ARTICLES AND NOTES

RICHARD CLARK*
Coleraine

FURTHER CONSIDERATION OF FALKLAND ISLANDS PERIGLACIAL LANDSCAPES

Abstract

The paper examines the relationships of deep chemical-weathering to recent landscape development, and the effects of varied lithological and structural controls upon landforms. Relationships between glacial and periglacial processes and forms are discussed, as are reasons for lateral variability in hillside debris movement. Alternative views of the kind of climate associated with the processes are noted and a drier climate is thought to have been more likely than a maritime periglacial climate otherwise proposed. The requirements for any model intended to analyse the history and forms in Falkland landscapes are clarified, and the importance of the history of episodic denudation is stressed.

INTRODUCTION

A recent commentary upon cold-climate landscape development (CLAPPERTON, 1975) and especially on the extensive 'stone runs' makes a number of points about the characteristics of Falkland Islands morphology which require additional consideration. Other observations in the same paper serve to reinforce conclusions already made in a previous discussion on Falkland landforms (CLARK, 1972).

CHEMICALLY WEATHERED REGOLITH

CLAPPERTON draws attention to the presence of chemically-degraded quartzites underlying solifluction debris in a (presumably) coastal cliff near Stanley in the east of East Falkland. He then suggests that the extensive stone runs resulted from the "mechanical disintegration of chemically fresh bedrock" but that the "presence of a regolith of fine particles derived from deeply rotted bedrock was probably of vital importance" to their movement. Following this, and in proposing a model for the development of Falkland upland relief, CLAPPERTON suggests as possible the occurrence of a Tertiary age complete mantle of chemically-deteriorated rock over Falkland uplands, that is, throughout their height range.

This interpretation may be sound, but it will need to accomodate certain points to which attention should be drawn. Firstly, the effect of lithological variety within the uplands is not included. Secondly, the evidence bearing on historical develop-

* Education Centre, New University of Ulster; Coleraine, Northern Ireland.

ment of the upland is not taken fully into account. Both these are returned to below. Thirdly, the evidence that a Tertiary chemically-weathered regolith influenced development of the present sheets of cold-climate solifluction debris itself requires examination.

In this context it is interesting to note that the only site of presently-exposed deteriorated quartzite referred to by CLAPPERTON is at sea-level. The only sites for such rock found by the present writer included two sites on the south shore of Stanley Harbour, west of Stanley, and sites on the coast at San Carlos Water in the west of East Falkland. Extensive examination of outcrops over the whole altitude range of the length of principal East Falkland uplands did not disclose other sites.

It may be argued that the present topography does not correspond to the earlier Tertiary form and that there is not a high probability of finding a Tertiary regolith on slopes severely modified in the Pleistocene. There is some force in this argument but, as described below, there are remnants of probably Tertiary erosion surfaces in the uplands and no chemically-changed rock was found on these. However it may be that the cold-climate debris mantle conceals older regolith away from sea-level, and it would be a long task to examine all quartzite outcrops. But it may be further observed that there is no certainty that the valleys where degraded rock was observed were reduced to their present depth in Tertiary time and it is thus not clear that the deterioration is of Tertiary age. The cover of debris and the percolation of acid ground water, as well as some exposure to salt spray are common to the known sites of changed quartzite. It would be necessary to rule out absolutely the possibility of recent chemical weathering of rock to strengthen the case for earlier weathering, and its necessity in Pleistocene landscape development.

Moreover, the hillside strata consist of interbedded shales and sandstones (many being dense quartzose sandstone generally called quartzite). The quartzite outcrops feed debris spreads both from ridge-top and valley-side positions. At many of the sites it may be inferred that the whole thickness of the quartzite unit is chemically-fresh. But as the intervening slopes are generally reduced (degraded) more than the quartzite outcrops, it is difficult to imagine that the postulated mantle survives under the cold-climate debris spreads between the quartzite and sandstone outcrops. Thus it is concluded that any involvement of chemically-changed regolith from *in situ* positions had ceased before the latest cold-climate episodes. Consequently it may be premature to describe angular crags as tors (CLAPPERTON, 1975, Fig. 1) if the term is intended to imply the contribution of deep chemical weathering and subsequent stripping of the resultant regolith to the present crag shapes.

