

# Landslides in South Australia

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2

**SUMMARY** Many South Australian landslides are due to mass movement of hillslope debris and have occurred during periods of intense rainfall. Earth flows, incorporating rotational movement, occur in Permian Sediments on the Fleurieu Peninsula and are due to the effects of land clearing. Massive rotational slumping, occurring in bedded rocks, has been recorded at several localities as have numerous rockslides in quarries, open cut mines, and road cuts.

## 1 INTRODUCTION

South Australia has the lowest average rainfall of any Australian State and a very subdued topography. Nevertheless mass movements (landslides) are widespread. Many of them are due to the results of changing land use and other human activity and have occurred within living memory, while some may have been the result of past seismic activity. Because of this the State Planning Authority requires geological inspection of slopes steeper than  $15^{\circ}$  (1 on 4) before residential subdivision is permitted.

This paper summarises the main types of landslide which are known to have occurred and provides a guide to the recognition of situations where mass movements could occur in the future. The simple classification given in the Field Geologists Manual by Berkman (1976) has been used. Localities mentioned in the text are shown in Fig. 1.

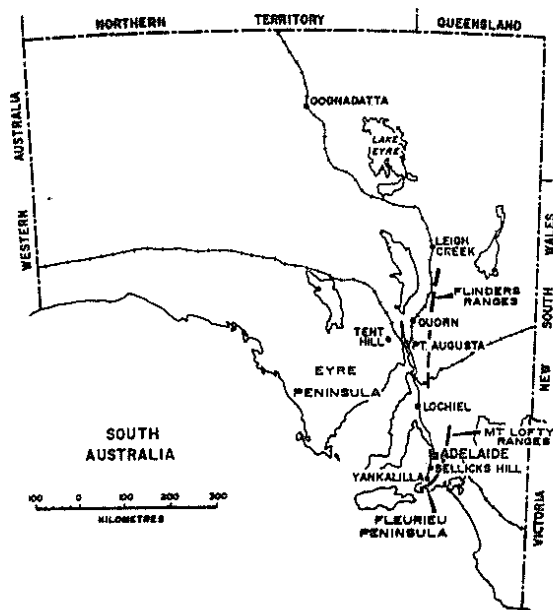


FIG. 1 Location Plan

## 2 MASS MOVEMENT OF SOIL

If the word 'soil' is used in its civil engineering sense it is apparent that most South Australian landslides are due to mass movement of this material. Several different modes of failure can be recognised:

### 2.1 Debris Slides

In the Flinders Ranges and Mt Lofty Ranges, which form a central spine to the most settled area of the State, debris slides are fairly common and have been described by Twidale (1968). Stream erosion has revealed that some of the lower slopes in these areas consist of several metres of hillslope debris (colluvium) consisting of poorly graded material of extremely variable grain size. A railway cutting along the Pichi Richi Pass near Quorn shows nearly 8 m of colluvium, ranging in size from silt to boulders, occurring as a thick layer on the floor of a narrow valley. Foundation investigations for a proposed water treatment works near Adelaide showed up to 10 m of heterogeneous hillslope debris in an area of suspected shallow bedrock. This caused a modification of the foundation design to incorporate a retaining wall tied in with rock anchors (Fig. 2).

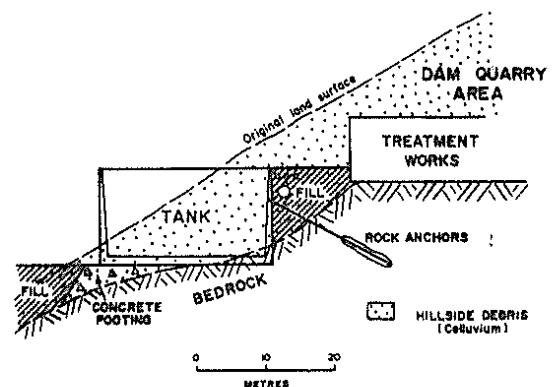


FIG. 2 Proposed water treatment works on Hillslope debris.

Areas of debris material can often be recognised in the field and on air photographs by a characteristic hummocky terrain best seen under conditions of low incident light. On many lower hill slopes, the material has been temporarily impounded behind obstacles such as large boulders and trees to form terracettes. Evidence of hill creep can also be seen in inspection trenches which often show distortion of upper weathered rock layers indicating down-slope movement.

