A MORPHOMETRIC ANALYSIS  
of the GRAMPIAN HIGHLANDS.  

BY  

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(With Map, Diagrams and Illustrations)  

THESIS PRESENTED for the  
DEGREE of DOCTOR of PHILOSOPHY,  
UNIVERSITY of EDINBURGH  

October 1936
INTRODUCTORY: -

The existence in the Grampian Highlands of certain platforms due to sub-aerial and marine erosion has been suggested from time to time by various writers.

These platforms of erosion are first mentioned by Geikie in his "Scenery of Scotland," (1865 - 2nd edition). He recognises that the Highlands and Southern Uplands are dissected table-lands - which he interprets as plains of marine denudation, where the planing may have been spread over, or repeated during many ages from Silurian times onwards. Geikie was quite clear that the "great leading features" of Scottish scenery, apart from lake-basins, are pre-glacial. The minor features, he thought, must have lost in ruggedness, owing to the smoothing effect of glaciation. (1865. pp. 77-8, 150-3, 256-7). In later editions of "Scenery of Scotland," Geikie suggests that the summits of the Highland table-land mark "a former base-level of erosion. In other words, they represent the general level to which the Highland region was reduced after protracted exposure to sub-aerial and probably to marine/
marine denudation." (1901. 3rd edition, p. 155.).

The existence of platforms of erosion in the Grampian Highlands is referred to by Peach and Horne in "The Scottish Lakes in relation to the Geological Features of the Country" which is contained in Volume I. of "A Bathymetrical Survey of the Fresh Water Lochs of Scotland," (1910. pp 439-513), under the direction of Sir John Murray and Laurence Pullar. These writers give very few details about the existing platforms but they recognise three main levels of erosion:

"(1). The High Plateau or peneplain, varying from 2000 to 3000 feet in height, with Ben Nevis, the Cairngorm Mountains and other peaks appearing as monadnocks;

(2). The Intermediate Plateau, the upper limit of which is about 1000 feet;

(3). The Continental Shelf."

Although other writers have suggested the existence of platforms of erosion in the Grampian Mountains, up to the present only Peach and Horne have assigned even approximate altitudes to them. F. Mort, however, in "The Sculpture of North Arran," (Scottish Geographical Magazine, August 1914. Vol. 30, pp. 393-404), gives a description of a plateau (called the thousand-foot platform - formed in late Tertiary times, before the separation of Arran from the mainland) believed by him to be of marine origin. The occurrence of such a platform in Arran was first/
first described by J. Smith in "A New View of the Arran Granite Mountains," (Transactions of the Geological Society of Glasgow, Volume X, No. XXII, 1896. (p. 219)). He remarks upon "the immense amount of marine denudation which has taken place............at a time when the sea worked between the 600 feet and the 1300 feet contour lines."

In an essay contained in "Great Britain, Essays in Regional Geography" (2nd edition 1930), A. Stevens states that "a most interesting and at present puzzling feature throughout the greater part of the Highlands, is the stepped nature of the upper slopes............These various plains or platforms at different elevations.............must be independent of each other, because their differences of level are so great that they must be steps rather than slopes. They could only be connected by slopes of considerable steepness which would contrast forcibly with the slopes it was sought to connect."

If such platforms of erosion exist, they are (according to Geikie - c.f. para. 2) pre-glacial. While glaciation would affect the minor feature of the platforms, it would not alter their main outlines to any appreciable extent.

Although no map of these erosion surfaces in the Scottish Highlands has been prepared, Professor Ogilvie has already published the first tentative Scottish map of erosion platforms in a description which covers the central and south-eastern parts of the kingdom. ("Great Britain," 1928/
In view of this previous literature, the present Research was undertaken.

PURPOSE: -

To ascertain whether such platforms exist; to identify them by altitude and to discover their limits as precisely as possible, and their relationship to one another.

To determine how far rock structure and surface form are accordant; also to fix the amount of later dissection.

To try different experimental methods with a view to ascertaining which are best suited to carrying out these aims.

The research is not final since it rests upon map study only and is a necessary prelude to work in the field.

It is hoped, however, that it will form a basis for further work of a more genetic character.

EXTENT: -

The area covered by this research is bounded on the

NORTH by a line joining Beauly Firth and Huntly;

SOUTH by a line drawn from the south-western extremity of Loch Tay through Brechin;

EAST /
EAST by a line passing through Bennachie, Hill of Fare and Kerloch;

WEST by a line drawn from Loch Tulla through the Blackwater Reservoir and Loch Treig to Beauly.

The area lies between Latitudes 56° 27' N. and 57° 30' N., and between Longitudes 2° 30' W. and 4° 55' W.

The area is covered by the following Ordnance Survey Sheets:
The maps used were:

(1). The Ordnance Survey map of Scotland, Popular Edition, one Inch to one Mile \( \frac{3}{53,360} \).

(2). The Ordnance Survey map of Scotland, 1" Engraved edition, with hachures and contours.

(3). The Ordnance Survey 4 miles to 1 inch layered map.

On the above named sheets of the Ordnance Survey map of Scotland, Popular Edition, upon which most of the work was done, the relief is shown by contours and spot heights.

In reply to an enquiry for information on the accuracy of the heights shown on Ordnance Survey maps of the Grampians, a letter was received from the Ordnance Survey Office. The letter stated that: - "the spot heights shown on the 6-inch plans of the area........are probably correct to within a very few feet. The next stage in contouring the area was to run lines of water level contours at 250 feet intervals between the spot heights. These water level contours might at a rough guess be something like 10 feet in error, although it is naturally difficult to provide such an estimate owing to the large effect of a small error in position in such steeply sloping ground.

The 50 feet contours were obtained by interpolation between the 250 feet water level contours by means of hill sketches and are necessarily given to a much lower degree of accuracy. Their purpose is mainly to show the slope of the ground."

From/
From the above quotation it is seen that the contours can be in error by only a few feet, and as the main object of this research was to ascertain the existence of platforms, the data on the Ordnance Survey maps were deemed sufficiently reliable for the present purpose. This assumption has been justified since the platforms revealed by the research have been found to differ in altitude by several hundred feet.