RELATIONSHIPS OF STONE RUNS TO CORRIES AND GLACIATION

CLAPPERTON (1971) observed that hill ridges rising to summits over 600 m nourished corrie glaciers but an important ridge crest height appears to be 520 m. Corries are found on the flanks of uplands attaining this height where their widths and

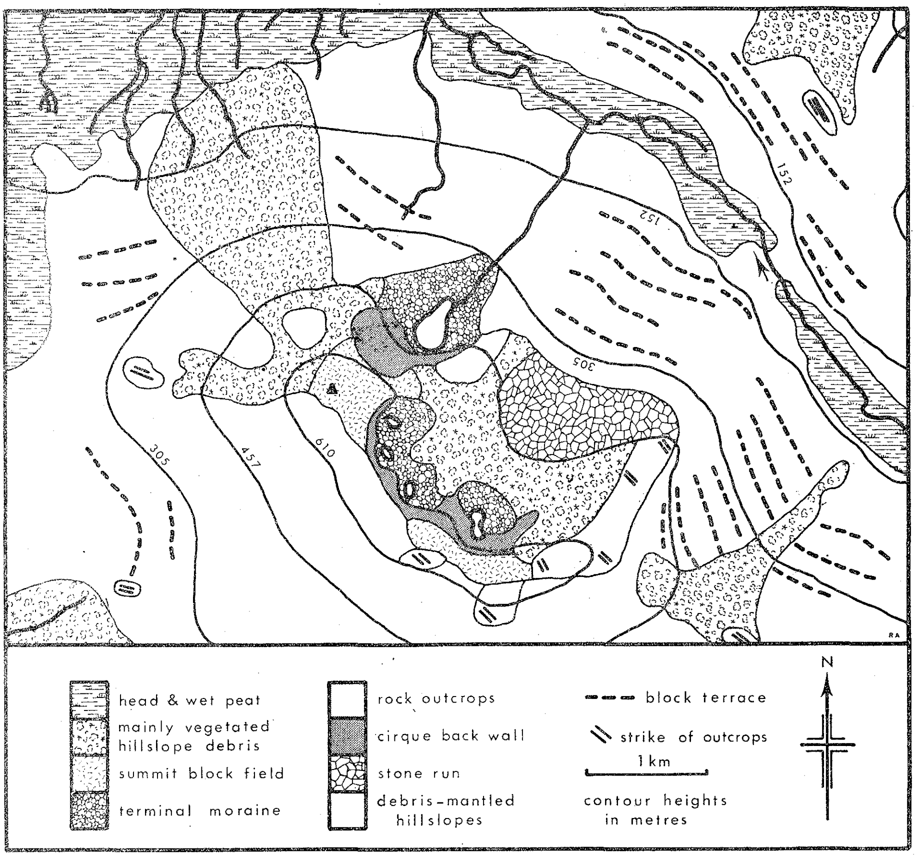


Fig. 1. Mt. Usborne, East Falkland, showing the relationship of glacial to periglacial landforms

orientations are favourable. It was further observed (CLAPPERTON, 1975) (a) that stone runs are "either very small or totally absent from the cirques, troughs and their catchment slopes above, but are widespread beyond them", and (b) "the parts of the Wickham Heights below 540 m, lying to the east of Mt. Usborne are extensively covered with stone runs", and (c) "trough-like valleys on West Falkland suggest that small plateau ice caps may have generated short valley glaciers in places".

The implications seem to be that stone run formation was dominantly contemporary with cirque (corrie) growth, a point made by CLARK (1972), that stone runs are not extensive above 540 m and on and west of Mt. Usborne, and that the trough-like valleys are evidence for plateau ice caps. It should be noted that stone-runs are extensive on hills west of Mt. Usborne and there appears to be no significant variation in the intensity of stone-run distribution associated with difference in longitude. It does not appear to be true that periglacial slope debris is absent or poorly-developed above 540 m. For example, on Mt. Usborne cold-climate debris extends continuously from the summit (700 m) to the foot (60 m). The summit areas, and those of other high and broad uplands, carry block fields associated, as on Mt. Usborne, with residual crags. They are part of the upland weathering--transport-deposition suite described earlier (CLARK, 1972). This is not younger than the corries, and, if the views of IVES (1973) are sustained on the length of time required for the production of felsenmeer and altiplanation terraces, may represent a period of some thousands of years of frost climate. On Mt. Usborne several of the small fresh corries embay the longer and more degraded backslopes of a larger basin. This may be seen in CLAPPERTON'S (1975) plate 4. But the floor of the larger basin is covered by coarse quartzite rubble and does not appear to have been occupied by snow when the small corries were being shaped. Fig. 1 shows how periglacial features surround and lie above and below the youngest glacial features, and occupy the floor of a possible older cirque.

