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THE ROCKFALLS OF JAMES VALLEY, ST HELENA.

A PRELIMINARY REPORT GIVING A SUMMARY OF RECOMMENDATIONS.

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The Rock Falls of James Valley, St Helena. A Preliminary Report giving a Summary of Recommendations

1. Introduction

This preliminary report lists the main findings of a reconnaisance survey carried out in March 1975 to determine the causes of rockfalls in James Valley, St Helena and to suggest possible means of reducing the risk of injury and damage caused by these falls.

Jamestown, the principal town of St Helena, lies in a deep, steep-sided valley on the north west side of the island. The valley sides rise to a height of 180 m. on the coast but the crest of the slope rises to in excess of 400 m. some 1.5 km. inland. The floor of the valley which is approximately 0.2 km. wide at the mouth of the valley rises from sea level to a height of 160 m. beneath High Knoll. The average slope angle is approximately 37° on the west (Ladder Hill) side of the valley and 36° on the east (Side Path) side.

2. Geology of St Helena and James Valley

Baker (1968 & 1970) following the work of Darwin, Daly and others found that there had been two main eruptive episodes, one centred in the N.W. and the other in the S.E. of the island. These were followed by a third, later eruptive phase, centred near the middle of the island. The main two eruptive phases of lavas and interbedded pyroclastics (including tuffs) were mainly from fissures now seen as the dyke swarms in the centre of both volcanoes

In James Valley rocks of the N.E. volcano are only exposed in an 'erosional window' in the bottom of the valley and on the eastern valley side above the hospital (see Figure 1). These rocks are nowhere involved in the rockfalls in the valley and can be distinguished from the later rocks elsewhere in the valley by their generally westerly dip of about 15°. They consist of the normal basaltic flows together with some pyroclastic material.

Most of the valley sides of the James Valley are composed of extrusives from the Main Shield phase of the S.W. volcano. Over seventy individual flows have been counted in the valley side near the hospital, most of which belong to the Main Shield. Pink, medium to course grained tuffs are found between the flows and are developed over a large area. It is sometimes possible to trace a tuff band from its outcrop in the sea cliffs right the way up James Valley. These tuff bands have a different permeability than that of the overlying flows and consequently are often the source of intermittent springs. However, it is now certain whether the primary permeability of the tuffs is less than the secondary (joint) permeability of the basalts. Consequently springs may be at the base or top of the usually thin (up to 1m) tuffs. Observation in the field, during a period of no rainfall, did not resolve this point.

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Following the main phases of activity there was late intrusive activity which resulted in the extrusion of five trachybasaltic flows from the region of High Knoll which cap the valley side between High Knoll and Ladder Hill.

3. Previous Rockfalls and Their Relation to Rainfall

No systematic records of the occurrence of rockfalls have been kept on St Helena by any of the Government Departments. However between 1860 and 1923 a number of weekly newspapers were produced and these contained some references to the rockfalls that took place between these years. Table 1 gives the date, location (where given), size, proceeding weather conditions and casualties for all falls recorded, and their locations are plotted on Figure 2.

Figure 3. shows a histogram of the number of rockfalls recorded as having occurred during each calendar month. This clearly shows that the vast majority of rockfalls have occurred during the seven month period from February to August. This part of the year is also the wettest time of year on St Helena. Figure 3. also shows average monthly rainfall plotted for Jamestown. This is taken from records for the period 1932 to 1973.

Clearly, there is a correlation between rainfall and rockfalls. Further study of the old newspapers showed that many of the falls recorded were preceded by periods of often heavy rainfall. This is further emphasised by the fact that the very recent fall on the wharf was apparently preceeded by a period of wet weather.

4. The Causes of Rockfalls

Observations of the valley sides showed that those parts of the hillside that had been the source of rockfalls in the past and which are in a dangerous condition at present often contain, within the succession, bands of pink tuff. As already mentioned in Section 2. these tuffs have a different permeability to the jointed basalt and consequently water seeps out at the base or the top of at least some of the tuffs during periods of rainfall. This water erodes the soft, weak tuffs and consequently undercuts the overlying basalts. As these basalts are cut by large numbers of high angle cooling joints the undercutting produces toppling of sometimes large but usually discrete blocks of basalt. In all parts of the hillside from which rockfalls have taken place tuffs have been observed within the succession though this does not mean, of course, that the cause of every fall is erosion of underlying tuffs.