Furthermore, glaciation is presumed to have affected these platforms subsequently to their formation (see p. I.). For this reason also small errors in the map altitudes could safely be disregarded.

TRIAL METHODS OF RESEARCH: -

1. Study of Sections drawn along Watersheds.

Sections were drawn along the main watersheds. Although these sections gave indications as to the form (height, slope, break of slope, etc.) of the higher isolated ridges, extensive areas of lower land between the watersheds were not included. This method, therefore, was abandoned as a major method of attack, but the sections were used later as confirmatory evidence related to the cross-sections drawn from the synoptic map. Further reference to these sections will be found on page 39.

2. Study of River Profiles.

Profiles were drawn of all the main rivers and their tributaries/
tributaries (source to mouth). These profiles clearly indicated breaks of slope. Knick-points, however, may possibly be related to glaciation. Again, although these breaks of slope quite possibly occurred at the edges of the suggested platforms, they gave no information as to the interiors of the platforms. Also, as this method could only be applied to those areas through which the rivers flowed, this method was postponed, but the profiles were kept as it was thought that they might possibly be studied later with effect in relation to the upland surfaces, if identified. This method, however, was found unfruitful and was abandoned.

Since these two methods, even when taken in conjunction, left large areas untouched, a method was sought which would cover the whole area of the Grampian Highlands.

**FINAL METHOD:**

A method of examination which included the whole area to be studied and the one which was finally adopted was that of Projected Profiles, invented by Barrell. A description of the "Method of Projected Profiles" is given in Barrell's paper. "The Piedmont Terraces of the Northern Appalachians," (Edited by H. H. Robinson), contained in the American Journal of Science (Fourth Series), Volume 49. No. 292. April 1920. (pp. 242-245). This method was first applied in 1912, but it has never before been applied to any considerable area in Great Britain although it has been/
been used in Austin Miller's recent work on the Forest of Dean. A description of this work appears in "The Entrenched Meanders of the Herefordshire Wye," (The Geographical Journal, February 1935, Vol. 85., pp. 160-178.). On page 173 appears "Fig. 5. Projected profile of north shore of Severn estuary between the Usk and the Wye," and on page 169, Miller states that "Fig. 5 is a projected profile constructed in the manner described by Professor Barrell." The method of projected profiles was first used by Professor Barrell in a study of the Piedmont Terraces of the Northern Appalachians. Professor Douglas Johnson, of Columbia University, New York, has also developed it and applied it with success to a study of the Appalachians. On page XIV in the preface of "Stream Sculpture on the Atlantic Slope," Professor Johnson states, "The Study......involve a detailed analysis of Appalachian topography by means of hundreds of projected profiles specially designed to reveal the significant elements of the landscape along contiguous belts of country one or two miles in breadth. Preparation of such profiles is a long and arduous task, one which has already consumed several years and must continue for several years more."

Projected profiles differ from ordinary profiles since the ordinary sections are drawn along lines whereas the sections of the projected profiles are not. It is not necessary and not often desirable to draw a section along/
along a geometrical line; some natural line such as a valley floor or the crest of a ridge may be followed. Projected profiles are drawn to depict the features one would most readily see on viewing the actual country horizontally from a distance. Each projected profile represents in effect an elevation of a given strip of country in the architectural sense. Barrell states that "the projection of a belt of country upon one plane gives a projected profile." This method was adopted because as Barrell says: - "the method of projected profiles which shows all visible summits...........is a method more free than others from the subjective defect of picking and choosing the facts. Belts of country are selected which stand up highest. That line of sight is taken across this belt which is at right angles to the general slope of the topography and which gives, therefore, the least concealment of the background by the foreground. It is the direction of sight which is best adapted to show the character of the culminating upland surface as to whether it was a plane or a series of planes." As will be seen later, the modification of this method recommended by Professor D. W. Johnson was the one adopted. By this method a composite "skyline" profile is obtained for each two-mile strip of country by purely mechanical means, thus eliminating any possibility of subjective element affecting the result. Johnson's method of setting up these profiles was also followed, as will be seen later.
Choice of Direction of the Profiles.

Since the "grain of country" of the Grampian Highlands follows various directions, North-South and East-West profiles were thought to be as good as any. This allowed the use of the Ordnance Survey grid.

Choice of Strips of Land.

Strips of land two miles wide from front to back were found to be the most convenient as this choice again allowed the Ordnance Survey grid to be used without omitting any essential detail.

Choice of Vertical Scale.

In comparison with the horizontal scale (\(\frac{1}{63,360}\)), which is that of the map, the vertical scale was greatly exaggerated in order to bring out the breaks of slope (or steps) more clearly without, however, affecting their relative heights and positions. The vertical exaggeration, slightly more than ten times (1" : 500'), was chosen to suit the rulings of a standard squared paper.

DESCRIPTION OF METHOD.

To obtain North-South Profiles.

A strip of cross-section paper (S) is fastened parallel to the left-hand edge of the drawing-board and to the North-South strips of the Ordnance Survey sheet.
The direction of projection is perpendicular to this and thus parallel to a T-square placed against the left-hand edge of the drawing-board. Beginning for convenience at the left-hand side of the map and at the top of column I, the greatest height recorded in the 2" vertical strip is noted and marked at the corresponding point of the cross-section paper. The T-square is now moved downwards by one unit of the section paper, in this case \( \frac{1}{10} \)". The greatest height along the T-square and across the 2" strip is again noted and marked down on the cross-section paper. With the aid of the T-square, the greatest height is thus obtained at every \( \frac{1}{10} \)" to the bottom of the 2" vertical strip. The dots thus plotted on/
on the cross-section paper are now joined to form a profile.

This method is used for drawing profiles for each 2" North-South strip of the sheet. North-South profiles are also drawn in the same way for every sheet to be studied.

To obtain East-West profiles.

The procedure is the same as that outlined above for obtaining North-South profiles except that the cross-section paper (S) is fastened parallel to the lower-edge of the drawing-board and to the East-West margin of the Ordnance Survey sheet.

The greatest heights are marked on the cross-section paper for every 1/10" of a 2" horizontal strip working from left to right.
EXAMINATION OF THE PROJECTED PROFILES.

