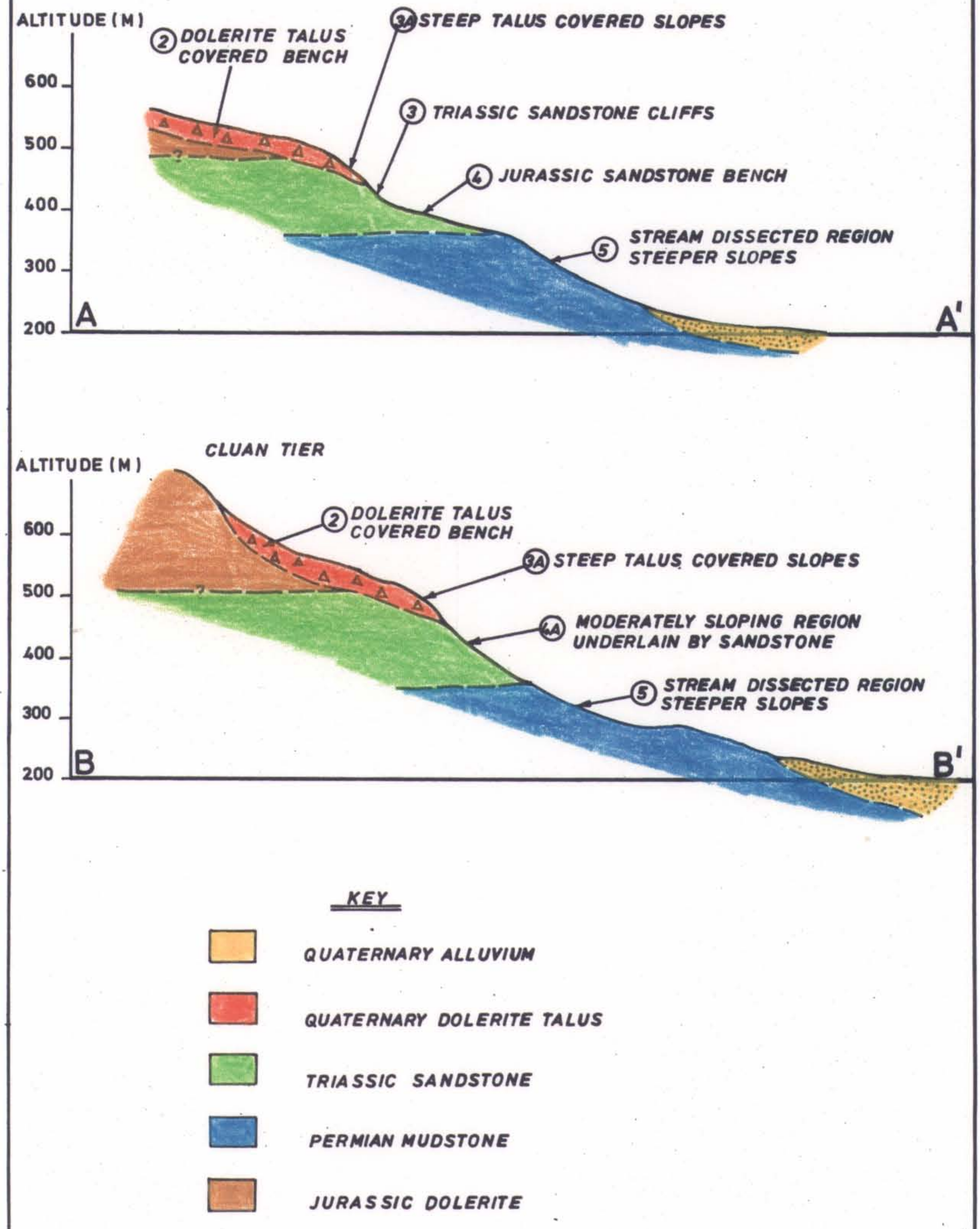
Fig. 2

5 cm

DIAGRAMMATIC CROSS-SECTIONS—WESTS BLOCK



HORIZONTAL SCALE 1 25,000 APPROX

VERTICAL EXAGGERATION = 2·5

GEOLOGIST J.SLOANE

Fig. 3

5 cm

a more recent deposit produced largely by physical processes such as freeze-thaw activity. The dolerite talus has most likely formed during cold climatic conditions, probably during or towards the end of the last glacial period. At this time vegetation was sparse and physical weathering and mass movement were the dominant processes. The talus is thought to have formed as a solifluction deposit which moves by creep and flow in a near water saturated condition. The angular boulders present in the talus would have been supplied by freeze-thaw activity on dolerite outcrops and the silty-clay matrix probably originates from material formed by deep weathering of the dolerite during warmer interglacial periods. Some of the boulders in the talus are very large and have, in places, been rafted considerable distances from the nearest dolerite outcrop.

SLOPE INSTABILITY

One active landslip occurs in an area on Cluan Tier to the south of West's Block and at a slightly higher altitude. The failure has occurred where the road passes around the toe of a talus lobe. Several other features attributable to old landslips occur in this area. No other examples of instability were observed, despite the presence of some moderately large road cuttings where both dolerite talus and deeply weathered Triassic sediments are exposed. The stability of these cuttings is partially attributed to good embankment construction, with batters of approximately 1:1 slope in places. The West's Block access road is well located, in the main part traversing the Triassic bench in Unit 4 and thus minimising embankment excavation.

Without extensive and detailed mapping of the area reference must be made to experience gained from studies of areas with similar topography and geology. Experience gained from investigations of slope stability for the Forestry Commission in the Fingal-St Marys-East Coast region indicates initially that potentially unstable areas occur in Units 3 and 3A, 4 and 4A, and to a minor extent in Unit 5. Unit 3A has probably the highest potential instability, with dolerite talus overlying Triassic rocks on steep slopes. These areas often have underground drainage with a large amount of rainfall infiltrating through the talus and draining along the talus-Triassic bedrock interface. Several examples occur elsewhere where road excavation has exposed the underlying Triassic rocks with numerous springs