With regard to the trough-like valleys, their cross sections, straightness, and local steps in the long profile are reminiscent of valleys shaped by moving ice. But, while relatively fresh moraine arcs enclose many of the corries, moraines and other glacial phenomena have not been noted from the troughs although there is abundant frost debris. It is possible that an earlier glaciation shaped the troughs.

BLOCK TERRACES AND STONE RUNS

CLAPPERTON (1975) in noting the variety of depositional forms on hillslopes and valley sides, refers to screes, stone lobes, terracettes and large boulder terraces. The place of these features in the suite of cold-climate landforms has been discussed by the present writer (1972). However, the observation that "stone runs cascade over 3—5 m high boulder terraces" in certain places may be considered further. Many hillsides are diversified by quartzite outcrops which tend to run along the slope with various degrees of continuity. Slopes are varied by depressions running down the slope. Some descend from crestline cols, and the crestlines are broken from place to place by upstanding rock outcrops (see CLAPPERTON, 1975, Pl. 2; and CLARK, 1972, Pl. 2). Consequently it is expectable that hillside downslopes debris movement would show lateral variation due to differences in quantity of weathering and amount of involved water-ice. There would then be paths of greater discharge and more rapid movement. The north flanks of Mt. Usborne below the corries display evidence of this. Moreover, this would impose on such hillsides a diachronous cessation to major debris movements.

CLIMATE IMPLICATIONS

In discussing the climatic implications of the landforms CLAPPERTON (1975) appears to seek an analogy between a climate responsible for Falkland stone runs and present climates in parts of Iceland and Spitsbergen "which, with a high number of freeze—thaw cycles is considered to be very favourable for mechanical frost weathering". It is not entirely clear whether there is meant the cumulative effect of the major annual thaw—freeze cycle or the occurrence of many small cycles within each year. The former is of probably greater significance in the large scale development of summit block fields that form an integral part of the system of periglacial landforms in the Falklands.

The climate responsible for those features is described by CLAPPERTON as "severe but maritime periglacial" with "precipitation from westerly air masses" possibly "considerably higher" (presumably higher than presently experienced) "because of very cold dry air from the Patagonian ice sheet becoming unstable on passing over the open ocean west of the Falkland Islands". It has seemed to the present writer (1972) that the evidence for quantity of accumulated snow in the last cold phase, the probable duration of that phase, and the amount of ice necessary for the formative morphological processes combine to suggest a lower precipitation. The interpretation of the likely regional context supported this view. It seems unlikely that westerly air from a cooler south Pacific, crossing a relatively higher Andes with broad ice cap, cold Patagonia, narrower and colder shelf sea could have supplied more moisture to the Falkland Islands especially in winter than they presently receive.

THE DEVELOPMENT OF UPLAND TOPOGRAPHY

The model of upland landscape development presented by CLAPPERTON (1975) requires some detailed examination. It appears to refer to the hills developed in Upper Palaeozoic strata where these are characterised by prominent folding, that is, especially in East Falkland. It is unfortunate that in the illustration the absence of horizontal and vertical scales enforces speculation upon the size of the features represented. Also, while the uplands are described as built of quartzite, sandstone and shale it is notable that the part played by shale in landscape development is not discussed. Nor, from the diagrams, is the relation of shale units to postulated relief inversion clear.

The interpretations which may be placed on the diagrams are:

(1) at some time there existed a landscape in which land surface conformed with one stratigraphic unit expressing symmetrical folds of uniform size,

(2) Tertiary landscape development produced a general inversion of relief and a uniformity of summit height,

(3) periglacial processes produced slope retreat but little change in valley depth and magnitude of relief while the general inversion of relief was sustained,

(4) all major valleys remained located along anticlinal axes and all valley walls are escarpments: hill masses are synclinal,

(5) only the periglacial episodes during the Pleistocene modified the landscape produced in the Tertiary era.