Most debris slides in South Australia appear to be stable unless disturbed by human activities such as changing land use or civil engineering works. The alignment of a dam near Adelaide had to be changed after slide debris began to move as a result of earthmoving operations and diversion of a stream to the toe of the slope. Every year in the hills around Adelaide many small debris slides are reported along road cuts during the heavier winter rain storms. In most cases permanent slope stabilisation would prove too expensive and the material is merely removed. One recent slide however required extensive treatment: In this case hillside colluvium began to move after wetting caused by the combined effect of a leaking culvert and rising reservoir water at the toe of the slope. A seismic refraction survey showed several metres thickness of debris which was subsequently removed, replaced with rock fill, and the road section completely rebuilt. Examination of these debris slides shows that the bedrock surface forms the main sliding plane, particularly when lubricated by perched groundwater. Many of them occur on south west facing slopes - the direction of prevailing winter winds.

## 2.2 Earth Flows

These differ from debris slides in that failure takes place within a thick body of unconsolidated sediments (soils) and is accompanied by rotational movement. Failure depends on the strength and degree of saturation of the sediments and can occur rapidly and spontaneously without the agency of civil engineering works. Nevertheless these earthflows so far recognised in South Australia are believed to have been caused indirectly by man's activities (Twidale, 1976).

They occur mainly on Fleurieu Peninsula (Fig. 1) where Permian sand and clay occurs to a considerable thickness within buried valleys which frequently bear no relationship to the modern topography. They have been studied by Van Deur (1978) who located 33 earthflows on slopes ranging from 8 to 20° in an area of approximately 100 km<sup>2</sup> south of Yankalilla (Fig. 3). All of these slides apparently formed after European settlement but there has been a time lag between occupation and the majority of mass movements. This was acquired by slow physical and chemical changes in the soil, brought about by deforestation and a rising saline water table, gradually reducing its shear strength. The mechanism causing failure is not clearly understood but is no doubt related to rainfall and possibly, seismic activity.

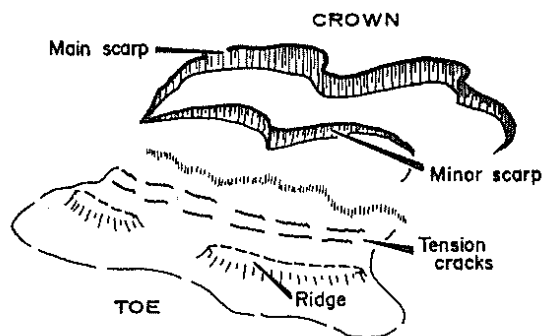


FIG. 3 Typical earthflow in Yankalilla area

## 2.3 The Adelaide area

A large number of cuts and excavations are opened up every year in Metropolitan Adelaide, chiefly in soil materials. The stiff to hard Pleistocene clay which underlies the City of Adelaide stands up well for short periods in dry conditions and a 10 m high unsupported face was described by Cox (1970) as being stable for three months on a 45° batter. However, the effects of drying out make the material treacherous as it breaks up into coarse lumps which can collapse suddenly. A mantle of low density calcareous silt of wind blown origin (loess) is distributed as a shallow layer up to several metres thick over much of the Adelaide Region. When dry this material will stand vertically but collapses quickly when wetted.

Problems with saturated alluvium frequently occur on the outwash fans which underlie the eastern part of metropolitan Adelaide. On the coast 3-4 m deep dewatered sewer trenches have stood vertically without support in the silt, sand, and soft clay of the coastal estuarine deposits.

## 3 MASS MOVEMENT OF ROCK

The Flinders and Mt Lofty Ranges consist largely of well bedded and jointed sedimentary rocks which have been extensively folded and faulted. Alternating beds of quartzite, dolomite and shaly siltstone provide a wide range of materials of differing strengths and resistance to weathering. Mass movements in these materials may be divided into three types:

### 3.1 Rotational Slumping

Large masses of slumped rock material have been reported near Oodnadatta by Heath (1963). These can be up to 400 m long with an approximate volume of 3/4 million cubic metres. They occur in shales which form a steep escarpment 60 m high, and are the result of rotational movement caused by water saturation of joints and partings (Fig. 4). In each case the shale block is capped by a solid mass of duricrust which has protected the material from severe distortion and mechanical breakdown during slumping, so that the shale appears to dip steeply into the face of the escarpment. Similar features have been recognised from the Tent Hill area west of Port Augusta by Thomson (1965). Here large masses of quartzite, up to 150 m long, have slumped and travelled laterally on an underlying weaker shale formation (Fig. 5).

