

RE-EXAMINATION OF SOME GRITSTONE TORS OF THE ENGLISH PENNINES

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The term "tor" is generally used to refer to an isolated mass of weathered rock, left prominent upon the sides of summit of a large rounded hill or on flattish watersheds. Linton, D. L. (1955 p. 476) has used the term scientifically, but defines it genetically on the basis of his understanding of genesis.

"A tor is a residual mass of bedrock produced below the surface level by a phase of profound rock rotting effected by groundwater and guided by joint systems, followed by a phase of mechanical action".

Many outhors have rejected Linton's genetic definition of tors (e.g. S.E. Hollingworth and W.V. Lewis, in the discussion of Linton's paper, 1955). Palmer and Neilson (1962 p. 317) have however given a different genetic definition.

"A tor is a residual upward projecting fragment of naked bedrok, the result of differential weathering and mass movement".

This later definition resemebles that propsed by Pullan (1959).

Since neither the origin nor the age of the tors are well understood, it is perhaps more reasonable to use the

term only to refer to the shape and form of such features on the ground. The writer, therefore, considers that,

“A tor is rock eminence standing isolated or as one of a group either in a summit position on a valley side”.

This definition differs with that suggested by Ford (1963 p. 149), since he considered the castellated escarpments of 200 feet or more in height and up to half a mile in length to be true tors. Before reviewing hypotheses concerning the origin and age of tors, it is convenient to examine the shape, form and general morphological characteristics of such features in an area of about 200 square miles on the south eastern flank of the Pennines. The area is drained by the Sheaf, Upper and Middle Don streams, and lies in the County of Yorkshire-England.

The rocks in the area under consideration are mainly members of two major groups of the upper Carboniferous system, the Millstone Grit Series, and the Coal Measures. The former emerge from beneath the latter along the eastern flank of the Pennines, and comprise beds of gritstones, sandstones, shales and mudstones that total about 2000 feet in thickness. The Lower Coal Measures are formed of alternating beds of resistant sandstones and less-resistant shales, intercalated with frequent coal-bands and having an average thickness of about 1600 feet. The Lower Coal Measures represent a part of the total Coal Measures sequence outcropping on the eastern flanks of the Pennines and occupy a west central position in relation to the Yorkshire, Derbyshire and Nottinghamshire Coalfield. Though exposed in the area under consideration, further east their eastern margin is concealed beneath the Mesozoic formation.

Morphological characteristics of tors in the area under consideration

Field examination of tors has revealed that they are mainly confined to the gently-dipping outcrops of the Millstone Grits. An analysis of 66 major tors and tor groups indicates that the Kinderscout Grit yields 61 per cent of the tors, while the Middle Grit and Rough Rock groups contain 35 per cent and 4 per cent respectively. No tors have been identified on Coal-Measures Rocks, even though the sandstones of the Coal-Measures and the the gritstones of the Millstone Grits are both current-bedded, variable in texture, generally resistant or very resistant to erosion and have similar mineralogical compositions. Measurement of joint directions in these types of rocks, indicates the occurrence of two main groups of joints intersecting at an angle about 110° to 130°.

Since the Kinderscout and Rivelin Grits yield about 96 per cent of the tors in the area, it may be concluded that the nature of the jointing, the texture of the rock, and the altitudinal range at which the rocks are exposed are among the chief factors influencing the development of tors. On these rocks the joints are found to be more open, reaching in places about 10 feet across and penetrating very deeply. Furthermore, both the Kinderscout and Rivelin Grit are more thickly bedded, coarser in texture, conglomeratic and generally feldspathic in nature compared with the relatively thinly bedded medium grained sandstones of the Lower Coal Measures.

Tors vary in shape, and joints are the main structural factors controlling their shape. Where the joints are very closely spaced and comprise deep vertical fissures,

tower-like tors such as, Head Stone, and Howshaw Tor, are produced (*Plates 1 and 2*). In lamellar structure (i.e. where the pseudobedding is closely spaced, and the vertical jointing is not well developed), tors may become more tabular in shape. Where the lamellar structure is steeply inclined and vertical joints are developed in one major direction, then rounding is considerable on different sides and large dome-shaped tors usually result. Such an example occurs about 100 yards to the west of Head Stone on the southern valley side of River Rivelin.

