

Cryptic Landslides

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SUMMARY The existence of a sub-group of landslides, dating from periods of low sea level and preserved today under a covering of either water or alluvium, is postulated. Examples of these cryptic landslides are given, together with some mention of their significance to civil engineering.

1 INTRODUCTION

The phenomenon of reactivation of Pleistocene landslides in terrestrial environments is well documented. Because of erosion, evidence of coastal landslips dating from the Pleistocene, in particular from periods of low sea level, is less available. Nonetheless, indications of past instability can sometimes be inferred today from retrogressive movements.

In the terrestrial environment, fossil landslip structures are now usually recognised in reconnaissance. Where these structures are preserved or partially preserved beneath water or recent sediments, they pose a problem of subterranean weakness of possible significance to civil engineering.

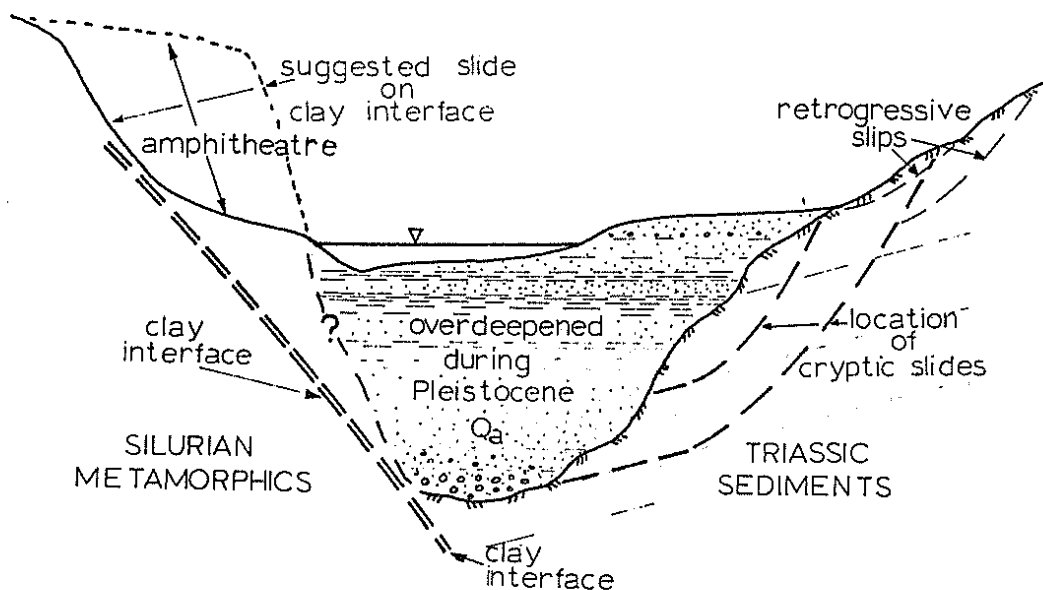
This paper is concerned with circumstantial and quantitative evidence pointing to the preservation of such cryptic structures, and with the environments in which they can be expected to occur.

2 GEOLOGICAL SETTING

The full sequence of sea level fluctuations throughout the Pleistocene has not been established in detail, but a number of sea level changes are known to have taken place, with the present level being possibly a relatively constant maximum (\pm a few metres) to which the sea has intermittently returned. The most recent low, -100m. approx., occurred around 25,000 to 20,000 yrs bp, and was followed by a fairly rapid rise back towards the present level which was attained perhaps in the last few thousand years.

Enormous fluvial downcutting during the sea level lows can be inferred today, at least in tectonically stable regions, from the overdeepening of stream beds, e.g., the Brisbane River. Such overdeepening must have been accompanied by considerable landslip activity.

Subsequent sea level rises, in addition to reworking the Shelf sediments, would have



1. Brisbane River : typical overdeepened section considered conducive to past landslides

eroded the recently dissected shorelines, providing an environment for further landslide activity. Finally, fluvial and estuarine sedimentation associated with the rises would have progressively stabilised and covered many of the slide zones then extant.

Examples are given to illustrate these points.