In some cases the passage of water through the joints has eroded the rock away, widening joints and reducing frictional forces till ultimately blocks have toppled. However the joints are too open for pore water pressures to build up. It is for these reasons that rockfalls invariably follow periods of heavy rain and are less likely to occur during the dry months of the year.

5. The Location of Potential Future Rockfalls

The fieldwork together with the knowledge of the location of some old falls revealed that the majority of falls have been and are likely to be restricted to certain parts of the hillside (see Figure 4). On the east (Side Path) side of the valley falls are likely to originate in one of three areas, namely:

a) The crest of the valley side (that is approximately the upper 30 m. of the slope) between the navigation triangle (Marked as a 'tower' on the 1:10,000 map) and Mundens Point.

b) The upper part of the gulleys which are situated above Napoleon Street.

c) The whole of the valley side above the track to Ruperts Bay between the Botanical Gardens and Mundens Point (i.e. between the up-valley end of Sisters Walk and The Steps). This area continues upwards to area a).

On the west side of the valley areas are less clearly defined being more related to individual flows or small groups of flows. Two flow groups, in particular, stand out on the valley side and have been labelled L2 and L3. Flow group L2 runs from the seaward side of Jacobs Ladder as far as Pierie's Revenge which is part of the flow group and includes a number of precipitous, overhanging and dangerous crags including the locally wellknown 'Emily's Jump'.

Flow L3 occurs higher in the succession at a height of 160 m. seaward of Jacobs Ladder and rising to about 220 m. above Pierie's Revenge where it was the source of the terrible fall of 1890. This flow group also contains a number of potentially dangerous outcrops particularly seaward of Jacobs Ladder and in the vicinity of the 1890 fall.

Apart from these two flow groups the whole of the slope above flow L3 is a likely source of rockfalls. This is particularly true of the upper group of flows along the crest which are interbedded with pink tuff bands. One or two ancient fall locations were observed in this area and many rock and cement pillars have been built to support severly overhanging rocks. These uppermost flows are potential rockfall sources from the mouth of the valley as far as High Knoll (though observations were only made along the ridge top as far as the area known as Cowpath).

While the areas noted above and shown on Figure 4. have been the source of the vast majority of past rockfalls and are the potential source of most future falls, isolated crags do outcrop on other parts of the slopes. These too may produce falls of rocks but make up only a small percentage of the total area of hillside and were generally too small to be exactly located and observed in detail in the time available for fieldwork.

6. Possible Measures to Restrict Future Falls

Whatever course of action is decided upon to try to prevent rockfalls in James Valley it is unlikely that Jamestown will ever be completely free from the danger of falling rocks. The scale of the remedial measures undertaken and therefore their degree of effectiveness depends on how much money is available to carry out the work. If it is decided to embark on a major stabilisation programme it will be necessary to carry out a more detailed survey of those areas designated in Figure 4. and Section 5, to determine quantitatively the stability conditions of these rock faces.

This survey, which would include a full joint survey of the designated zones, would probably involve several man-months work and would be necessary to design the appropriate remedial measures to prevent further rockfalls. In some cases it is likely that rocks may be in such a dangerous condition that removal is the only solution. This in itself would be a tricky operation as great care would be needed to make sure no debris fell on the town below. However in the majority of cases rock bolting of large areas of the rock faces would probably be necessary. The purpose of rock bolts is to tie blocks of rock together into larger units which will be less likely to fail. To do this it is necessary to identify the "keystone" which, when removed produces progressive failure up the slope. On the valley sides of James Valley it seems that the tuff bands are effectively acting as "keystones". These are being rapidly eroded by percolating water and the rock above is consequently undercut so that eventually it fails by toppling. In those cases where the percolation of water is merely reducing the shear strength along joints rock bolting would probably be sufficient to secure a given face. However in the situation described above which is common to the slopes of James Valley rock bolting alone may not be sufficient as erosion of the basal tuff bands would still take place. In these cases it may be necessary to cover the exposure of tuff with gunite. This is a form of mortar consisting of fine-sand, cement and water which is sprayed on a face by air pressure. This will help prevent further erosion of the tuff. Drainage holes would have to be provided through the gunite to allow ground-water to escape. Gunite might also be used on those basalt faces that are breaking into smaller rock fragments too small for rock bolts to hold together.