Tors are also confined by altitudinal range in the area under consideration. They are never found below 900 feet O. D. though beds of both Rivelin Grit and Rough Rock occur below that height. For instance, tors-formed of Kinderscout Grit are seen at heights above 1200 feet O.D., while tors of Middle Grit and Rough Rock Groups are at heights not below 900 feet O.D. It is considered that the areas below 900 feet O.D. were probably less exposed to very cold humid climate of the Pleistocene Periglacial and Postglacial conditions.

Field examination has also indicated that at least 80 per cent of the tors examined stand on the primary watershed of the Derwent-Don basins. (Fig. 1). Valley side tors are less developed, none occurring within the Kinderscout Grit, but in the Middle Grit and Rough Rock outcrops, valleyside tors represent a half of the total in the former and all those in the latter. (Fig 2). Furthermore, no summit tors(1) in any kinds of rocks are

(1) Isolated summit tors are considered to be extensively periglacialated, while valley side tors are perhaps less modified by such conditions since most of them stand in groups and are commonly still attached to free-faces.

found below 100 feet O.D., while 90 per cent of the tors stand at an average height of 900 feet O.D., were valley side tors. Derwent Edge, which stands more than 700 feet above the level of the Ladybower Reservoir, in a distance of less than one mile, carries the best developed, and about a half of the total tors examined. The edge is formed of resistant bands of kinderscout Grit, resting on shales, dipping very gently at 2° to 5° towards the east and north-east. Along the axis of the Rivelin Anticline, Ladybower Brook is deeply incised, separating Derwent and Bamford Edges.

Figure 3, shows the relationship of eight groups of tors on Derwent Edge to surface configuration, drainage and underlying geology. All but the "Cakes of Bread" tors (Plate 3) are situated on the fringe of the Derwent Edge which is not dissected by streams or vales (Plates 4 and 5). Cakes of Bread tors are, however, situated on a spur like-feature bounded on the north and south by the upper tributary streams of Strine Dike. The following is a description of selected groups of tors in the area under consideration :—

1) *The White Tor Group* :

The base of this group of tors generally stands at a height of 1530 feet O.D. overlooking the deep valley of the Derwent. However, they stand at least 15 yards back from the break-of-slope marking the eastern valley side of the Derwent, on the summit surface (Plate 6). They are mainly cubic tors varying in height from 15 to 35 feet, the whole group having a relative extent of about 48 yards. The group is influenced by a series of joints of which two major sets intersecting at an angle of 120° are predominant. The vertical joints occur along the whole height

of the tors and vary in width from a few inches to open joints of more than 6 feet and they are about 6 to 10 feet apart. (Fig. 4) The tor-forming rocks are strongly current bedded which controls the differential erosion (Plate 7). In view of surface morphology, the height of the tors, and the rocks exposed immediately below on the valley side, the tors in this locality have been fashioned from a gently-dipping thick bed of gritstone.

2) *The Dovestone Tor Group* :

About 150 yards to the north of the White Tor, the largest group of tors, namely Dovestone Tor, occupies the western margin of the summit surface and stands abruptly on its fringe, overlooking the deep and steep eastern valley side of the Derwent. (Plate 8). The western part of this tor group stands at a height of 50 feet above the surrounding ground, but the constituent blocks lower towards the east and pass beneath the surface at their extreme eastern margin. The tors here have similar geological characteristics to those of White Tor, and are also influenced by two major sets of open joints intersecting at about 115° . Immediately, below the tors, several blocks have fallen onto the steep valley sides.

3) *The Hurkling Stone Tors, Back Tors, Howshaw Tors and Low Tors* :

These occupy the southern and northern margins of Derwent Edge, and are grouped together, because they are of similar shape and form, and stand in analogous locations. (Fig. 3). The lowest of this group "The Hurkling Stones" stands at a height of 1400 feet O.D., while the highest „Back Tors" are at a height of 1725 feet O.D. However, they stand between 10 to 30 feet above the surrounding ground but are lower and smaller

in extent than those of the white and Dovestone tors described above. Their smaller extent may be partly related to the variation in thickness of the grit bands and /or to the amount and degree of weathering and erosion.