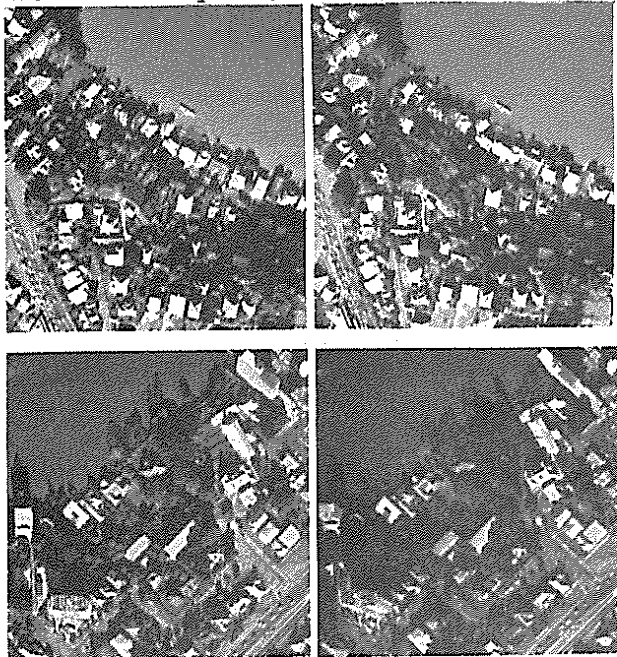
3 FLUVIATILE ENVIRONMENT

3.1 Brisbane River

The lower reaches of the Brisbane River contain some 30m. of recent bed sediments, Fig.1. The region is tectonically stable and if the present land surfaces are taken to be only slightly degraded versions of the pre-Pleistocene topography, then at the time of maximum downcutting the banks on either side of the river would have stood thirty or more metres higher than at present. Drawdown conditions after recent floods showed that these present banks are only quasi-stable in many places. It is therefore reasonable to assume that landslide activity along the higher banks, at the time of maximum downcutting, was fairly common.

The problem today is to delineate not only those zones where late Pleistocene slides might have occurred, but also where these slides might be preserved.

A special geological association occurs in the area and this was highlighted by a small slide (1970) which disrupted excavations for a road underpass in the city. The slide took place on the dipping junction of a Triassic sedimentary series unconformably overlying Silurian metamorphics. Both the formations are of moderately hard rock, but flexural slip during folding had produced clay seams and mylonites along the interface, with very low, near residual



2. Stereo views of two "amphi-theatres"

strengths, James (1971).

As for the road cutting today, so for the river in the past. In virtually all locations where the river intersects this dipping interface between these two strata, large amphi-theatre like depressions, with a microtopography suggestive of old slides, occur in the banks. Stereo air photos of two such features are shown in Fig.2.

The mechanism of failure may be inferred from Fig.1: the slides occurred around the time of maximum downcutting by the river and they owe their present stability to resedimentation.

It should be pointed out that no drilling to confirm or disprove the above proposition has been undertaken. Quantitative data is, however, available from the Canonvale site.

3.2 Canonvale Site

In 1973, the writer inspected a small seaboard site at Canonvale, N.Qld, proposed for development. The site contained a small conical hill of meta-volcanics, with side slopes that flattened out towards the base. No evidence of instability was noted on the steep elevated slopes. However, along the moderate and gentle colluvial slopes at the base of the hill, (11° to 12°) there were indications of down slope movements. The low relief, hummocky topography might be seen on the stereo view, Fig.3. The unusual factor here was that this "unstable" zone abutted against, and even appeared to continue beneath, the alluvial flats which were themselves at around high Spring tide level.

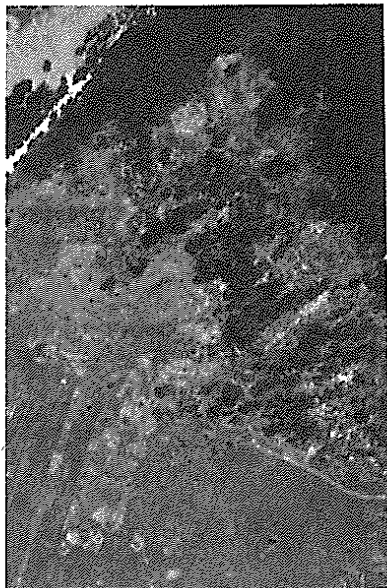
A number of trial pits were excavated. Those in the hummocky ground revealed shearing both in the colluvium and in the weathered rock, to depths of 2m. The orientation of the shearing confirmed the surface impression that the unstable zones continued below the level of the flat alluvium.

Undisturbed block samples of the shear zones and the intact colluvium were taken and tested under drained conditions in the shear box. In the shear zones a value of $\phi' = 13^\circ$ was obtained on first shear. Repeated shear tests gave $\phi' = 12^\circ$. Tests on the ambient clay gave a peak value of $\phi' = 20^\circ$. Thus, considerable movement along the shear zones is indicated.

Landsliding which continues below a flat ground surface requires some explanation. The implication here is that the instability must have been initiated prior to the existence of the alluvium, i.e., on an old land profile associated with a period of low sea level.

The existence of cryptic land-

sliding at this site was deduced from the retrogressive movements up-slope. It is, however, possible to conceive of situations where past landslip activity could be completely covered by Holocene alluvium or by water. Traditional site investigation methods would be fortunate indeed to pick up any evidence of such a situation, and while the existence of such cryptic structures might have little or no effect on small scale developments, the same could not be guaranteed in the case of large projects involving dams, bridge foundations, land reclamation schemes, etc.