In those cases where undercutting has already progressed some way, underpinning of the overhanging rock would be required. These pillars would have to be founded on an underlying basalt flow, not on soft weathered material as some of the pillars seen below Ladder Hill seem to have been founded. In addition, existing pillars will have to be rebuilt as a few of these have cracked, probably due to movement of their bases rather than failure due to loading. In those instances where none of these stabilisation methods could be used due to the instability of the rock, controlled removal of the blocks would be required. This may be achieved in some cases by either lowering a rock to the nearest road below or by lifting it to the valley top. However, it may be necessary to use explosives in other cases, as was apparently contemplated by the Royal Engineers in 1912. However the writer has no experience of the use of explosives for such purposes and advice would have to be sought elsewhere.

All these measures would require the importation of materials, equipment and trained personnel. The work would take many months and possibly years (depending on the size of the areas to be stabilised) to complete and consequently would be very expensive, costs running into tens of thousands of pounds and probably more, remembering the relative inaccessibility of St Helena.

It is possible, however, that other measures could be taken locally which, whilst being nowhere near as effective as the measures described above, may somewhat reduce the risk. These measures could fall into three parts. Firstly as much loose rock as possible should be removed from (initially) those areas designated in Figure 4. using local labour and equipment (and possibly some imported equipment if necessary) under the direction of the Chief Engineer. Secondly the construction of terraces across the hillside beneath the more dangerous crags may "catch" many of the small and medium sized rocks. It is noticeable that wherever paths have been constructed across the hillside on terraces they collect large amounts of rock pieces and boulders. This is particularly noticeable along those old paths that have now been abandoned, for example those seaward of Jacobs Ladder and the path to Mundens Hill that climbs the valley side above the

Botanical Gardens.

Where these paths run beneath the foot of a crag even quite large blocks are contained as they have failed to gain any degree of momentum having fallen only a few metres. Such terraces would be highly labour intensive in their construction but have the advantage of being built from local materials. They would probably be successful in containing small and medium size rocks but would not of course contain a massive fall on the scale of the 1890 disaster.

A third preventive measure would be the vegetating of those parts of the valley sides that at present have some degree of soil cover, using seeded mulches consisting of grass seed, fertilizer and liquid rubber or plastic which is sprayed onto the slope. The rubber binds the soil, seeds and fertilizer together until growth has become established. Such mulches have successfully been used in the United States of America in areas of very low rainfall. Such a measure would reduce the amount of erosion on the valley slopes and prevent further gulleying of the type seen above Napolean Street which is bound to lead to increased rockfalls as flows are undercut. Indeed it is said that James Valley in common with the rest of the island was once covered by vegetation, most of which was destroyed when goats were introduced by man in the 16th Century. The truth of this is not known but certainly now that goats are strictly controlled both in numbers and in the land they can graze the natural vegetation might gradually recover. Any assistance in this process would be beneficial in reducing erosion. The Agricultural Department on the Island or the Land Resources Division in UK may be able to advise further on this matter.

The planting of trees along the foot of the slopes has given some houses slightly increased protection from small rockfalls (the trees Mr Adams planted behind his house in Napolean Street prevented one rock from the

August 1974 fall from reaching his house) but the trees need much attention (watering etc.) if they are to grow to maturity and such effort would best be left to individual householders whose land backs onto the valley side.

