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GODARD, Alain. **Recherches de géomorphologie en Écosse du Nord-Ouest.** Tome I. Paris. Publications de la Faculté des lettres de l'université de Strasbourg, 1965. Société d'éditions *Les Belles Lettres*.

The 25,000 square kilometres of Scotland north-west of the Great Glen provide some of the most beautiful and striking scenery in the British Isles, if not in all Europe. Sixty years ago the area was the subject of a classic geological study by Peach and Horne, but until recently has been sadly neglected by geomorphologists. Publication of this massive tome by Alain Godard, totalling not far short of half a million words and based upon nine seasons of field work does much to redress the balance.

The work is divided into three parts, the first outlining the climatic and geological background, the second being a long and detailed description of six regional sub-divisions, and the third a discussion of some of the main topics arising out of the regional description. In practice the form of the presentation has certain disadvantages, for there is little attempt to separate description from interpretation, and much of the analytical argument is in fact to be found in the second part and is merely summarized in the third. As a consequence full comprehension of this final summary requires a good deal of cross-referencing and this is not facilitated by a very limited index. There is also a strange reluctance to use the National Grid reference system so that locating many of the minor features referred to in the text will pose a considerable problem for those not familiar with the area. It is thus not an easy book to use, which is the greater pity for it contains much that is excellent, is almost invariably stimulating, and deserves a wide readership.

Two major intertwined themes may be discerned running through the work. The first concerns the pre-glacial evolution of the landscape which, Godard maintains, can be readily deciphered despite the locally severe glaciation that the area has experienced. Few who are acquainted with the field evidence will contest the view that extensive planation surfaces exist along the western seaboard of Scotland, and although for long ignored by British geomorphologists they have recently been receiving increased attention. Godard recognizes four major surfaces : *a*) *Surface supérieure*, which, although warped and thus ranging in altitude from over 900 metres in the south to under 750 metres in the north, has escaped the type of disturbance preceding the outpouring of Eocene lavas and is thus dated as no earlier than late Eocene ; *b*) *Surface intermédiaire*, which, at altitudes of 375 to 600 metres, is much more extensively preserved and by means of contouring can again be shown to be warped ; a date between late Oligocene and mid-Miocene is suggested ; *c*) *Surface écossaise*, for which a date in the late Miocene is tentatively adopted, comprises both small erosion flats and extensive plateau fragments, generally at a height of about 300 metres, and although comparatively little deformed on a regional scale is quite sharply displaced by certain faults which must have continued active until at least middle or late Tertiary times ; and, finally, *d*) *Niveau pliocène*, which, at 90 to 180 metres is the most extensively preserved of all the erosion surfaces and is assigned to the middle Pliocene. It was already deeply dissected before the advent of the earliest glaciers.

The second major theme concerns the resistance to erosion of the various rock types found in north west Scotland. This provides the excuse for a very extended account of the geology in Part One. To devote some 40,000 words to general geological considerations is unnecessarily prolix, although to describe in a short compass rocks ranging from ancient Pre-Cambrian metamorphics to Cretaceous chalk, and from Caledonian granite to Tertiary basalts is no easy task. It is true, moreover, that the summary of the geology which Godard provides is one of the best currently available. Assessment of the relative resistance of the various rock types is attempted in a number of ways, but primarily from the field relations of their outcrops, from examination of sections, and from granulometric studies of such superficial deposits as moraine, fluvio-glacial gravel and alluvium. Each method contributes a wealth of data but leaves unresolved a number of interesting problems. It is to these problems that Godard devotes an important section of Part Three. It is suggested that there are at least five major variables affecting the response of a rock to weathering and denudation, and each is examined in some detail : *a*) joint spacing often appears to be important but no simple relationship to rock resistance is established and it is not always clear whether the observable joint system is the cause or the effect of weathering ; *b*) grain size also yields little correlation with apparent resistance, although with the same mineralogical

