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THE EFFECT OF SOME ENVIRONMENTAL FACTORS ON RAPID MASS MOVEMENT IN THE HUNUA RANGES NEW ZEALAND

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Abstract

This paper describes some of the relationships between rapid mass movement and environmental factors in the Hunua Ranges.

Extreme climatic events appear to be important in triggering mass movement, while vegetation has a marked effect on mass movement processes and resulting landforms. The main effects of lithology and soils are connected with their influence on site conditions of mass movement. Drainage basin morphometry is affected by the addition of channels produced by mass movement.

INTRODUCTION

The mass movement features considered in this paper are similar to those described by Selby (1967a) and have already been discussed in relation to forest and grass vegetation (Pain, 1968b; in prep.). They are generally small, the mean slope length of a sample of 50 features being 40 metres, and width 15 metres. The types of mass movement and their frequency are given in Table 1, while Figure 1 illustrates their occurrence on a north-west facing slope.

The environmental factors which receive most attention here are lithology and soils. Vegetation and climate in relation to mass movement have been discussed elsewhere (Pain, 1968c; in prep.) and, together with drainage basin morphometry, will be considered only briefly in this paper.

Vegetation has a distinct influence on the type and frequency of rapid mass movement (Pain, 1968b; in prep.). Under forest the whole soil mass becomes saturated, and flowage usually results. Under grass, however, the A horizon of the soil remains coherent except where it cracks vertically, so that when slope failure occurs, the A horizon slides on a wet shearplane, and the deposits are in the form of a number of coherent blocks, or rafts, of soil A horizon material. Rapid mass movement occurs more frequently per unit area under grass than under forest.

Table 1. Mass movement types in the Hunua ranges.

Mass movement type*	Frequency (N = 50)
Block slump	5
Block slide	2
Debris slide	5
Debris avalanche	23
Debris flow	2
Earth flow	13
Total	50

* Modified Varnes (1958) classification. See Pain, 1968b, pp. 50-56.

Figure 1. Mass movement on steep hillslopes in the Hunua Ranges (G. R. Ponui 703415). On the right deposition in the channel has taken place, while on the left a mass movement scar is being gullied.

CLIMATE

The main feature of the climate of the Hunua Ranges affecting mass movement is the occurrence of high-intensity rainstorms of tropical cyclonic origin during late summer (de Lisle, 1967; Sparrow, 1968).

Sparrow notes that intense rainfalls which are associated with severe depressions of extra-tropical origin or stationary fronts also affect mass movement. During these climatic extremes, long periods of intense rainfall (26 mm per hour for 8 hours on 28 February, 1966) and high winds (up to Beaufort force 9) produce considerable numbers of mass movement features. A study of rainfall data prior to storms producing mass movement revealed no significant correlations between prior rainfall and mass movement occurrence during a given storm (Pain, 1968c). It appears that these climatic extremes trigger most of the mass movement which at present occurs in the Hunua Ranges, as Selby (1967b) concluded from similar studies in the Waikato Basin.

GEOLOGY AND LITHOLOGY

The Hunua Ranges are an uplifted block of finely bedded, indurated Jurassic siltstones and sandstones (greywacke), bounded on the west by the Wairou Fault and on the east by the Firth of Thames Fault (Schofield, 1967). To the south the Mangatangi Fault divides the Ranges from the lowlands of the lower Waikato Basin, while to the north, the Ranges border the coast and Tamaki Strait. In the headwaters of Cossey's Creek and Aro Aro Stream (Figure 2) there are local areas of Tertiary siltstones overlying the greywacke. The main streams flow in a generally radial pattern from Kohukohunui, the highest point in the Ranges (688 metres, 2256 ft.).

There are areas of Late Quaternary depositional material derived almost exclusively from greywacke. Most of the Ranges have been covered with volcanic ash from an unknown source, and the finer fractions of colluvial and alluvial deposits may be partly derived from this ash. The oldest depositional surface in the Upper Orere Catchment has ash lying conformably on both alluvial and lacustrine deposits. These ash beds have not yet been correlated with any of the known beds in South Auckland, and no age can be assigned to them. Ash also overlies depositional material near the coast, but no ash was found on any of the 6 depositional surfaces in the lower Orere Valley discussed by

Pain (1968a). Apart from one mass movement feature in the headwaters of the Mangatangi River, no ash has been found associated with mass movement scars.