occurring along the bedrock interface. The concept of a threshold slope angle is important in planning the development of an area with respect to potential slope instability. This threshold slope value is a slope angle above which the potential instability is very high, if slope disturbance occurs. Fortunately the maximum slope angle at which most logging machinery can operate is about 20° (35%) which closely corresponds to the threshold slope angle of a dolerite talus covered terrain. This figure has been deduced by investigation of several areas where dolerite talus overlies Triassic bedrock. The figure of 20° is understandably not an exact figure but more an indication of the sort of angle above which disturbance should not occur. As in all situations there are probably many slopes above this figure which would remain stable if disturbance occurred and there are probably several slopes below this figure which may fail. The reason for this is simple in that the prediction of groundwater conditions is virtually impossible without obtaining subsurface information from drill holes. There is therefore a need for a buffer zone around this threshold slope angle. This zone must be treated with caution, especially where road construction is envisaged. In the talus situation, a buffer zone between 15° and 20° (25% to 35%) is proposed. Similar slope angle guidelines should be applied to Unit 4A, where steeper slopes are underlain by Triassic sediments. As mentioned previously, the

Triassic rocks are deeply weathered in places to sandy clay. The clayey weathering products are derived from mudstone and often contain montmorillonite, a clay with high shrink-swell properties and prone to landslip where underlying steep slopes.

Unit 5, underlain by Permian mudstone, may have isolated instability problems on steep slopes underlain by deeply weathered materials. Landslips associated with Upper Permian sediments occur in several parts of the state. From a brief field inspection, it appears that soils are thin and stony with only isolated horizons susceptible to weathering, especially those horizons that are friable and easily break into small lumps. An example of this breakdown of the mudstone occurs in road cuttings on the lower slopes of West's Block, adjacent to the quarry on the main access road. Generally, the Permian mudstone is less susceptible to weathering, hence its use as road material, and the stream dissection and erosion in Unit 5 has probably removed a large amount of weathered material. Areas requiring inspection and possible caution exist on steep slopes above 17° (30%).