composition medium-grained rocks tend to be less susceptible to weathering ; *c*) porosity yields a correlation inverse to that expected for certain of the granites and quartz-syenites, and is not statistically significant in other cases ; *d*) mineralogical composition, as one might expect, appears to be relatively important, but the relationships are complex. Quartz-rich rocks do not invariably prove resistant and much seems to depend upon the structure of the quartz crystals themselves. Also of considerable importance is the content of biotite, lying near the other end of the proposed scale of weathering : quartz, muscovite, orthoclase, plagioclase, biotite, amphiboles and pyroxenes. Godard attempts to assign a numerical value to each of these minerals and thus to establish an « index of weathering » for each rock type ; when this index is plotted against the altitude attained by the outcrop a rough correlation becomes apparent ; *e*) texture is suggested as a possible factor deserving closer examination than it has so far received.

Yet clearly the reaction of a rock to weathering cannot be dissociated from considerations of climate, and Godard is at pains to emphasize how climatic changes may have influenced weathering styles. It is in this context that the two major themes of the volume are brought together, for it is argued that the erosion surfaces betoken a very long period of sub-aerial erosion during which great changes of climate occurred. Thus at each stage — and by inference at each level — rocks may have reacted differently, and this concept is used to explain some of the contrasts in form between the different erosion surfaces. The explanatory chains are often long and involved, and rely for instance upon palæoclimatic reconstructions for which there is little or no local evidence ; in such circumstances it becomes very difficult to avoid circular arguments creeping in. Moreover, to argue, as Godard is apt to do, from the detail of form shown by a particular surface is to treat landforms as extremely static ; the *surface écossaise* which is regarded as originating in a semi-arid late-Miocene environment must presumably have been subjected to prolonged modification under the more humid climate invoked for the *niveau pliocène* — to say nothing of the changes wrought during the Pleistocene.

It is instructive to compare Godard's reconstruction of Tertiary events with that suggested more recently by T. N. George (*Scottish Journal of Geology*, 1966, vol. 2, pp. 1-34). Both authors advance very cogent arguments for discarding the long-cherished belief that the summits of the Scottish mountains may represent an exhumed sub-Cenomanian surface, and Godard shows convincingly that possible exhumed surfaces of a variety of ages constitute only a minute fraction of the modern relief pattern. But whereas Godard would place some of the erosion surfaces in the early Tertiary, George argues on geological evidence that they are all more recent than the « Alpine » structures which deformed the early-Tertiary basalts with folds attaining an amplitude of as much as 7,000 feet. The two writers also disagree about the nature of the erosion surfaces, for George contends that they are nearly all ascribable to marine erosion. The reviewer finds the infinitely more painstaking work of Godard much more compelling on this point, but is willing to accept the later dating advocated by George who concluded that « when incidental exhumation is discounted, the British landscape appears in major features to be almost wholly of Neogene origin. »

It is of course axiomatic in Godard's thesis that many of the pre-glacial forms survived little modified during the Pleistocene glaciation, and he often stresses the geologically very short duration of the Quaternary era. This in itself is now a somewhat controversial point, and his unwillingness to concede significant geomorphic activity to interglacial periods may not command universal assent. This is true, for instance, when he relegates incised meanders on the floors of certain glacial troughs to a pre-glacial epoch in order to demonstrate the limited glacial scouring throughout the Pleistocene period. Yet the basic contention that the locus of glacial erosion was often influenced by a preceding phase of deep weathering has much supporting evidence. Rotted rock still remains *in situ* at a number of places, and X-ray analyses of the clay minerals in what Godard describes as palæosols are regarded as indicative of a Pliocene rather than an interglacial origin. As is so often the case in geomorphology, generalization is dangerous, for the extent of glacial erosion seems to have fluctuated greatly from one location to another.

The broad scope of Godard's study is readily apparent from the foregoing paragraphs, but in the course of a review of this length it is impossible to do full justice to the immense amount of work which it incorporates and the very carefully reasoned arguments which it presents. Everything is on the grand scale, with almost 500 references, 63 well chosen photographs, and 187

diagrams, many of them folding out. The number of textual errors is kept relatively small and the whole production is one of which to be proud. Among the numerous subsidiary topics touched upon are raised beaches, tors, patterned ground, stream hierarchies, landslides, coastal landforms, post-glacial weathering processes, and man's role as a geomorphic agent. Inevitably in a work of this range few will find themselves in complete agreement with every conclusion drawn, but all should be grateful to Alain Godard for an outstanding contribution to geomorphic literature.