In the field the tops of tors show evidence of differential weathering as a result of the variable lithological characteristics of the rocks. On the top of both the Back Tors (Plate 5) and Howshaw Tors groups (Plate 2) good examples of differentially weathered tower-like tors occur. Below each of the group of tors, structural benches have also been observed as a result of the alternating resistant gritstones and less-resistant shales (Plate 9) Thin sandstone bands forming the front edges of the benches usually support the development of small low tors, or act as constant sources of debris to the valley bottom by creeping blocks and solifluction deposits (Abou el Enin, 1964).

The rocks giving rise to these tor groups, have similar characteristics of lithology and structure as those of white and Dovestone Tors, mentioned above. The majority of the tors are extensively weathered and during heavy rainfalls water runs in furrows down the tors, and stand behind an "apron" of detritus from them. Sheltering animals probably influenced the apron's shape (Palmer, 1961). Such examples have been recognised at Back Tors and Low Tors (Plate 10).

4) *The Wheel Stone Tors :*

This group of tors varies in shape from the groups discussed above. They do not stand on the surrounding surfaces as tower-like features but are actually composed of a large heap of unsorted

blocks, that stand a few feet (i.e. about 15 feet) above the ground. Some of these blocks appear to be in situ and partially rooted in the ground, while others show evidence of downslope movement that has become arrested. Field examination of these blocks indicates that they are frost shattered, having sharp and steep edges, and are comprised of conglomeratic gritstones. It also appears that the rocks in this location are more heavily joined and cracked than those in the White or Dovestone Tors. (Plate II, and Fig. 4).

5) *The Cakes of Bread Tors* :

This group of tors is not situated on the fringe of the Derwent Edge, but is found on a spur-like feature bounded by valleys. The tors in this locality are composed of five individual tower-like tors, which are about 4 to 10 yards apart. They vary in height from 7 to 20 feet above the surrounding flattish surface and all are strongly current bedded and modified by recent weathering. Differential erosion indicates vertical and lithological changes in the rock bands of the tors.

Similar examples of tors are found at Ox Stones, half a mile to the south-west of Ringinglow (Plate 12) and at Head Stone, about one mile to the west of Rivelin Dams. In these localities good examples of current bedded, frost shattered and extensively weathered tower-like tors, are well developed on spurs bounded by shallow valleys.

Origin And Relative Age Of The Tors

A) *Previous Explanations.*

As mentioned in the preceding account, the term "tors" was introduced by Linton in 1955. However, similar

features, named as "Pillar rocks", were noted by the 19th Century geologists who attributed their origin either to the work of marine planation or to subaerial erosion.

Mackintosh (1865) considered the pillar rocks to be sea-stacks, and could only satisfactorily explain their shape by marine denudation. Another group of geologists considered tors to be the result of atmospheric denudation. De-la-Beche (1853), noted that tors resulted from differential weathering, and Geikie (1882) accepted such views. Wynne (1867) differentiated between "true tors" developed inland, and "sea stacks" occurring on the sea-coast. Later Miss Dale (1900) examined tors in the Millstone Grit rocks of Derbyshire — Yorkshire, and she noted that they are produced by wind abrasion.

A periglacial origin for the tors, was first advanced by Albers (1930), who claimed that the Dartmoor tors were completely like the "ruins" of Spitzbergen, described by Høgbom (1914) and were similarly due to the splitting action of frost and to movement occasioned by solifluction.

However, the present views regarding the origin and age of tors in the British Isles are mainly those of Linton (1952, 1955 and 1964) and Palmer (1956, 1961 and 1962). Linton, has concluded that tors, corestones, and possibly other residual rock-forms are the result of a two-stage process, the earlier stage, being a period of extensive sub-surface rock rotting whose pattern is controlled by structural considerations, and the later stage being a period of exhumation by removal of the fine-grained products of rock decay. He has also claimed that,

"The deep rotting responsible for tors must be of interglacial ... but the possibility is not

excluded that the period of rock rotting was in fact much earlier, possibly Late-Tertiary. This possibility that the weathering implied by the upland tors in late-Tertiary is attractive because of the known warmth of our Pliocene climate”.

Linton has also suggested that what he termed “the basal platforms”, represents the position of the water table during the period of rock decomposition, but King (1958) has pointed out that the platforms are however, too smooth and regular, and contrast too abruptly with the tors, to be related to such a fluctuating datum. King (1958) has also noted that the “sky line tors” or summit tors” can be observed forming under surface drainage and mass movement without deep weathering. However, Linton in 1964 has rejected any other possible origin for tors and noted that,

“...the hypothesis I put forward in 1955 for the British tors, may be regarded as being also the best available for the upland tors of the gritstone Pennines.