The real landscape is not susceptible to description through a single restricted model for two sorts of reason. The first of these concerns structure and lithology. Sandstones vary from rather soft, fine-grained, micaceous, close-bedded rocks to very dense quartzose rocks. The hardest sandstones, the orthoquartzites especially, are the most prominent for the other rocks are generally concealed except in sea, river, and cirque cliffs. The thickness of the units is most easily observed for the most resistant rocks and, if thin shale partings are discounted, many units exceed 30 m. It is these that are most conspicuous in the landscape. Two types of shale occur interbedded with the sandstones, fissile black and brown blocky rocks.

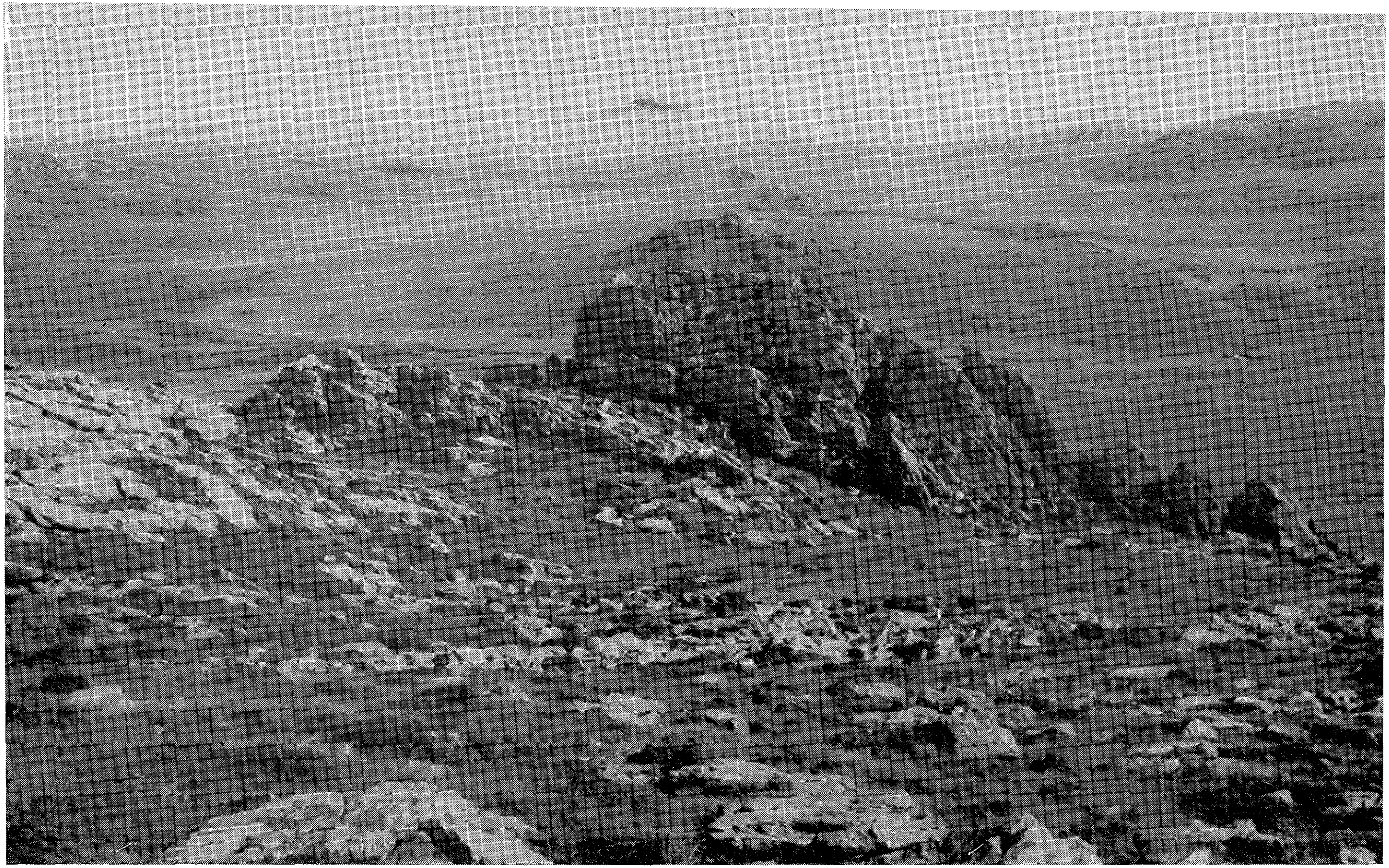
The main upland of East Falkland is a fold tract. There are areas, as near Falkland Sound, where the orientation of fold axes changes rapidly over a short distance. The principal axial direction changes from WNW—ESE in the west to W—E in the east of the island: this is reflected in the trend of the elongated upland area, of individual hill masses, and of outcrops. Folds vary in width from 6 m to 1200 m. There are very tight folds, some with pinched roots and vertical limbs, and open gentle folds. There are asymmetric folds, usually with a steep north limb in the anticlines, and these have developed locally into overfolds. Folds of different style lie alongside each other. Many folds appear to be elongated periclines. There are traces of an open cross-folding in the eastern part of the hills crossing the dominant folds from NNW to SSE and thus complicating the pattern of culminations and lows on individual rock units. Since HALLÉ (1912) regarded the Falkland Islands to be a group of fault-blocks, the significance of faulting has been rather neglected. Faults occur in the rocks of East Falkland which displace fold axes and change strike direction.