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BRUNING, Herbert. **Vorkommen und Entwicklungsrythmus oberpleistozäner Periglazialerscheinungen und ihr Wert für pleistozäne Hangformung.** Dargestellt an Beispielen aus dem Bereich der nördlichen Lössgrenze, aus dem Leinetal und den Leinetalrandgebieten. (Existence et rythme de développement des phénomènes périglaciaires du pleistocène et leur valeur pour la formation pleistocène des versants ; exemples de la limite nord du Löss.) Bad Godesberg, Bundesanstalt für Landeskunde und Raumforschung, Nr. 156, 1966

Dans ce travail très détaillé, 52 sites des environs de Hanovre recèlent les formes caractéristiques des sols pléistocènes soumis au gel pérenne. L'auteur se demande si les phénomènes périglaciaires ont, au-delà de leur signification climatique, une importance pour la formation des versants.

L'objet le plus important des recherches est le coin de glace et les phénomènes de cryoturbation qui l'accompagnent. Il faut distinguer entre les formes *épigénétiques* et les formes *syngénétiques*. La majeure partie des coins de glace est d'origine épigénétique, c'est-à-dire que les coins se sont formés dans un sédiment qui est plus ancien que l'accident périglaciaire. Ils ne se sont donc pas formés lors du dépôt des sédiments comme les formes syngénétiques typiques. D'autre part, on a pu observer une formation synchronique des coins de glace et des fentes de gel, où ces dernières doivent probablement être considérées comme des formes secondaires. L'auteur est d'avis que certaines fentes de gel sont des formes de transition vers les coins de glace. Tout l'ensemble des formes dépend en premier lieu du climat, mais elles sont également influencées par les facteurs roche et temps.

La position des coins de glace est très intéressante, ainsi que les phénomènes de cryoturbation qui l'accompagnent en paliers entremêlés ; ceux-ci peuvent atteindre plusieurs mètres. Dans la région étudiée, une structure en quatre étages a pu être étudiée. Chaque palier comprend un processus de formation différent et une série de formes spécifiques et typiques. L'auteur attribue ce phénomène à des conditions climatiques différentes, les horizons élevés sous des températures bien plus basses. Si les paliers inférieurs datent de l'époque « drenthe » et les supérieurs de l'époque « würmienne », ces conclusions sur le climat nous paraissent prématurées et peu fondées. À l'avenir, il sera probablement nécessaire de faire des analyses climatiques plus nombreuses lorsque les formes actuelles apparaissent et se développent. Ainsi l'on obtiendrait des conclusions sûres concernant les conditions climatiques glaciaires.

À propos du problème de la formation des versants, dans les paysages à relief accentué (inclinaisons supérieures à 5°), le mouvement aval de la solifluxion est un phénomène répandu et bien connu qui, par son action nivellante, est de la plus haute importance dans la formation d'un paysage. Par opposition, les mouvements du sol sur les versants très peu inclinés (inférieurs à 5°) sont désignés comme « solifluxion passagère ». Les mouvements horizontaux sont de l'ordre de quelques centimètres jusqu'à 8 m, atteignent une profondeur approximative de 0,50 à 1,30 m, perdent de leur intensité au fur et à mesure qu'ils avancent en profondeur, et ne déforment pas les phénomènes périglaciaires au point de les rendre méconnaissables. En ce sens, les formes *cryergiques* indiquent les processus d'aplanissement d'un espace strictement délimité ; avec leur solifluxion passagère, ils peuvent influencer des versants peu inclinés.

En résumé, l'auteur nous présente un travail intéressant et soigneusement documenté. Les illustrations sont excellentes et facilitent la compréhension des phénomènes qui caractérisent