Though Linton has recorded deep weathering in several parts in the British Isles, no proof has been offered of their Tertiary origin. Furthermore, in the area under consideration, no “deep rotting”, of Tertiary age has been recognised underneath the solifluction deposits. Ford (1963 p. 153) has also concluded that the dolomite tors of Derbyshire can-not entirely be considered parts of a senile landscape of Tertiary origin.

On the other hand, Palmer (1961) has also suggested two stages in tor formation. First, the chiseling of

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the tors out of hard rock. Secondly, the subsequent modification of the tor by subaerial denudation into the present form. He has, therefore, claimed that the Pennine tors are not correstones, but are apparently a transient feature produced in the "Periglacial period".

B) *Views Of The Present Writer*

In the preceding account it has been shown that all the tors stand on bedrock and are heavily jointed. The open joints exhibited in every free-face are smooth and frost shattered. The vertical joints are more important than horizontal weakness for most spilling has been vertical. The joints have been enlarged and are wider at the top of the rocks, and the vertical joints probably extend into the ground. Where solifluction and peat deposits have been removed, joints near to the surface are found to be unweathered, fresh, and only narrow fractures.

The tors are believed to be one of the chief sources of rock creep and solifluction deposits of large blocks (type 2 solifluction deposits ... see Abou el-Enin, 1964, 1966). The majority of tors are surrounded by large frost shattered blocks resting on a thin mat of peat. Furthermore, chemical weathering is not really significant in the production of tors, though it is one of the probable factors forming furrows (Fig. 4) and pot-holes on the tor's blocks. The tors are still being modified under the present conditions. Recent weathering, strong wind action, and heavy rainfall, all cause slight modification on the tors and facilitate the rock-fall downslope.

It is believed that tors were produced under different climatic conditions to these of today. The climate would seem to have been very cold, wet and characterized by successive freeze-thaw actions. Such conditions occu-

red under the peri-glacial conditions of the Last Glaciation. It is therefore, considered that the tors are fossil features related to such conditions. According to the altitude, thickness and lithological characteristics of the gritstones in the area under consideration, it is thought that the free-faces of the gritstone bands have been subjected to more intense periglaciation than those of the comparatively narrow bands of sandstones exposed on lower ground. As a result of the successive freezing and thawing action on the scarp faces formed in gritstones, joints have been opened and widened and blocks have subsequently been split. Great amounts of rock fragments fell down the free-faces and moved down slope, causing the lowering and rapid retreat of the scarps.

During the cold wet phases of the Post-glacial period, congelifraction in the free-faces continued their development and tors were subsequently lowered in height, reduced in size and isolated. Where the tors were developed in extensively jointed rocks, frost action completely destroyed them, giving rise instead to residual masses of large blocks or to boulder fields.

It is therefore belived that the tors in the area, are fossil features, having developed in periglacial times and having survived Postglacial conditions. Many other tors probably once existed, but have been completely destroyed, their products forming solifluction deposits and boulder fields.

The amount of lowering of the surface under peri-glacial conditions is very difficult to assess. Thought it is taken for granted that free-faces and surface convexities are exposed to erosion and the lower slopes and

surface concavities to deposition, the deposited materials on the lower slopes have been eroded by streams or partially removed by subsequent erosional processes.

With regard to the height (i.e. above the surrounding ground) of free-faces and tors, and the location of the valley side tors to the associated free-faces, it is fair to assume that at least 40 feet of the upper part of the rocks have been subjected to erosion and weathering under periglacial and Postglacial conditions. Consequently, the whole surface configuration has generally been reduced by at least 15 feet and the scarps have retreated towards the dip slopes, probably by as much as 20 to 30 yards.