At this stage, the profiles were examined experimentally in the following way.

Three successive profiles were placed behind each other and held upright. In this way, certain features, such as continuous heights, were noted. It was found, however, that this method was defective because:

1. It was difficult to hold the profiles rigid and at their correct distances apart;
2. The paper was not transparent;
3. Only a few profiles could be studied at the same time.

A glass table was then tried. Although this made it possible to see through three profiles at once, it was found that if more profiles were placed on the table at the same time, they were not sufficiently transparent to be of much use. The objections to this method were:

1. The profiles had to be placed on top of each other instead of at their correct distances apart;
2. Only a few profiles could be studied at the same time as the light only penetrated a few profiles at once.

METHOD OF EXAMINATION FINALLY ADOPTED.

The method developed by Professor Douglas Johnson for examining the projected profiles was therefore adopted. Professor Johnson kindly transmitted an unpublished description of the method which involves the mounting and cutting out/
out of the profiles by fret-saw. The procedure described below was followed in respect of all the North-South profiles, mounted in continuous strips, each covering two Ordnance Survey sheets. But the mounting of the East-West profiles was postponed in view of the labour and expense until the examination of the North-South was completed. These profiles were later examined in the unmounted state for corroborative evidence only. An inherent weakness of this method if profiles with only one direction are used is seen when the highest portion of a strip does not coincide with a crest-line but falls within a slope which culminates in the adjacent strip, thus giving rise to a spurious summit. The use of profiles of perpendicular direction is necessary to reveal their true nature and serves also to enable recognition of portions of surfaces that were not "caught" by the North-South profiles.

The East-West profiles were examined on the glass table (p. 14).

All the profiles mounted and unmounted are preserved in the Department of Geography, Edinburgh University.

In order to keep the North-South profiles rigid and to set them up in their correct relative positions, they were mounted on ply-wood. The mounted profiles were then cut out exactly by means of a machine fret-saw. A framework, consisting of two wooden bars, was made. Each bar was slotted at 2" intervals. As the thickness of the ply-wood/
wood, on which the profiles were mounted, was found to vary, each slot was made wide enough to take the thickest mounted profile, and each slot was of the same depth. The thinner mounted profiles were held firmly in the framework by means of wooden wedges. The ends of the wooden bars and one of the wedges are clearly shown in the photographs included in the description of the "General examination of the Mounted Profiles." The framework was large enough to hold profiles covering four Ordnance Survey sheets. It was thus possible to set up the mounted profiles in their correct relative positions.

This method has the following advantages over the other methods tried: -

1. The outstanding features of the country are shown in miniature, though with great vertical exaggeration;

2. The detection of surfaces is greatly facilitated by varying the eye position both horizontally and vertically.

At first, much practice was needed in "reading" the assembled "models". It was found that on being viewed from a particular elevation and direction, certain minor features on the "models" were obscured by intervening major features but that this difficulty could be overcome by varying the eye position both horizontally and vertically.

3. The profiles are placed in their correct relative positions. By placing the maps under the profiles, the correct heights and actual positions of any required places can be read at once.

4. Profiles covering an area of approximately two thousand square miles can be studied at the same time, whereas the older methods limit the/
the area to a few hundred square miles.

5. The heights are readily obtained by the use of a moveable wooden stand carrying a vertical scale of heights. The stand is clearly shown in the fourth of the photographs which follow.

6. The profiles can be left in their correct positions as long as required.

GENERAL EXAMINATION OF THE MOUNTED PROFILES.

All the mounted profiles were set up in turn and a general examination of them made. (see "2" above).

Each of the accompanying photographs shows certain features which are seen when each respective assembled "model" is viewed from a particular elevation and direction but if each "model" had been photographed from other elevations and directions, additional features would have been shown. For example, if the "model" shown in the first photograph had been taken from the west instead of from the north-east, the Loch Ness depression would have been shown much more clearly. With the "model" in its present position, the depression is nearly obscured by the higher land on either side of it.

The chief features shown in the photographs are named and their positions indicated by arrows on the superimposed tracings. In the case of surfaces, the arrows are drawn in the directions of the slopes of the surfaces.
(P1). Model showing erosion surfaces in the Grampian Highlands.
(PI). MODEL SHOWING EROSION SURFACES IN THE GRAMPIAN HIGHLANDS.
(P2) Model showing erosion surfaces in the Grampian Highlands.

This model is the same as that shown in (P1), but the eye position has been slightly altered both horizontally and vertically.
(P II). Model showing erosion surfaces in the Grampian Highlands.

This model is the same as that shown in (P I), but the eye position has been slightly altered both horizontally and vertically.
Model showing erosion surfaces in the Grampian Highlands.

This model is the same as that shown in (PI) and (PII), and the photograph illustrates the effect of varying the eye position both horizontally and vertically.
(P. III). Model showing erosion surfaces in the Grampian Highlands.

This model is the same as that shown in (PI) and (PII), and the photograph illustrates the effect of varying the eye position both horizontally and vertically.
(P 4). Model showing erosion surfaces in the Grampian Highlands.
(III). Model showing erosion surfaces in the Grampian Highlands.
(D V). **MODEL SHOWING EROSION SURFACES IN THE GRAMPIAN HIGHLANDS.**

This model is the same as that shown in (D IV), but the eye position has been altered both horizontally and vertically.
(P V). Model showing erosion surfaces in the Grampian Highlands.

This model is the same as that shown in (P IV), but the eye position has been altered both horizontally and vertically.
In the general examination of the mounted profiles, those of the eastern Grampians were first studied since this region evidently exhibited the most continuous tracts of platform. The most striking feature was the elevated mass of the Cairngorm Mountains which rise, in isolated peaks, to over 4000 feet, the highest peak being Ben MacDhui, (4296').

The Cairngorm Summits are composed of granite and appear to be remnants of an ancient higher platform as there is a definite break of slope around them. They are probably related to smaller areas of similar elevation, e.g., Ben Nevis, but these areas are represented in the Grampian Highlands only by peaks. This evidently most ancient surface is not further discussed.