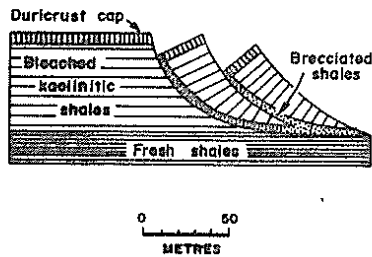


FIG. 4 Large scale rotational slumping near Oodnadatta.

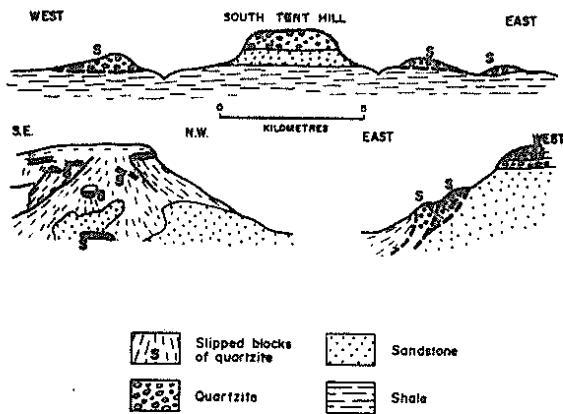


FIG. 5 Rotational slumping of Quartzite

The rock types described above are common in South Australia and, although these are the only cases so far documented, it is likely that other naturally occurring landslides of this type exist, possibly covered by scree debris, elsewhere in the Adelaide Hills and Flinders Ranges.

An example of incipient rotational slumping in shales underlying a coal seam occurred at Leigh Creek Coalfield and has been described by Townsend (1978). Removal of 50 m of overburden and the coal seam caused upward buckling of the underlying shales as a result of hydrostatic pressures and the weight of overburden dumps placed on the edge of the open cut (Fig. 6).

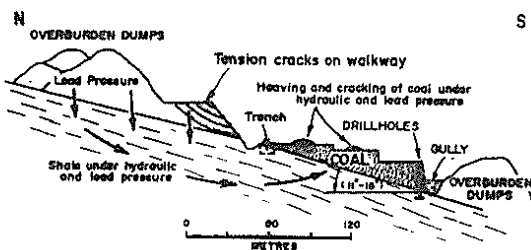


FIG. 6 Slope failure at Leigh Creek Coalfield

Remedial measures consisted of relieving hydraulic pressures in the shales by construction of a trench and a line of pressure relief wells at the toe of the slope.

### 3.2 Rockslides

A large number of rockslides caused by man's activities have occurred within the bedded rocks which form most of the hill country in South Australia. One of the most spectacular happened in 1974 at a dolomite quarry near Adelaide. A massive rockslide covering the whole of one face took place along a wedge failure direction formed by the intersection of the rock cleavage and a major joint set (Hazeldine, 1975). This slide happened over a period of days during a time of heavy winter rainfall and was due to excessively steep batter slopes which caused the wedge failure to daylight out of the quarry face. Remedial measures consisted of removing and regrading the entire face.

Another major rock slide occurred at an open cut iron ore mine on the Eyre Peninsula over a period of 11 days. Movement took place along a syncline whose axis plunged out of the face. It appears to have been initiated when a passive wedge of rock supporting the toe was broken by blasting.

An unusual rock slide having no direct cause has been reported from the Lochiel area by Twidale (1976). It took place on the sides of gently sloping hill (slope 16-21°) in 1974 after a period of heavy winter rain. Movement occurred within a quartzite formation dipping at the same angle and direction as the slope, possibly as a result of lubrication of thin clay seams within the quartzite by percolating rainfall. A detailed map of the slide, which involved about ½ million tonnes of rock, is given in Fig. 7.

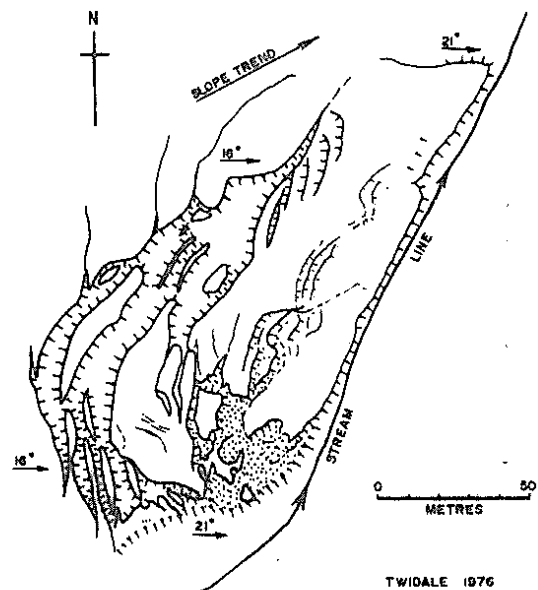


FIG. 7 Sketch map of the Lochiel Landslip.