Since the majority of tors in the Sheaf, Upper and Middle Don Basins are developed on gently inclined structures, one can illustrate the probable stages in the evolution of tors on such structures (Fig. 5) Free-faces are considered to be exposed to frost action under periglacial conditions. Though active ground on the top of "permafrost" is broadly considered to be of about 10 feet in thickness under such conditions, frost action might, in places, reach greater depths (i.e. up to 35 feet) as a result of uneven thawing. Joints would facilitate the work of frost action and congelifraction. Successive frost action, solifluction, mass movements, differential weathering and erosion may then have produced the tors from the frost shattered heavily jointed free-faces. Destruction of the original free-face was such that they now appear as isolated blocks on the top of the present free-faces higher than the surrounding ground (Figure 5c). By the end of Pleistocene periglacial conditions, tors had become reduced in height and extent and the surrounding slopes were completely covered with frost shattered blocks which had fallen from the tors and free-faces and moved

downslope (Fig 5 D). A later stage may be the destruction of the heavily jointed parts of the tors and the removal of rock-fragments downslope (Fig. 5 E) However, the cold wet climatic conditions of Postglacial time might also have caused the complete destruction of some tors, giving rise to residual blocks or boulder fields accumulated in places on a thick blanket or on a thick sheet of solifluction deposits of very small angular sand- stone fragments. (Fig. 5 F.).

It is therefore, believed that the uplands in the area (i.e above 900 feet O.D.) have been more extensively periglacial than the lowland (Fig. 1). Comparatively thickly jointed grits were extensively frost shattered and subjected to the successive work of congelifraction and congeliturbation leading to the splitting of the free-faces and the shaping of isolated tors. Some of the latter have been destroyed or modified in shape during Postglacial time. In other words, Pleistocene periglacial conditions gave rise to the construction and development of tors, while the modification of tors under Postglacial climatic conditions, caused their mature and subdued form (i.e. large heap of blocks on surface slopes). The tors are not developed within the Coal-Measure sandstones in the lowland, and this may be related to some of the following points :—

- a) The relative thinness of the Coal Measure sandstones.
- b) The finer texture and closer jointing of these sandstones.
- c) The lower altitude at which the resistant rock stand.

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- d) The shorter length of time to which the sandstones were exposed to periglaciation.
 - e) The lower intensity of periglaciation.

On the other hand, tors have survived in different forms on the gritstone country because of one or more of the followings :

- a) The cessation of the processes of periglaciation before their complete destruction.
- b) The present isolated tors might be less extensively jointed than the surrounding split blocks.
- c) The relative thickness and lithological characteristics of individual band of rocks forming tors.
- d) The short priod of the Postglacial, with its moderate climatic conditons, has been unable to destory all tors completely.

Therefore, the results of the present investigation support Palmer's view on the origin and age of tors.

BIBLIOGRAPHY

- Abou-el-Eain, H. S.**, "An examination of the evolution of surface forms with a particular reference to the Quaternary Era". Ph. D. Thesis, Univ. Sheffield (1964).
- Abou El-Eain, H. S.**, "Glacial and associated features in southwest Yorkshire" Bull. Fac. Arts. Alex. Univ. (1966), 17 — 33.
- Dale, E.**, "The scenery and geology of the Peak of Derbyshire", London (1900).
- De-La-Beche**, "The geological observer" Vol. 2 (1853) London.
- Ford, T.D.**, "The dolomite tors of Derbyshire", E.M.G., vol. 2, No. 19 (1963), 148—154.
- Geikie, J.** "Text book of geology" London (1882).
- King, L. C.**, "Correspondence on the problem of tors". Geog. Jour., Vol. 124. (1958), 289 — 291.
- Linton, D. L.**, "Significance of tors in glaciated lands", The 17th Inter. Geog. Cong. Washington (1952).
- Linton, D. L.**, "The problem of tors" Geog. Jour., Vol. 121 (1955), 470 — 481.
- Linton, D. L.** "The origin of the Pennine tors — an essay in analysis", Ann. Geom. Band 8 (1964), 5 — 24.
- Mackintosh, D. E.**, "A tourist's notes on the surface geology of the Lake District", Geol. Mag. Vol. 2 (1865), 299 — 306.
- Palmer J.**, "Tor formation at the Bridestones in north-east Yorkshire..." Insit. Brit Geog., vol. 22 (1956), 55 — 71.
- Palmer, J.** "Gritstone tors of the English Pennines" Ann. Geom., Vol 5 (1961) 37—52.
- Palmer, J., and Neilson, R.A.**, "The origin of granite tors on Dartmoor Devonshire P.Y. Geol. Soc., Vol. 33 (1962), 315 — 339.
- Pullan, R.A.**, "The geomorphology of Mid-Wharfedale with special reference to periglaciation", Unpublished M. Sc. Thesis, Univ. of Birmingham, (1954).
- Wynne, A. B.**, "On denudation..." Geol. Mag. Vol. IV. (1867), 3 — 10.