From the topography and geology of the region, areas of potential instability have been outlined and guidelines concerning the use of slope angles to further delineate areas have been presented. Areas such as Units 4A and 5 cannot be excluded on the basis of the brief investigations described above. Field inspection with measurement of slope angles will be required to accurately assess slopes and to subsequently apply the slope criterion described above. The other major input into the decision making process will be the evidence of previous instability in such areas. The presence of old landslips indicates that failure of a region has occurred and disturbance, especially by road construction, should be avoided. The use of slope angle criteria and field evidence of instability generally indicates areas to be avoided. Features associated with old landslips have been described and indicated to APPM officers during the field inspection. In summary, the morphological features to be recognised as indicative of old landslips are the following (fig. 4):

Drainage

Stream flow or gully depressions aligned along the slope rather than across the regional contours. Caused by drainage disruption by landslips.

Swampy depressions, especially where associated with backsloping slope segments. Caused by ponding of runoff on slip masses or may be fed by aquifers exposed at head scarps after failure.

Slip morphology

Head scarp regions - arcuate areas of steeper slope on an otherwise uniformly sloping area.

Toe regions - 'bulges' or hummocky ground. Convex profile humps on an otherwise even or concave slope profile. Often an area where flow of slip materials is dominant. Sometimes exhibit seepages at toe front. (Examples of the above features were indicated in the field in the area adjacent to the active landslip).

Slip mass region - often hummocky and ridged across the slope. The slip mass may have a 'back slope' caused by rotation along a near-circular slip plane.

5 cm

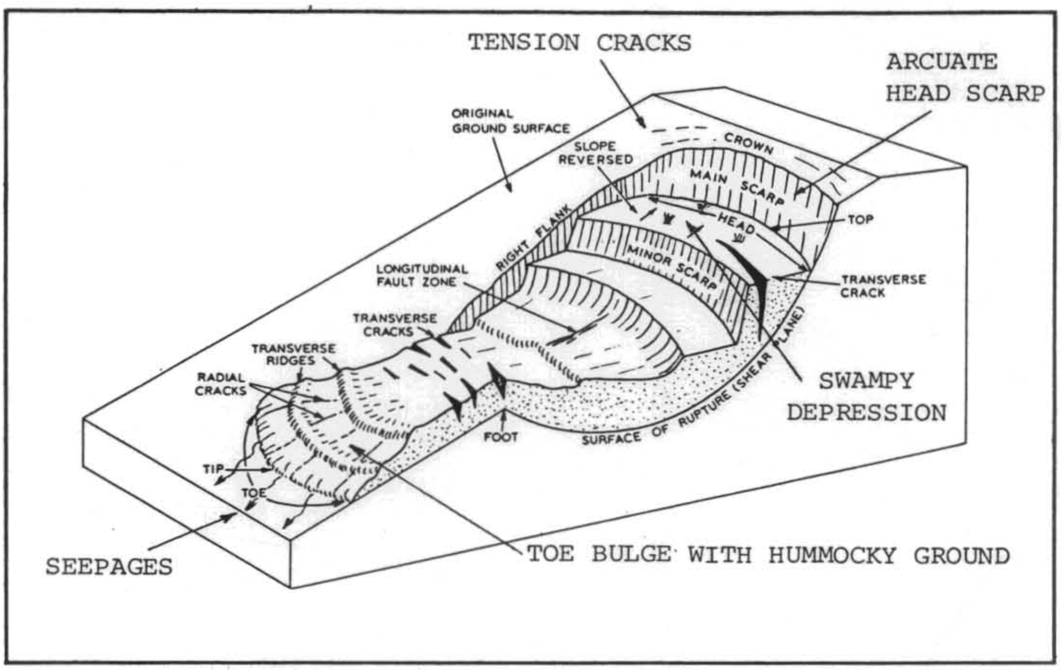


Figure 4. *Essential features of a rotational landslip.* [*Adapted from Cooke and Doornkamp 1974 (after Varnes, 1958)*].