Weathering of the greywacke is extremely variable. Mass movement scars reveal all degrees of weathering from unweathered rock to strongly red weathered material. The greywacke first weathers to a yellow-brown material (10 YR 5/8 in the Munsell notation) and with more intense weathering, it becomes red in colour (2.5 YR 5/6). On the origin of red weathering, Te Punga (1964, p. 314) states: 'It is tentatively assumed that the red weathering of silicates requires a tropical or subtropical climate with a mean annual temperature over 60 degrees (and a hot dry season) and over 40 inches of annual rainfall.' Te Punga considers the Wellington beds to be relict from the Mindel-Riss or Riss-Würm interglacial. Selby (1967a) assumed that the South Auckland red beds are of the same age, and the present writer can find no evidence to either support or reject this assumption.

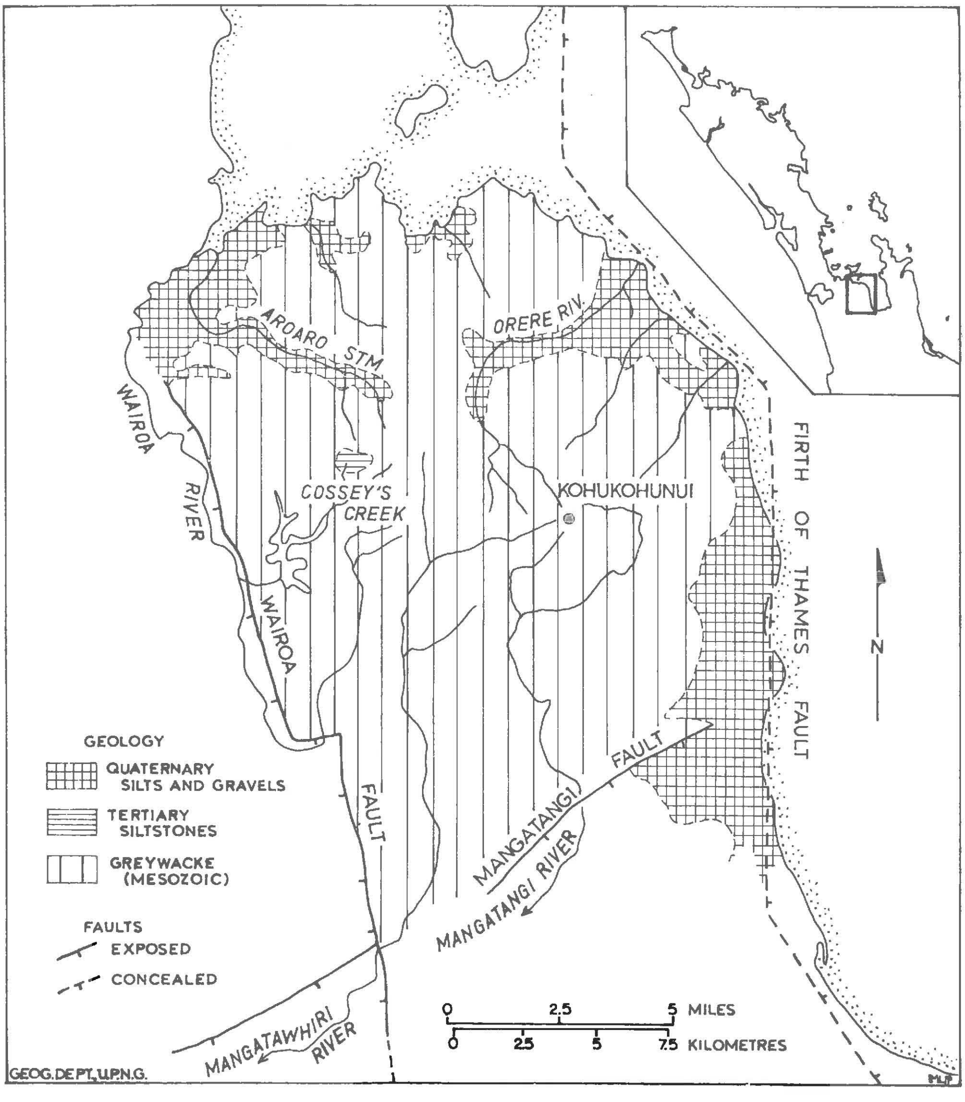

Figure 2. Location and geology of the Hunua Ranges (after Schofield, 1967).

Much of the red weathered material which covered the greywacke hills south of Auckland has been removed by slumping (see Selby, 1966; 1967a). Selby contends that where the red material is sufficiently thick deep-seated slumping occurred and largely removed it from the interfluves and valley sides. Removal of the red weathered material has also occurred in the Hunua Ranges. Little red weathered material is left on the interfluves or valley sides, whereas it is up to 12 metres thick on rolling hills north of the Hunua Ranges. As well as this presumed loss of red beds, some of the steeper slopes have also lost the yellow-brown weathered material which occurs below the red beds. This leads to a complicated areal variation in weathering type over the Ranges.