It is clear that on any horizontal plane a variety of rock units would outcrop. Additionally, the varied fold structures truncated by such a plane would impose irregularity on the outcrop on that plane of the rock units. This impresses a control over potential erosion. For example, different thicknesses and extents of shale tracts would occur at any level, some in the cores of anticlines, some in synclinal cores, some on the flanks of each fold size and type. Erosion could not proceed evenly, and a uniform and persistent inversion of relief would not be expectable. Nor would a close correspondence between hill mass and individual fold be expectable everywhere. Neither occur.

The second reason why a simple model is inapplicable involves the interaction of episodic denudation history with structural control. Field examination and map analysis demonstrate the existence of a sequence of almost horizontal surfaces cut across rock structure throughout the Falkland uplands. Although subsequent erosion can have degraded some of these, while others may have received soliflual debris, the occurrence of such surfaces with significant frequency at certain restricted parts of the overall height range seems quite clear.

Two summit surfaces are recognised, at about 700 m and 550 m in both West and East Falkland. Upland surfaces have been identified at about 300, 245—230, 180, 150 and, more locally, at 120 m. Lowland surfaces are widespread in the interval 75—30 m above sea level. There are at least three surfaces in this range.

A landscape history that includes periods of quite steady base level alternating with periods of relatively falling base level has significance for the present discussion:



Pl. 1. Characteristic landscape of the lower hills of East Falkland

Strike outcrops of fold limbs separate shallow valleys with axial stone runs and finer soliflual debris, and flanking debris slopes. Hilltop debris characteristic of the lower hills is seen in the foreground, its movement having been from left to right. The view is taken looking west over the ground mapped by CLARK, 1972, Fig. 3, western part, and CLAPPERTON, 1975, Fig. 1, eastern part