Note: All of the above features may not be present, depending on the type of failure. The failure plane may not be circular. The slip may have more of a flow component resulting in a long, narrow failure with few of the slip mass features described above. With increasing age, the slip features become more subdued due to erosion.

Slope complexity - often used as an indicator of previous instability. Can be identified in the field or from good, close interval, contour maps. Outline areas of complex or varying slope segments on an otherwise uniform or simple regional slope profile.

Other features

Tension cracks above head scarp features, on toe bulges and slip masses. Generally associated with active or recently active landslips, but may still be preserved in older slips.

Leaning or 'kinked' trees. Caused by instability during the growth of trees resulting in trunk deformation.

These features should not be considered in isolation as indicative of old failures. Several features will usually be associated, giving greater confirmation of past instability. Once both active and old landslip features are located on the map, together with slope and pertinent information such as depth of soil, seepages, swampy depressions *etc.*, a decision can be made for the exclusion of areas on the basis of the instability criteria.

The areas of low potential for slope instability are Units 2 and 4, the talus covered bench and the Triassic sandstone bench, obviously because of their low slope.

SUMMARY AND CONCLUSIONS

From a brief field inspection and aerial photograph interpretation, West's Block has been divided into five topographic units. An overlay of the topography and geology has been prepared and from experience gained from stability investigations elsewhere, areas of varying potential instability can be outlined.

Steep slopes underlain by dolerite talus are potentially unstable (Units 3 and 3A). Slopes above 15° (25%) should be treated with caution, with modification or careful planning of operations on slopes of between 15° and 20° (25% to 35%). Slopes above 20% should remain untouched. Most of Units 3 and 3A will probably be unsuitable for clear fell forestry operations.

Steep slopes underlain by deeply weathered Triassic sandstone and mudstone are also potentially unstable. The same slope criteria indicated above should be applied in these areas, which are largely covered by Unit 4A. This area requires further field inspection to determine slope angles and the possible presence of old or active landslip features before a planning decision is made. The area is most likely to be marginally suitable for plantation operations.

Sections of Unit 5 may be suitable for plantation depending on further inspection of slopes as outlined previously. The suitable sections of Unit 5 may be too fragmented to allow suitable plantation organisation. Areas of slope greater than 17° (30%) should be avoided and potential problem areas are likely to be isolated and restricted to areas of thicker soils and deeper weathering.

On the basis of slope and geology, the areas most suitable for clear fell operations and plantation development appear to be the Triassic and dolerite talus bench areas of Units 2 and 4.

Any future road construction should be carefully planned and preferably located along hill slope benches to minimise embankment excavations. Embankments are areas of maximum slope disturbance and hence have a higher instability potential. A vegetation retention strip 30 m in width should be retained above embankments where roads traverse steeper slopes. A retention strip is considered advisable where the West's Block access road traverses Unit 4A. A 10 m retention strip should be retained on the lower side of roads where fill embankments are large. Good standards of road construction should be maintained, especially with regards to embankment batters.

Using topographic and geologic inputs, broad zones of potential instability can be recognised, enabling an initial selection of suitable areas. Some regions require field inspection to determine their topographic characteristics before stability guidelines can be applied. Planning decisions can then be made on the basis of this information. It should be recognised that these are guidelines and due to the variable nature of any topography, all possible situations cannot be covered. In this case, the intuitive feelings of field officers about the instability of an area should not be ignored. Delineation of areas requires a 'common sense' approach and it is hoped that the field inspection conducted in the presence of Company officials in conjunction with the guidelines described above will aid in the planning of forestry operations in West's Block.

REFERENCES

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