There are other important differences in the weathered material. Unweathered greywacke has an uneven distribution of jointed and massive rock. In some places joint lines persist right through to the red weathered material, while in others the weathered rock is massive. Dark coloured material is found in the joint lines of strongly weathered greywacke, the main constituent being manganese.

Variations in mass movement form which can be related to weathering type are mainly the result of these joints, which act as planes for subsurface water movement. Joints have more effect in yellow weathered greywacke than in the more strongly weathered red material. Fourteen of the 50 mass movement features occurred in yellow weathered greywacke, and 11 of the 14 had shearplanes coincident with joint planes, compared with 14 of the 36 which occurred in red material. These observations suggest that red weathered greywacke is more prone to slope failure than the less strongly weathered yellow material, and this was supported by reconnaissance surveys throughout the Hunua Ranges.

SOILS

Soils in the Hunua Ranges have been described by the N.Z. Soil Bureau (1954), Pohlen (1965) and in more detail by Johns (1967). The two main soils considered here are Te Ranga clay and stoney loams (skeletal soils of the steep hillslopes) and Marua clay loams (semi-mature podzolic and associated hill soils). Both soils are members of the Marua suite, developed on greywacke.

Numerous profiles of each member were studied at the headwalls and side-walls of mass movement features. In this way the relationships between the soil profile and mass movement form could be observed.

Soil profiles for Te Ranga clay and stoney loams are often truncated by soil creep or mass movement. These soils are commonly found on the steeper slopes of the Hunua Ranges. A modal profile is:

A_1	4 inches	10YR 4/4; friable; gravelly clay; moderate nut structure; some weathered greywacke fragments. Diffuse boundary.
A/C	2 inches	10YR 5/6; weak nut structure; friable to firm; weathered greywacke fragments common. Diffuse boundary.
C	36+ inches	10YR 5/8; gritty and stoney clay; firm and compacted; large amounts of partially weathered greywacke.

Poorly developed Te Ranga profiles show a very shallow A_1 horizon, and a massive, compacted A/C horizon. On the other hand, Te Ranga soils which are well developed show the development of coarse blocky structures at the base of the A/C horizon.

Marua clay loams commonly occur on lower valley slopes, and on areas of low hills in wider valleys. They were also noted on some of the wider crests in areas of predominantly Te Ranga soils. A modal profile is:

A_1	8 inches	10YR 3/4; silty clay loam; fine to medium nut structure; friable. Diffuse boundary.
A_2	4 inches	10YR 4/4; silty clay; faint brown and yellow mottles; coarse nut structure; hard. Sharp boundary.
B_t	14 inches	10YR 5/6; silty clay; coarse prismatic, some blocky structures; hard; prominant greying of structure faces by colloidal material. Sharp boundary.
C	22+ inches	10YR 6/6; clay; sticky; massive, or weak blocky structures.

A poorly developed Marua profile has markedly less development of both clay skins and structures. A well developed Marua profile shows the development of an incipient A_e horizon, and structures in the B_t horizon become very marked with thick clay skins.

Thus there is a sequence through from virtually structureless soils to soils with very marked structure. This pattern affects various form characteristics of mass movement features, because while some soils have no development of planes of weakness, others have marked planes of weakness.

Table 2. Relationship between soil type and position of shearplane in the soil profile.

Soil type	Position of shearplane: A	between A/B	B	between B/C	C	Total
Poorly developed Te Ranga	0	0	0	0	8	8
Well developed Te Ranga	0	0	1	2	2	5
Poorly developed Marua	0	0	2	7	8	17
Well developed Marua	0	1	2	11	3	17
Colluvial	0	0	0	0	3	3
Total	0	1	5	20	24	50

Table 2 shows the relationship between soil type and the position of the shearplane of a mass movement feature in the soil profile. The data are taken from the sample of 50 mass movement features in the Hunua Ranges. Some points should be noted.

1. In 21 cases the shearplane occurred at the boundary between soil horizons, and in all 21 cases these soils showed the development of structures. In fact soils with marked structure development showed a greater frequency of shearplane occurrence between horizons (e.g. well developed Marua — 12 out of 20).
2. No shearplanes were found in A horizons, and only 5 out of 50 in B horizons. On the other hand, 24 cases showed shearplane occurrence in C horizons. Of these 24 cases, it is interesting to note that only 3 occurred in well developed Marua soils, while 13 occurred in Te Ranga and colluvial soils.
3. The actual loss of soil should be noted. As the soil types become more mature, the tendency is for some of the soil profile to remain after mass movement. Thus while mass movement in Te Ranga soils tends to remove the solum entirely, only parts of the solum are removed in the better developed soils.
4. Thirty-four of the 50 mass movement features in the sample occurred in Marua soils. It is not known whether this is representative. It may have been a chance occurrence, or Marua soils may be more susceptible than Te Ranga soils.