Another conspicuous elevated mass was that of Lochnagar, where there is a considerable area above 3000 feet, the highest peak being Cac Càrn Beag (3796').

Several other smaller areas above 3000 feet were noticed. They occurred to the west of Lochnagar and to the south-west of the Cairngorm Mountains.

Around the Cairngorm Mountains there was a definite break of slope which occurred at heights varying between 2750 and 2500 feet. From this break of slope there was a gentle slope away from the Cairngorm Mountains, which is terminated at a height of about 2400 feet by a much steeper slope.

This suggested a former continuous surface. On examining/
examine the mounted profiles, other extensive gently sloping areas bounded by definite breaks of slope above and below were found lying roughly between the heights of 2900 + and 2300 + feet. Apart from a few quite detached areas, the platform remnants were found to be continuous, or nearly so.

Surrounding all the areas just mentioned, other extensive tracts bordered above and below by breaks of slope and standing between 1500 and 1800 feet were noticed, but some of these rise up to 2000 feet and descend to 1400 feet.

The result of the investigation up to this point is thus to reveal the existence of remnants of two upland surfaces which may clearly be interpreted as surfaces of erosion. Each of these groups of remnants covers a large area over which the platform may be presumed formerly to have been continuous.

Furthermore, the altitudinal limits of each upland surface have been determined.

Besides these two surfaces, a number of almost level areas were found at altitudes between 750 and 1000 feet. These occur in three distinct regions: a) around Loch Ness; b) in the district of the Moor of Rannoch; and c) to the South-east of the Grampian Highlands.

DETAILED EXAMINATION OF THE MOUNTED PROFILES.

The existence of certain platforms having been ascertained generally, a detailed study of their altitudes and/
and extent was undertaken.

Mounted profiles, covering four adjacent Ordnance Survey sheets, were set up in the framework, which rested on a large level table. Sheets of tracing-paper (each large enough to cover one Ordnance Survey sheet, and each having a 2" grid marked upon it) were numbered to correspond with the Ordnance Survey sheets under consideration. The tracing-papers were placed in their correct positions on the table and under the mounted profiles. By the aid of the moveable vertical scale, the approximate positions and heights of the breaks of slope, as shown on the profiles, were marked on the tracing-papers. The approximate heights and positions of the intervening summit levels were also marked on the papers. The tracing-papers were then placed over the corresponding Ordnance Survey sheets and the exact positions of the breaks of slope and of the heights determined. The exact positions of the breaks of slope and of the heights are not given on the mounted profiles since each profile represents a strip of land two miles wide from front to back. Therefore, a height shown on a profile may occur on the map at any position along a 2" line drawn at right-angles to the height on the profile.

For examination of the East-West profiles for corroborative evidence, see p.15.

The mounted profiles were then removed from the framework and others set up. The detailed procedure given above was again carried out. This was continued until the required heights on all the profiles had been marked/
marked on the corresponding tracing-papers, and the exact positions and heights had been determined from the respective Ordnance Survey sheets.

Since the analysis deals with summit levels, the next step in the procedure was as follows:

One of the tracing-papers was placed in its correct position over the Ordnance Survey sheet of the engraved hachured edition. This map has a special value in the present investigation in view of the fact that in the original survey of the Highlands on the six inch scale the vertical hachures were drawn immediately under the direction of the Surveying officer who had himself been responsible for water-level contours and the horizontal hachures drawn in the field. The 50 foot "contours" of the present edition, on the other hand, (see p.6), were interpolated in the drawing office only a few years ago. The white patches, (indicating level ground) if any, at the marked heights were outlined upon the tracing-paper, but it should be noted that absence of hachuring from small (e.g., quasi-conical) summits does not necessarily indicate level, or almost level, land. In turn, all the other tracing-papers were similarly dealt with. Thus while the recognition of the existence of the separate surfaces within each two mile strip depends upon the examination of the projected profiles, precise location of remnants of individual surfaces rested upon examination of both editions of the Ordnance Survey map.

All/
All the marked outlines of the patches of level land were then filled-in with coloured crayons as follows:

1. **In Blue:** - Those between 2300 + and 3000 feet;

2. **In Brown:** - Those between 1400 + and 2000 feet;

3. **In Black:** - Those between 750 and 1000 feet.

This differentiation by colour denotes the facts to which allusion has already been made that large and continuous areas bounded above and below by definite breaks of slope fall within these particular altitudinal limits.

It must be noted that there were not enough continuous areas of summit surface above the highest break of slope to be regarded as a platform. All ground that rises above the highest platform is shown in Red. There were insufficient areas, with the exception of the Cairngorms, for this to be regarded as constituting a still higher surface.

Dotted lines were then drawn to indicate generalised perimeters of the platforms which had been identified. As an indication of the degree of generalisation, the following excerpt is taken from an actual tracing-sheet, (1 inch to 1 mile): —

**Excerpt/**
The patches indicate areas of more or less level ground at the heights marked, and they are in their correct relative positions. Below each height marked, there is a definite break of slope. In order to connect all these breaks of slope, a dotted line is drawn on the outside of the patches. This line is drawn as smoothly as possible to include all the patches. In a similar way, generalised perimeters are drawn for the whole area.
contour lines. Obviously, these two patches at 1500' cannot be connected with those at 1500' occurring at the outer edge of the platform and seem to give clear evidence of the later origin of this section of the Findhorn Valley.

The difficulty of the two patches at 1500' is overcome by drawing a broken line thus 1 1 1 1 on either side of the River Findhorn to show that the platform has here been/
been cut away. In a similar way, generalised contour lines are drawn for the whole area.

FINAL MAP.

In order to depict the general result of the research conveniently, the data for the whole area were assembled on one map of smaller scale, drawn on tracing-paper placed over the Ordnance Survey map 4 miles to 1 inch ($\frac{1}{253,440}$) sheet with which it should be compared.

In making this drawing, every feature on the 1 inch tracings was carefully compared with the equivalent on the small scale map and inserted in its proper position on the synoptic tracing. In this way alone could proper fit of tracing to map be assured. Mechanical reduction of the 1" tracing-cloth drawings would not have obtained this result.