One part of Jamestown requires special mention and possibly special measures in relation to rockfalls. That area is the Wharf which is vital to the whole island being the only harbour on the island and the place where all imports are brought ashore. Recently the Wharf suffered damage from a rockfall that almost certainly originated in the cliffs above the track to Ruperts Bay (the face immediately above the Wharf was 'cleaned' in 1890). If it was decided not to proceed with measures to secure the areas shown in Figure 4, the Wharf could be protected separately by the construction of a rock shelter over it, similar to those used in many countries to protect roads and railways in rockfall areas. Construction of such a shelter would no doubt be very expensive and would completely alter the character of the Wharf but would prevent the island's lifeline to the outside world suffering further damage.

Finally it was brought to the writer's notice that consideration was being given to a scheme to construct blocks of flats on flattish land near the hospital between the bottom of Ladder Hill road and the foot of the valley side. It is advised that no construction takes place and that the construction of houses or other buildings at the foot of the valley slopes is not permitted as such buildings would be in the "front line" of any rockfall. If a block of flats were involved the loss of life could be substantial.

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TABLE 1.

Details of Rockfalls Described in St Helena Newspapers between 1861 & 1923

DATE	LOCATION	SIZE	PRECEEDING WEATHER	DAMAGE
8 June 1861	Ladder Hill side, up valley from Pigott's Revenge.	5 tons		2 dead
14 May 1863	Top of hill, east side at about top of Napolean St.	2 tons, 3 cwt. 83 lbs, $107\frac{1}{2}$ lbs.		
21 June 1863	Side of hill opposite Botanical Gardens.	some rocks		child dead
25 June 1863	Hillsides in town,	Large rocks	Heavy rain	Barnes Rd not safe.
16 July 1863	Top of ridge east side.			Path broken down for many yards. 2 dead.
2 February 1865	Barnes Rd, Side Path & Ladder Hill Rds. Heaviest fall at Chubbs Spring.	small	Heavy rain	Took parts of road away.
16 February 1867	Under Ladder Hill Telegraph.	20-30 tons		Destroyed saw mill and steam engine.
2 July 1879	Above Rd east of Maldivia, overhanging road.	30 tons	Good down-pour of rain in preceeding week.	Blocked road.
12 May 1881	Ruperts side of valley.	200 tons		Trees stopped 2 tons of rock at Botanical Gardens.
24 April 1884	Summit of western hill opposite upper burial ground.	enormous mass.		Much damage.
8 November 1887	West side, above St. Johns R.C. Church.	1lb to 3 to 4 Cwt.		For 300 yds along line of New Road.

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DATE	LOCATION	SIZE	PRECEEDING WEATHER	DAMAGE
20 March 1890	Ruperts Hill into Napolean Street.		Heavy rain in preceeding weeks.	No damage.
27 March 1890	Near the Botanical Gardens.		Heavy rain in preceeding weeks.	Damage to Property.
17 April 1890	Behind & between High Rock & Pierie's Revenge, Ladder Hill side.	Fall: 108 ft long, 25 ft high, 11 ft thick. Rocks 9, 5-6 & 25 tons.	Very heavy rainfall; hardly a fine day; almost incessant rain.	9 dead and damage to many houses.
16 August 1890	Round Drummers Point near little water-fall.	40 tons		Blocked roads.
9 June 1892				
23 March 1894				
16 May 1912	Two falls above Maldivia two from east side of hill above Public Gardens.		$\frac{3}{4}$" heavy rain	Little damage.

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KEY

UPPER SHIELD	Trachyandesites
	Lower Basalts
MAIN SHIELD	Intermediate Parasitic Flows
	Parasitic Cones
	Basalts (and Trachybasalts)
NORTH EAST VOLCANO	Late Scoriaceous Extrusives
	Parasitic Intrusives
	Parasitic Pyroclastics
	Shield Forming Extrusives

Original Size of Cones

○	< 100m
⊙	100 - 200m
15	Estimated Height of Base (in metres)
N	North East Volcano