These points suggest that the location of planes of weakness which develop as the soil profile develops may be important for rapid mass movement. A soil with well developed blocky or prismatic structures, and a sharp boundary between the B and C horizons may have inherent in its morphology a tendency for movement to occur along a plane of weakness. Water movement will also tend to occur more readily in well structured soil. A further point is that in the Marua soils clay tends to accumulate on structure faces so that a plane of weakness also becomes an area of clay accumulation. Since the main clays present in these soils are swelling clays (montmorillonite, interlayered hydrous micas, and metahaloysite, Fieldes 1957), the presence of these clays along a potential plane of weakness may be a contributing cause of mass movement.

DRAINAGE BASIN MORPHOMETRY

A map of the upper Orere catchment was prepared from aerial photographs to make available data for morphometric analysis. It was checked in the field and found satisfactory even under forest cover, where the canopy might have been expected to obscure smaller channels. A number of small channels were, however, added to the map after field study. The resulting map showed all channels which might be expected to carry surface water during prolonged and/or intense rainfall.

Selby (1967a) used air-photo mosaics to construct maps of channel networks, and reported that the smallest segments were found on fieldwork to be the scars of mass movement features. This was found to be the case in the upper Orere catchment, although every mass movement feature does not automatically become a channel segment. Mass movement features and other depressions which might have been termed channels were not added to the map unless there was a distinct junction of channels at their lower end (see Figure 1).

The channel network derived by the above method was divided into channel orders using Strahler's 1957 method. As Horton (1945) first pointed out, there is a simple geometric relationship between stream order and stream numbers, and this holds for the Orere catchment (Figure 3A). Figure 3B illustrates the

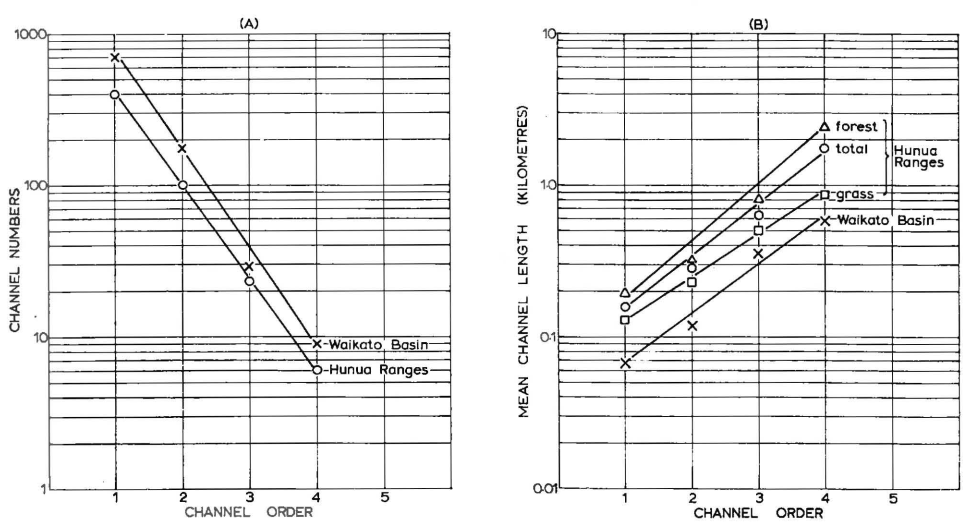

Figure 3. Plots of channel order against (A) channel numbers, (B) mean channel length. (Waikato Basin data from Selby 1967a.)

shortness of channel length in the Hunua Ranges. However, data from Selby (1967a) show that channels are even shorter in the Waikato Basin (Figure 3B).

Differences between forested and grassed areas are evident. Figure 3B shows that channels under grass tend to be shorter than those under forest. It appears that changes in the form of the land surface consequent on a change in vegetation have altered the order numbers in the grassed area so that channels that were originally order one have become order two. There has in fact been a stepping up of channel order numbers, with the provision of a new set of order one channels under grass.

CONCLUSIONS

Four main conclusions can be drawn from the results of the study of mass movement in the Hunua Ranges.

1. Climatic extremes are probably the most important trigger of mass movement in the Hunua Ranges, and moreover they result in the movement of a wave of sediment through the channel system.
2. Vegetation has an important influence on mass movement form and process in that it controls to a large extent the nature of water movement into and through the regolith.
3. Lithology and soils may be important in influencing the site conditions of individual mass movement features.
4. Drainage basin morphometry is influenced by the occurrence of mass movement which adds new order one channel segments to the channel network.

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