The coastline, rivers and lochs (with names) were marked in black ink for reference.

The inner and outer edges of all the platforms were marked in yellow waterproof ink. (The outer margin of platform remnants thus - - - - -; the margins of platforms where traversed by valley trenches thus 1 1 1 1.)

All the other details which follow were marked on the map by means of crayons: -

1. **In Red:** - All summit land above the highest break of slope, a few spot heights being marked.

2. **In Blue:** - A platform, the height of which varies between 2300 + and 2900 + feet/
feet but rising in Carn Ban in the Monadhliath Mountains to 3087 feet. Generalised contours were drawn in heavy blue lines;

3. In Brown: - A platform, the height of which varies between 1400 and 2000 feet. Generalised contours were drawn in heavy brown lines;

4. In Black: - A platform the height of which varies between 750 and 1000 feet. Generalised contours were drawn in heavy black lines.

Three small areas, the heights of which are intermediate between those of platforms 3 and 4 above. They were indicated on the map, in crayon, by thick black vertical lines. Generalised contours were drawn in black lines.

A triangle (A), where drawn, indicates the position of a conspicuous monadnock.

The altitudes of the platforms within a mile or so of the western margin of the map are more questionable as the areas beyond the maps used (see p. 5) were not examined.

MAP PROFILES.

In order to show the relations between the platforms and the intervening slopes, transverse profiles were drawn from the final 1/4" map, with information regarding the valleys taken from the 1/2" Ordnance Survey map where necessary. For convenience, these profiles were reduced and the reduced profiles are contained in the following pages. The horizontal scale is 8 miles to an inch and the vertical scale is 1000 feet/
feet to an inch. Again, as in the case of the projected profiles, the exaggeration of the vertical scale was found desirable in order to bring out the breaks of slope (or steps) more clearly.

The parts of the platforms shown on the profiles are indicated by waterproof inks as follows:

- **In Green**: The "Grampian Main Surface".
- **In Yellow**: The "Grampian Lower Surface."
- **In Black**: The "Grampian Valley Benches."

The "Grampian Summits" are indicated **In Red**, and the breaks of slope by **Black** dotted lines.

In order to make the platforms more distinct, washes of water-colours were placed under the inked outlines.

Profiles 1, 2, 3 and 5 contain parts of all the platforms and some "Grampian Summits." Profile 4 does not contain any part of the "Valley Benches" but part of an "Intermediate" area mentioned on p. 32 is included in it.

The profiles bring out very clearly the breaks of slope between the platforms. They also show the slopes of the platforms themselves and the nature of the river valleys cut in the platforms.
CREST-LINE PROFILES.

The actual crest-line profiles drawn from the 1" maps were used here for comparison. (See previous reference to this method of study on p. 7). The first crest-line profile is drawn from west to east across the map, and it coincides generally with the southern limit of the Spey and Dee drainage basins, but occasionally it diverges from this. The second crest-line profile runs roughly perpendicular to the first one and that part of it from Càrn Ealar to Beinn Iutharn Lòr is also included in the first profile. Profiles 2-6 are shorter than Profile 1 and radiate from the centre of the map. No crest-line profiles were drawn west of the L.M. and S. Railway in the south-west as this area is so dissected that no water shed is more than a few miles long.

Again, for convenience, these profiles were reduced and the reduced profiles are contained in the following pages. The scales of these profiles are: - horizontal scale - 4 miles to an inch, and vertical scale - 1000 feet to an inch. The vertical scale was again exaggerated for the same reason as before.

These profiles show definite breaks of slope in the crest-lines, and these breaks of slope correspond with those between the platforms identified. Although, for the reason already stated (p. 7), this alone is not sufficient evidence to prove the existence of platforms, it corroborates the evidence given in the profiles drawn from the final 4" map.
CREST-LINE PROFILE FROM RIVER BLACKWATER TO KERLOCH.
Crest-line profile from River Blackwater to Kernoich.

Section common to profile (2)
CREST-LINE PROFILE FROM CAIRN TOUL TO RIVER ARDLE (NEAR BLAIRGOWRIE).
CREST LINE PROFILE FROM BEN AVON TO HILL OF FAIRE.
CREST-LINE PROFILE FROM BEN AVON TO RIVER FIDDIEH.
CREST-LINE PROFILE FROM CARN BAN (MONADHLIATH MTS.) TO RIVER NAIRN (NEAR CONFLUENCE OF SRAIGIE BURN).
CREST-LINE PROFILE FROM BROAD CAIRN TO PROSEN BRIDGE.
CONCLUSION.

This Morphometric Analysis has revealed the existence of three platforms of erosion in the Grampian Highlands. They have been identified by altitude and their limits in altitude and extent discovered as precisely as possible by methods available. They are:

1. **The High Platform**, hereinafter called "THE GRAMPIAN MAIN SURFACE," varying in height from 2300 + to 3000 + feet, with the Cairngorm Mountains, Lochnagar and other peaks appearing as monadnocks. These monadnocks are hereinafter called "THE GRAMPIAN SUMMITS."

2. **The Middle Platform** hereinafter called "THE GRAMPIAN LOWER SURFACE," varying from 1400 + to 2000 feet, with Morven (2862'), Ben Rinnes (2775') and The Buck (2368') appearing as the chief monadnocks.

3. **The Low Platform** hereinafter called "THE GRAMPIAN VALLEY BENCHES," varying from 750 to 1000 feet. These benches may perhaps be correlated with the "UPPER LOWLAND PENEPLANE" of Professor Ogilvie.

It may be useful to recall (p. 2) that Peach and Horne recognised a "High Plateau," (2000' - 3000') and an "Intermediate Plateau," upper limit 1000', (as well as the Continental Shelf). The "High Plateau" would seem to have been the surface now recognised more precisely as the "Grampian Main Surface" and the "Intermediate Plateau" corresponds broadly to the "Grampian Valley Benches" and the "Upper Lowland Peneplane." In addition to these, a third platform, intermediate between these two, has here been recognised.

The recognition of the separate individuality of these platforms has not been based as in earlier work merely/
merely on the general accordance of summit levels but is supported by the following facts: -

1) Large and continuous surfaces of very low gradient fall within the altitudinal limits here assigned to the platforms.