FIGURE 1 Geological Map of the Jamestown Area

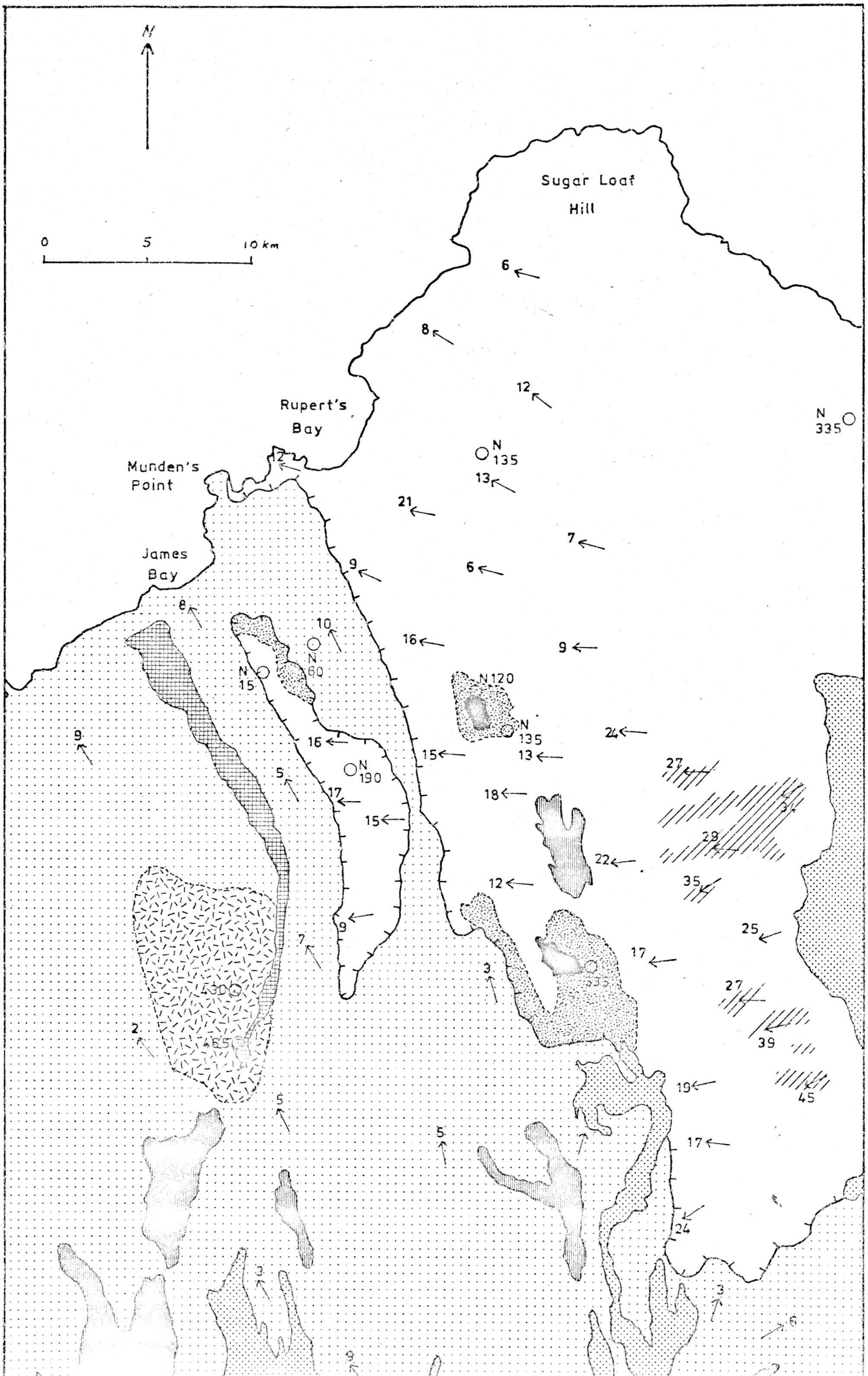
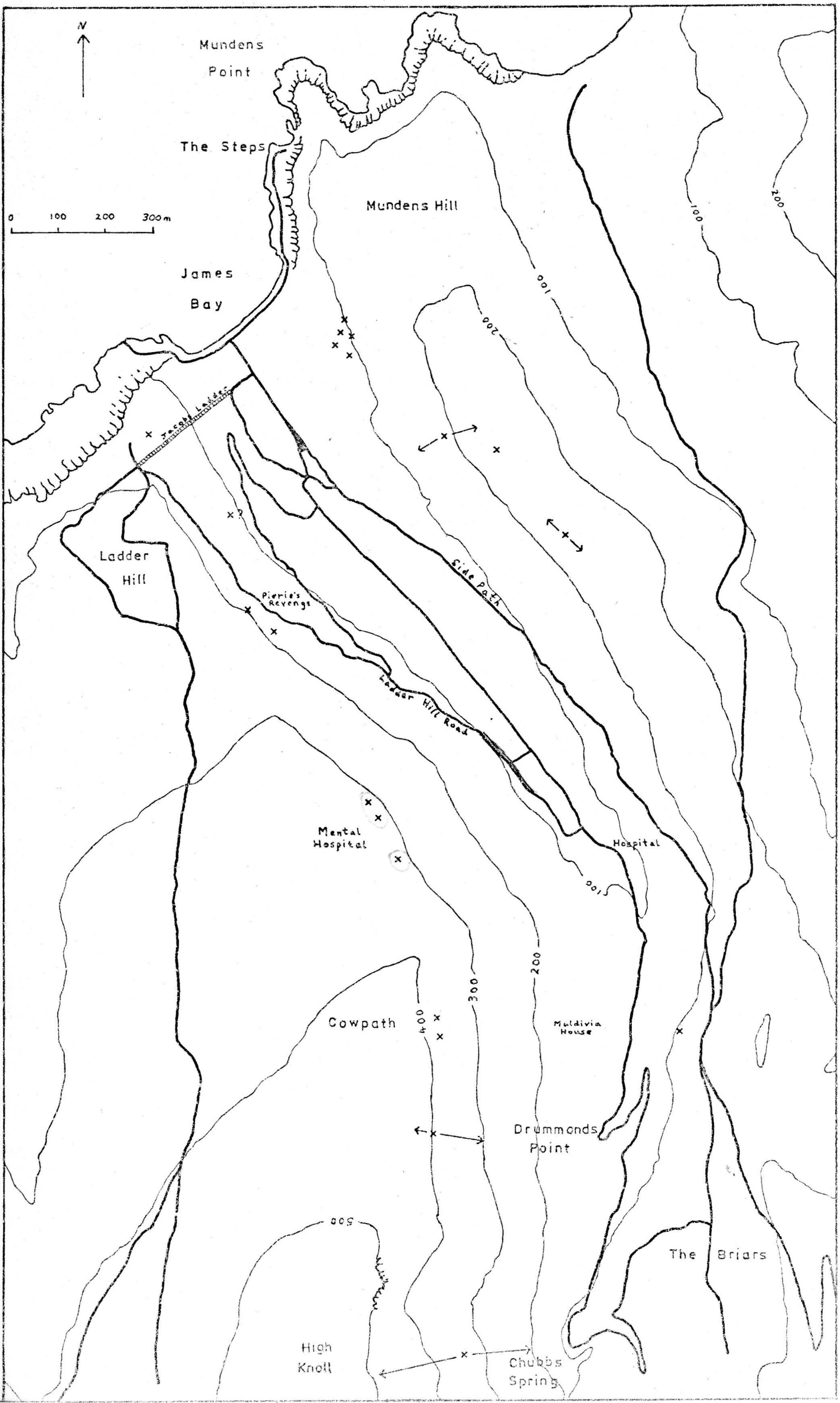