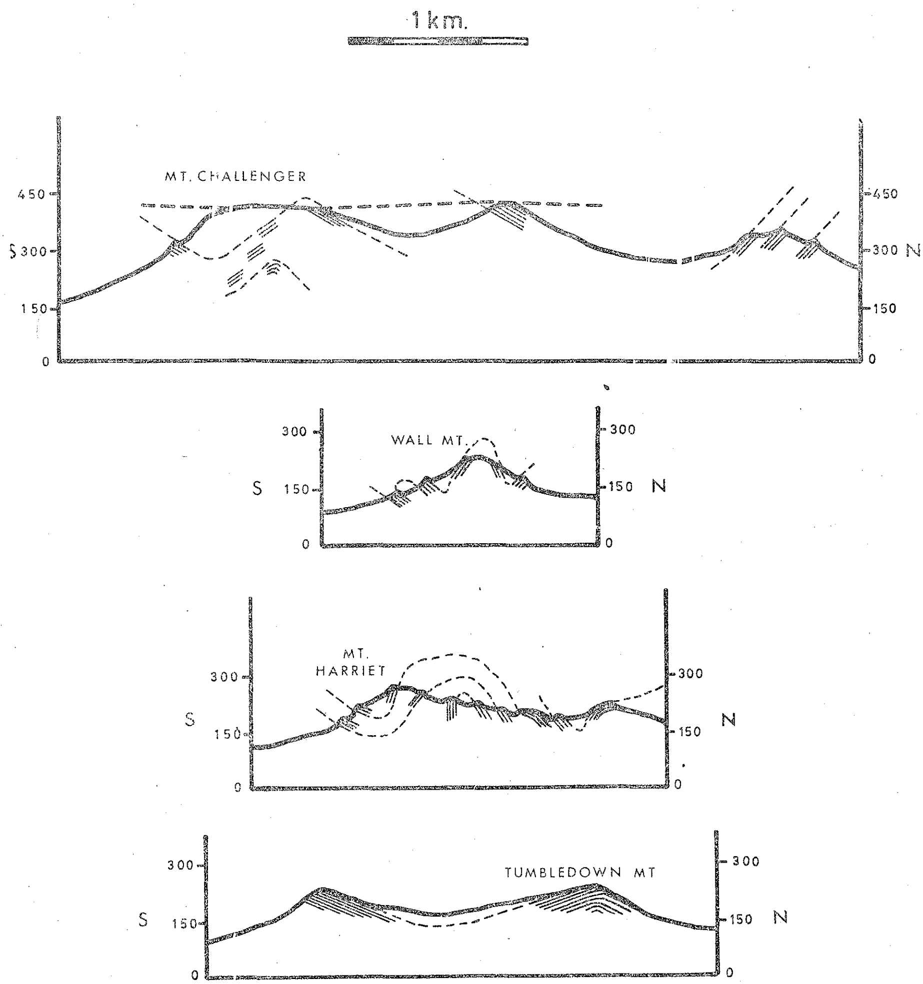


Fig. 2. Sections of selected hills in the east of East Falkland, showing the relationship of hill form to fold style. Heights in metres

(1) the summit surface, below which the rest of the landscape was cut, was not a structural surface and would expose a variety of structures and lithologies,

(2) a context for uniform creation of inverted relief would not exist,

(3) the denudation history determined that hill crests are not concentrated in one restricted height range,

(4) not all parts of the landscape are of the same age, and each successively lower and younger facet truncating structure would produce a variety of controls over subsequent erosion, repeating locally and sequentially the conditions of the summit surfaces.

The period during which this landscape developed may, perhaps, be presumed to include change from warmer Pliocene conditions to the fluctuating climates of the Pleistocene. It would be expectable that the higher hills would develop a deeper weathered mantle than the younger, lower parts. It is a central question whether such a mantle would be concealed or stripped away as a result of destabilizing climatic shifts and episodes of periglacial climate. The indication that ground between many quartzite outcrops has been lowered in the most recent such episode does not suggest that much regolith would survive from the end of the Pliocene, and consequently that it would play a controlling part in the most recent periglacial landscape evolution.

Slope and form development has advanced further in the higher areas such as Mts. Wickham and Usborne than in the narrower ridges especially those below about 450 m. The slopes of the former are characterised by a rather lower proportion of rock outcrop whereas in the latter structure is more readily interpreted. The higher hills tend to be more massive and to incorporate several folds. Even some of the narrower, sharper ridges so obviously parallel to fold axes are sufficiently broad to hold more than one fold as in Mts. Challenger, Wall, Harriet, and other hills west of Stanley (Fig. 2). Mt. Tumbledown in the same area is anticlinal rather than the expectable synclinal of the proposed model.

Falkland Islands uplands have a much more complex form and developmental history than can be represented in such a simple model of landscape evolution as that proposed by CLAPPERTON (1975). Although it is clear that the diversity in structures and rocks together with the multiple phases of erosion can be represented to some degree at the present time in a complex developmental model, it is evident that of the various effects of late Tertiary, and especially Quaternary, climates only the most recent are at all understood.

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