2) Definite breaks of slope occur at the inner and outer edges of the platforms.

3) Comparison with the published geological maps showed clearly that the platforms are independent of structure over wide areas. Further reference to this is made in the following descriptions of the platforms.

THE GRAMPIAN MAIN SURFACE.

This platform has an extent of approximately 1050 square miles, after deduction has been made for valleys cut in it.

Comparison with the published geological map shows clearly that the "Grampian Main Surface" is independent of structure over wide areas. This platform has been cut in igneous and metamorphic rocks of varying degrees of hardness. As an example of this independence of structure, it is seen from the geological map that the part of this platform to the east of Lochmagar is cut in such varied rocks as granites, diorites, schists, gneisses, limestones and quartzites, the general strike of which is from NE. to SW.

The "Grampian Main Surface" has been dissected into four main areas which are roughly indicated in the following sketch map, on which the approximate directions of profiles/
A. THE CENTRAL GRAMPIANS.

The largest of these areas, (A), covers the central part of the Grampian Highlands. It is bounded:—on the north by the "Grampian Lower Surface" in the Spey basin and by the Feshie-Dee valley; on the east and south by the "Grampian Lower Surface;" while on the west it reaches the edge of the map, four miles west of Loch Treig/
Treig. It extends from Loch Lee in Glen Esk on the east for 76 miles to the western edge of the map. From north to south, it extends from Braemar for some 16 miles to Mount Blair, north of the Forest of Alyth.

The central part of this area stretching westward from Lochnagar is the highest, and rises above the 2900 feet generalised contour throughout its whole length; it is clearly shown on Map Profile 3 between the River Truim and the River South Esk. Most of the "Grampian Summits" appear in this section of the "Grampian Main Surface", the largest areas of these summits being Lochnagar in the east and Ben Alder in the west.

The break of slope between this area and the "Grampian Summits" which occur in it, is in every case at about 2900 feet. From the highest part of the area, the platform slopes gradually northwards to the Feshie-Dee valley and southwards to its outer edge, but it ends abruptly to the east of Glen Tilt, north of Lochnagar and on the eastern and western sides of Glen Laggan.

**MAP PROFILES.**

The slopes of various parts of this section of the platform and the intervening slopes are clearly shown on all the Profiles 1 - 5 (pp34-36), which have been drawn along the following lines:

1. NW. - SE. Strath Nairn to Alyth;
2. N. - S. Dufftown to near Alyth;
3./
3. W. - E. River Roy to River North Esk;
4. SW.-NE. East of Loch Tay to River Don;
5. N. - S. River Beauly to River Tay.

On Profiles 1, 2 and 3, it is seen that the break of slope between this part of the platform and the "Grampian Summits" is at 2900 feet, and between the outer edge and the "Grampian Lower Surface" at 2500 feet. In addition, Profile 1 illustrates the gradual slope northwards to the Feshie-Dee valley and the gradual slope southwards to the outer edges; and Profile 3 the highest part of No.1 area (A) of this platform with its gradual slope to the northern outer edge.

Profile 4 shows part of this area of the platform to the north-east of River Ardle from which there is a gradual rise north-eastward to Lochnagar. Here the break of slope is again at 2900 feet, but to the north of Lochnagar the platform ends abruptly at 2700 feet, the lower portions having been removed by erosion.

On Profile 5, part of the platform between Riven Spean and the southern outer edge is shown. From the highest part at 2900 feet there is a very gradual slope to 2800 feet at the southern outer edge.

Crest-line Profiles.

The whole course of No. 1. Crest-line profile as far as Hill of Cat, near Mount Battock, lies wholly within this area of the platform. It is seen that many of the crest-line summits coincide with the altitude of the platform.

No. 2/
No. 2. Crest-line profile as far as Ben Vuirich, is included in this area but owing to the number of "Grampian Summits," only two small portions of the platform appear on it.

B. THE CAIRNGORM REGION.

The second area (B) of the "Grampian Main Surface" lies to the north of the area just described. It is bounded on the north and east by the "Grampian Lower Surface"; on the south by the Feshie-Dee valley; and on the west by the Feshie and the Spey. It surrounds the Cairngorm Mountains and extends from Scraulac, near Morven, in the east for 28 miles westward to the Spey, and from Geal Charn, above the Braes of Abernethy in the north for some 14 miles southward to the Dee valley. A striking northerly extension of this area is formed by the Ladder Hills, while the Hills of Cromdale, near the confluence of the rivers Spey and Avon, form an outlier of this platform. The central and highest part of this area is adjacent to the Cairngorms. Here the break of slope is at a lower altitude than that in No. I area, (A) and occurs at about 2700 feet.

The Cairngorms are the only "Grampian Summits" in this area. Of all the "Grampian Summits", the Cairngorms stand out as the most distinct and their area of nearly 100 square miles is by far the largest. Moreover, in no other part do the "Grampian Summits" reach 4000 feet; here there are four peaks higher than this, Ben MacDhui (4296') being the highest.
The probable nature of the Cairngorms has already been referred to. (p 23).

From the Cairngorms, the platform slopes gradually to the outer edge of this northern block.

Map Profiles.

This part of the platform is illustrated on Profiles 1 and 2. Profile 1 shows that between the Spey and the Cairngorms the platform is almost level but that it slopes fairly steeply from these mountains to the Dee valley. The break of slope at 2700 feet between the platform and the Cairngorms is clearly shown. Profile 2 shows the Ladder Hills and that part of the platform between the Don and the Cairn. Very little slope appears in the platform but the break of slope between it and the "Grampian Lower Surface" is at 2500 feet.

Crest-line Profiles.

Crest-line Profile 3, as far as Scraulac, near Morven, lies within this area. On it, the part of the platform shown has a gradual downward slope eastwards to the outer edge. Crest-line Profile 4, as far as Cook's Cairn, is included in this area and most of the summits in the crest-line are seen to coincide with the platform.