N
0
5
10 km
Sugar Loaf
Hill
Rupert's
Bay
Munden's
Point
James
Bay
N
335
N
135
N
60
N
15
N120
N
135
N
190

FIGURE 2 The Location of Recorded Rockfalls in James Valley



N
Mundens Point
The Steps
Mundens Hill
0 100 200 300m
James Bay
Jacobs Ladder
Ladder Hill
Pierie's Revenge
Side Path
Ladder Hill Road
Mental Hospital
Hospital
Cowpath
Muldivia House
Drummonds Point
The Briars
High Knoll
Chubbs Spring
100
200
300
400
500

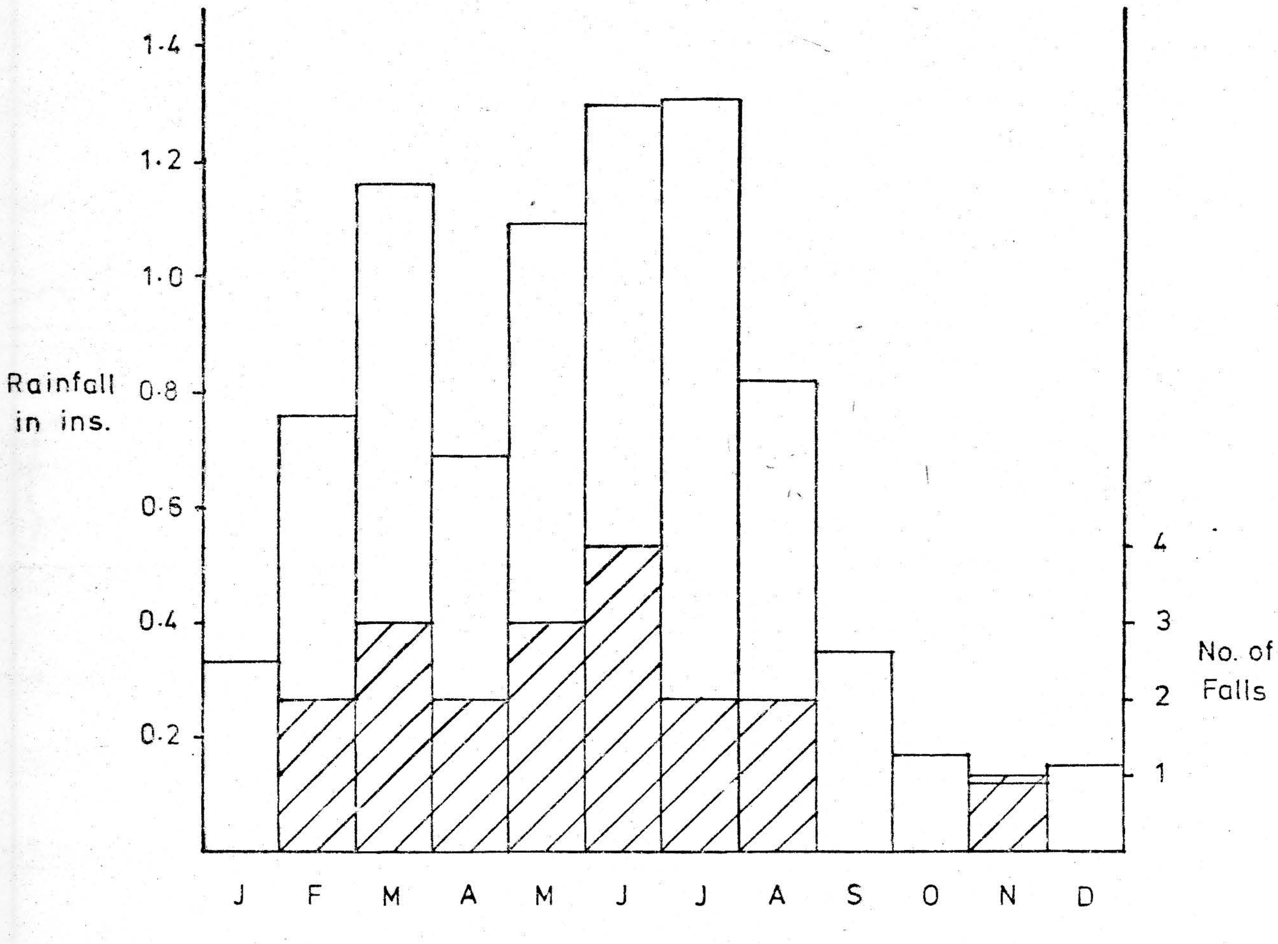


FIGURE 3 Histogram showing average monthly rainfall at Jamestown between 1932 and 1973 and monthly distribution of rockfalls between 1861 and 1923, and including the fall of August 1973.