4.1 Folkestone-Warren

The Folkestone Warren slips have been comprehensively investigated, most recently by Hutchinson, (1969). The oldest slips, still manifest, have been dated around 2,500 to 5,500 yrs bp, the earlier date corresponding to a sea level perhaps 7m. below the present.

The slips have occurred in the Gault Clay layer which divides the overlying Chalk from the underlying Lower Greensands.

There is a small component of dip of these strata towards the east, about 1 in 100, and if conditions were taken back say 10,000 yr it is possible to conceive similar landslip activity in the Gault, occurring at a lower elevation, well to the east of the present site.

Thus, the slips at Folkestone-Warren could be merely the final stages of a much larger zone of instability from a time of lower sea level.

The extent to which shear zones in the Gault - or, for that matter, large masses of slide debris in the Chalk - might be preserved is, of course, highly conjectural.

3. Stereo view of Canonvale site showing hummocky topography abutting against alluvium

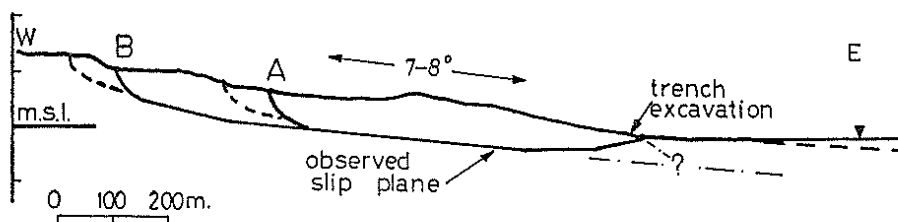
4 MARINE ENVIRONMENT

In the marine environment, more complex processes are involved, as already briefly outlined. In certain sheltered environments, however, submarine features such as old river channels associated with low sea levels can be recognised in the submarine contours, today. Where these exist, the possibility of cryptic shear zones can not be fully discounted. A slight reinterpretation of two well known coastal slides is offered as a hypothetical model to suggest the presence of cryptic shear zones in the submarine environment.

4.2 Portuguese Bend, California, (1956)

The Portuguese Bend slide, Merriam (1960), occurred in the montmorillonitic Monterey Shales, after a relatively shallow trench was excavated along the toe area, near to the sea, Fig. 4. The slip was an obvious reactivation of an older slip, and the slip plane was recorded at several locations allowing, with surface evidence, an accurate plot. Merriam distinguished a lower slip (A) with a large associated retrogressive movement up slope (B).

If there is retrogression, the question arises as to its extent or, rather, as to its point of origin. If a slightly



4. Portuguese Bend slide (1956)

lower sea level than the present is invoked, it is plausible to suggest that landslipping could have begun further down-slope than the present slip. In other words, the 1956 slip might not be merely the reactivation of a fossil slip of similar dimensions, but rather a recent manifestation of a retrogression originating somewhere out to sea.

5 CONCLUSIONS

In the past decade, there have been numerous instances where (terrestrial) slides have occurred in blatant contradiction to soil mechanics principles. The idea of Progressive Failure was put forward as an explanation in clays and clay shales. It is the writer's experience, however, that in the vast majority of cases the cause of failure could be attributed, not so much to true Progressive Failure, but to the presence of pre-existing shear planes in the ground. It is possible, then, that work in the future might also show a similar pattern for some unexpected submarine slides.

In this paper, largely circumstantial evidence has been proposed to show how late Pleistocene slip surfaces might be preserved under present day water or alluvium. Sufficient conditions for the development and preservation of these buried shear zones are: tectonically stable, fluvial environments which have been subject to overdeepening during periods of low sea level; associated landsliding along the banks; subsequent stabilisation of the areas by water level rises and resedimentation.

Recognition of the conditions favouring the development of cryptic shear zones could be important for large scale civil engineering works. In many cases, surface indications, such as retrogressive slides, could be diagnostic, but this need not always be the case. For this reason, it is the writer's contention that any steep, subterranean, erosion features should be investigated with some care.

The probability of preservation of cryptic shear structures in the marine environment is low. Yet many stretches of the present day coastlines are the result of the "dynamic" erosion forces of the changing sea levels of the Pleistocene; certainly these sea level changes have caused much reworking of the sediments of the Continental Shelf. Under certain conditions, some preservation of slip structures is possible. In the location of submarine tunnels, pipeline routes, in the design of land reclamation schemes, consideration could profitably be given to the historical evolution of the present day submarine contours, in relation to the geology.

6 REFERENCES

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