C. THE MONADHLIATH MOUNTAINS.

The third area (C) of the "Grampian Main Surface" is formed by the Monadhliath Mountains. This area is bounded/
bounded on the north and north-west by the "Grampian Lower Surface," on the south-west by the "Valley Bench" which borders Loch Ness and Glenmore; on the east by an extension of the "Grampian Lower Surface"; and on the south by the Spey valley. It extends from Allt Mòr, near Kingussie, on the east for 20 miles to the west, and from Allt Càilichtich, a tributary of the Nairn, southward for 16 miles to Geal Chàrn, a mile west of Glen Markie.

The highest part of the Monadhliath Mountains is in the south and south-east between the Findhorn and Dulnan. Here there is a small area slightly more than 3000 feet high, the highest peak being Càrn Ban (3087'). This is the only case of the "Grampian Main Surface" rising above 3000 feet. This summit is included in the surface in view of the complete absence of any break of slope. There are thus no "Grampian Summits" in the Monadhliath Mountains. From this high area, the gradients are everywhere small; the slope is steepest to the east and at first to the north. Then the platform slopes gradually to the outer edge.

Map Profiles.

Parts of the platform and its slopes are shown on Profiles 1 and 5. On Profile 1, only a very small part of the platform appears at 2500 feet between the Dulnan and the Spey but it clearly shows the break of slope at 2500 feet between this platform and the extension of the "Grampian Lower Surface" on the west of the Spey.

Profile 5 shows that part of the platform between the "Valley/
"Valley Bench," bordering Loch Ness, and the Spey as well as a gradual slope from south to north.

Crest-line Profile.

No. 5 Crest-line Profile covers practically the whole length of this area from south to north. Nearly all the crest-line summits are included in the platform and the gradual slope from south to north is most evident.

D. THE SOUTH-WESTERN GRAMPIANS.

The fourth area (D) of the "Grampian Main Surface" lies in the extreme south-west. It is bounded on the north by the "Valley Bench" bordering Lochs Laidon and Rannoch; on the east by the "Grampian Lower Surface"; while on the south and west it reaches the edge of the map. It extends from Meall-nam-Fuaran, near Loch Freuchie, in the east for 34 miles to the western edge of the map. From north to south it extends from Schiehallion for some 15 miles to the southern edge of the map, two miles south of Loch Tay.

The highest part of this area lies between the rivers Lyon and Tay and it stretches across this part of the platform from east to west. The whole of this highest part is above 2900 feet. This area of the platform contains three areas of "Grampian Summits". Two occur in the east, in the region of Schiehallion and Ben Lawers, on either side of River Lyon; the other, in the region of Beinn Dorain, is in the extreme west, while there are several other peaks appearing as monadnocks.
The break of slope between this area and the enclosed "Grampian Summits" is in every case at about 2900 feet. From the highest part, the slope is very gradual to the south but is much less gradual to the north.

Map Profiles.

Profile 5 shows the relatively steep slope from the highest part to the outer edge in the north, and the break of slope at 2600 feet on the northern outer edge. There are no crest-line profiles of the area; it is so dissected that no watershed is more than a few miles long.

From the above description it is seen that the highest parts of blocks A and D of the "Grampian Main Surface" stand at about 2900 feet. In block B, surrounding the Cairngorms, the break of slope occurs at about 2700 feet; while in block C, the Monadhliath Mountains, the surface rises to well over 3000 feet. No explanation of these diversities of altitude is possible without investigation in the field.

THE GRAMPIAN LOWER SURFACE.

The area of this platform is approximately 1300 square miles, a figure arrived at after deduction has been made for valleys cut in it.

As in the case of the "Grampian Main Surface," comparison with the published geological maps shows clearly that the "Grampian Lower Surface" is independent of structure over wide areas. This platform has also been cut in igneous and metamorphic/
metamorphic rocks of varying degrees of hardness. Thus, to cite only one instance, that part of the platform to the east of the Ladder Hills truncates many different kinds of rocks including granites, schists, gneisses, and quartzites, the general strike of which is again from north-east to south-west.

The "Grampian Lower Surface" surrounds the "Grampian Main Surface" in the north, south and east, and except where it has been dissected by later valleys, it forms a continuous surface. Roughly, its outer boundaries are:

- **North** - a line joining Inverness and Huntly;
- **South** - a line joining Loch Freuchie and Kerloch;
- **East** - a line passing through Bennachie, Hill of Fare and Kerloch.

The longest unbroken part of the platform extends from Aberlour in the north, southwards for 20 miles to Torbain, three miles south of Tomintoul.

The widest unbroken part extends from Kerloch in the east to River Muick in the west, the distance being 22 miles.

The narrowest part of the platform is between South Esk and West Water. Here the width is only three miles.

On the west, the platform occurs only in two places, namely:

1. To the west of Loch Ness which forms its eastern boundary. It is bounded on the north and south by portions of the "Valley/
"Valley Bench" near Loch Ness. On the west, it reaches the edge of the map. The wide west-east valley of the River Moriston divides it into two parts.

2. Between the Blackwater Reservoir and Loch Laidon. This is an arm of the main area of the platform extending from the River Garry to the western edge of the map.

Two other striking extensions of this platform are along the valleys of the Spey and the Dee.

3. In the Spey Valley the extension occurs at first only along the left bank from River Dulnan to Kingussie. Here it has an approximate length of 16 miles and an average breadth of two miles. Then it appears on the right bank and extends from Glen Feshie to Strath Mashie, again with an approximate length of 16 miles but an average breadth of three miles.

4. Along the Dee Valley the platform extends westwards from Ballater for about 12 miles to Braemar. From the River Gairn in the north to Balmoral Forest in the south its breadth is 6 miles.

The highest part of the "Grampian Lower Surface" occurs at its inner edge, i.e., nearest to the "Grampian Main Surface" and from this there is a more or less gradual slope to the outer edge. The most gently sloping parts are those near the outer edges of the platform between the Rivers Don and Dee and between the Rivers Garry and Ardle. The steepest slopes occur immediately to the south of the "Grampian Main Surface" to the west of the River Ardle, and to the south of Loch Garry.

While the inner edge, marked by the break of slope between/
between this platform and the "Grampian Main Surface" stands at levels between 1700 and 2000 feet, it generally occurs at about 1900 feet.