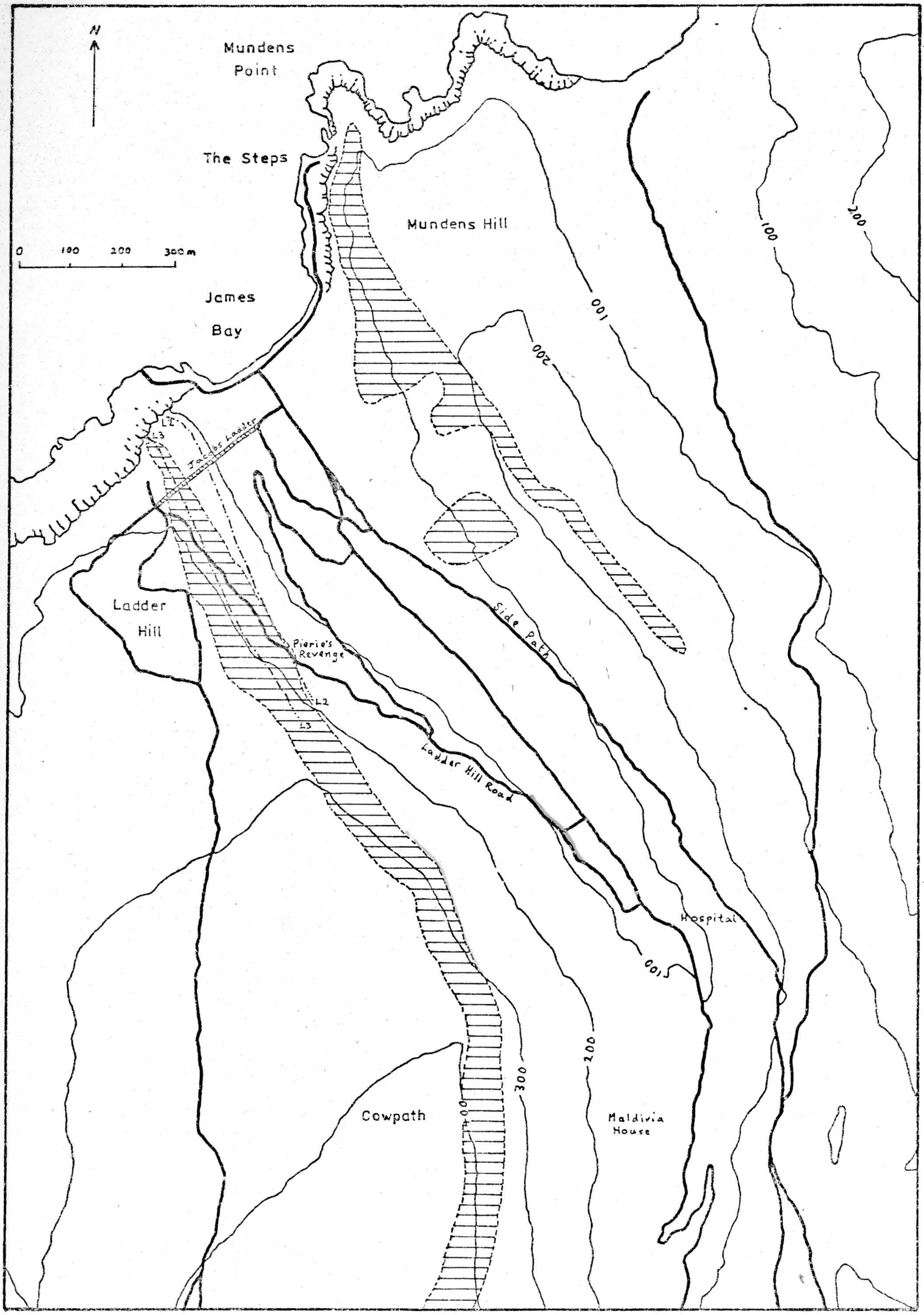


FIGURE 4 Map of James Valley showing areas of greatest potential instability and the outcrop of the northern end of flow groups L2 and L3.