Numerous examples of block and wedge rock slides are provided by road cuts in the Adelaide Hills. The Sellicks Hill road is probably the most spectacular of these where small movements are still occurring many years after construction. Other examples are given by Weber (1978).

### 3.3 Stability of valley sides

Site investigations for dam sites in the Mt Lofty Ranges have revealed that the valley sites can be potentially very unstable. The presence of sheet joints running parallel to the topography when combined with bedding or joint planes can cause large potentially unstable blocks which may not be revealed until site work has commenced (Fig. 8). It was the recognition of these features that caused a change in the design of Kangaroo Creek Dam from a concrete arch to a decked rockfill structure (Trudinger, 1973). During the investigations for Clarendon Dam in 1971 a 300 m long adit was constructed to evaluate the stability of a suspect abutment. Open sheet joints were also encountered in the abutments of Little Para Dam and these required careful evaluation and the installation of special drainage holes.

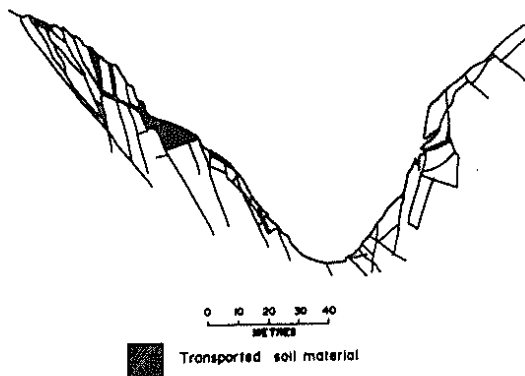


FIG. 8 Mechanical weathering of valley sides at Kangaroo Creek Dam.

## 4 CONCLUSIONS

Evaluation of potential slope instability is an important requirement of site investigations in South Australia. Even with careful investigation techniques, landslide situations may not become apparent until site works have commenced and it is important to cultivate a flexible approach to civil engineering construction.

## 5 REFERENCES

- BERKMAN, D.A. (1976). Field geologists' Manual. Monograph 9, Austral. Inst. Min. Metall, Melbourne.
- BOLT, B.A. and others (1978). Geological Hazards. Springer-Verlag.
- COX, J.B. (1970). A Review of the geotechnical characteristics of the Soils in the Adelaide City area. Proc. Symp. Soils and Earth Structures in Arid climates, Adelaide. Inst. Engineering Aust.
- HAZELDINE, R.K. (1975). The rock slope stability of the Riverview and Montacute aggregate Quarries S. Aust. Inst. Technology, School of Applied Geology, Grad. Dip. Thesis (unpublished).
- HEATH, G.R. (1963). Large Scale slump structures south-east of Oodnadatta. Q. geol. Notes, geol. Surv. S. Aust., 7.
- STEWART SHARPE, C.F. (1938). Landslides and Related Phenomena. Cooper Square Publishers Inc. New York.
- THOMSON, B.P. (1965). Erosional features of the Tent Hill Formation. Q. geol. Notes, geol. Surv. S. Aust., 13.
- TOWNSEND, I.J. (1978). Failure in overburden and coal, lode D, Leigh Creek. Q. geol. Notes, geol. Surv. S. Aust., 67.
- TRUDINGER, J.P. (1973). Engineering Geology of the Kangaroo Creek Dam. Geol. Surv. S. Aust. Bull. 44.
- TWIDALE, C.R. (1968). Geomorphology. Nelson, Melbourne.
- TWIDALE, C.R. (1976). The origin of recently initiated exogenetic landforms, South Australia. Env. Geol. 1.
- VAN DEUR, W.J. (1978). Earthflows in the Yankalilla area of South Australia. Trans. Roy. Soc. S. Aust. 102(6).
- WEBER, B. (1978). Land Instability in the Adelaide Metropolitan area, 1978: Two case histories. Geol. Surv. S. Aust. Rpt. 78/128 (unpublished).
- WILLIAMS, M. (1974). The Making of the South Australian Landscape. Academic Press.