Map Profiles.

Parts of the "Grampian Lower Surface" are shown on all the Profiles 1 - 5.

Profile I shows the slope of the platform from the outer edge in the north to its maximum elevation at 2000 feet between the Findhorn and the Durnan. The extension of the platform along the left bank of the Spey appears at 1900 feet. At the only other place where the platform occurs, it is seen that the inner edge is at 1900 feet and the outer edge at 1800 feet.

Profile 2 shows the slope from 1600 feet at the outer edge in the north up to the break of slope at 1900 feet between the platform and the Ladder Hills. The rest of the platform shown is at 1900 feet except where it slopes downwards to the outer edge at 1800 feet in the south.

Profile 3 includes only two small parts of this platform, the first at 1900 feet and the second at 1900 feet sloping outwards to 1700 feet.

Profile 4 includes a considerable length of this platform. The breaks of slope at the inner edges occur at heights varying between 1700 and 2000 feet, while that at the eastern outer edge is at 1500 feet. A comparatively steep slope from the River Tummel to the River Arde is shown.

Profile 5 includes the two areas of the platform lying on/
on the west. In the first area, the platform is rising southward from 1600 feet near the River Enrich to 1800 feet near Loch Ness. In the second area, it is descending southwards from 1800 to 1700 feet.

Crest-line Profiles.

With the exception of No. 5, all the Crest-line Profiles fall within the "Grampian Lower Surface."

No. 1. Crest-line profile lies within the platform from Sutrdy Hill to Kerloch, these two summits being at the height of the platform. The break of slope between the "Grampian Main Surface" and this platform is clearly shown at Mount Battock.

No. 2. Crest-line profile lies within the platform from Ben Vuirich to River Ardle, and the gradual downward slope to the south is shown.

No.3. Crest-line profile from Morven to Hill of Fare is included in this platform. There is a very gradual slope from west to east.

Very little of No. 4 Crest-line profile lies within the platform - Scant Hill to The Scalp. Here the platform slopes eastwards from 1700 to 1600 feet.

No. 6 Crest-line profile falls within the platform from the High Tree to Cat Law. The gradual slope to the south is shown.

The most notable monadnocks on the "Grampian Lower Surface" are Morven (2862'), Ben Rinnes (2755') and The Buck (2368').
THE GRAMPIAN VALLEY BENCHES.

The aggregate area of the "Valley Benches" remaining in this part of the Grampian Highlands is approximately 200 square miles.

The benches occur in three areas:

1. The largest, most extensive and unbroken area of this "Valley Bench" is that bordering Loch Ness and Glenmore; it measures approximately 12 miles by 6 miles. It is bounded on the north by Beauly Firth and the River Beauly; on the south by the River Enrich; on the east by Glenmore; and on the west by the River Glass. With the exception of small areas in the north and south, this platform is approximately 1000 feet high. Several monadnocks occur, the chief being Cain a Bhodaich (1642') and Meall na h Eilrig (1525').

This "Valley Bench" is shown on Map Profile 5. The slope from 1000 feet to 900 feet in the south is clearly shown.

2. The bench bordering Lochs Laidon and Rannoch includes the site of the Blackwater Reservoir. The approximate height of this area is 1000 feet, with the exception of the part to the south of Loch Rannoch which slopes from this height down to the Loch at 800 feet.

This "Valley Bench" is also shown on Profile 5, at 1000 feet throughout.

3. A Highland Border Bench overlooking Strathmore occurs in the south-east of the Grampian Highlands. It lies to the south of the Forest of Alyth and is limited on the west by the Forest/
Forest of Clunie. Its southern boundary is a line drawn from Blairgowrie through Alyth to the River South Esk. Its extent is 20 miles from east to west, and four miles from north to south.

The highest part of this Bench at 1000 feet is in the north, closest to the "Grampian Lower Surface", and it slopes gradually to the southern boundary at just below 900 feet. It is dissected by the Rivers Isla, South Esk and Ardle.

This "Valley Bench" occurs on both map Profiles 1 and 2.

It should be noted that whereas the "Grampian Main and LOWER Surface" have been determined by an examination of summit levels, the "Valley Benches" in the district of the Moor of Rannoch (including the site of the Blackwater Reservoir) occur as a system of old high level valleys, to the identification of which the method of projected profiles is not especially well suited. The information shown on the map for this region is therefore offered with reserve.

INTERMEDIATE PLATEAUS.

Three small areas whose heights are intermediate between those of the "Grampian Lower Surface" and the "Grampian Valley Benches," and which are situated between remnants of these platforms are found:

1. To the north of Loch Rannoch, where the height varies between 1100 and 1300 feet;

2./
2. Near the confluence of the Rivers Garry and Tummel, lying between 1100 and 1400+ feet;

3. Near the confluence of the Rivers Tummel and Tay, between 1200 and 1400 feet.

Although these areas do not fall within the limits assigned to the platforms identified, it was felt that they should be recorded on the map. They have, therefore, been included on the map in crayon by thick black vertical lines and generalised contours have been drawn in black. It seems possible that these surfaces may eventually be correlated with other remnants at similar altitudes lying beyond the region now studied.

This Research has shown that the method of projected profiles may be used with advantage for solving problems connected with the physical features of highland areas in Scotland.

Although this investigation has been limited to the discovery and definition of platforms of erosion in the Grampian Highlands, the mounted profiles may be used again as a basis for solving related problems such as the evolution of drainage systems. For example, during the examination of the mounted profiles two ancient valley systems were noted in the drainage basin of the existing River Don. The first occurs in the upper part of the basin incised from 2000 down to some 1300 feet; the second still further west incised/
incised from 2750 down to 2400 feet.

REFERENCES.


STEVENS, A., 1928. See Ogilvie, A. G.

ACKNOWLEDGMENT/
ACKNOWLEDGMENT.

The writer desires to acknowledge his indebtedness to Professor A. G. Ogilvie and Mr. D. L. Linton, M.Sc., for much helpful advice, criticism and encouragement during the course of this research; also to Mr. D. L. Linton for the negatives of the photographs submitted in this thesis.