(1) A tower-like tor at Head Stone on the southern valley side of Rizella.

- Note :
- a) Rock falls off the tor block,
 - b) Development of furrows on the upper part of the tor, cutting across the bedding plane



(2) A tower-like tor at Howshaw tor, on Derwent Moor.

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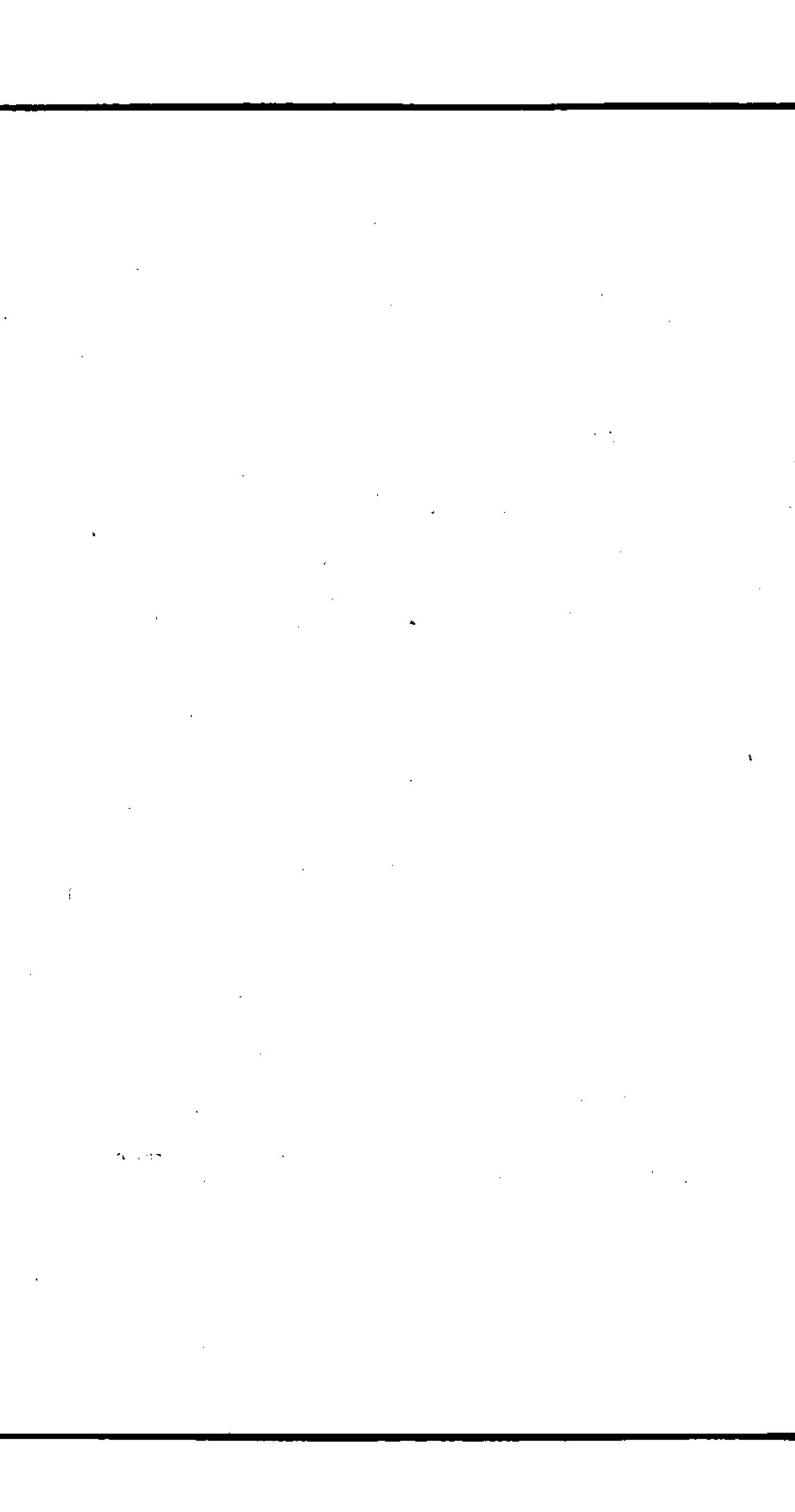




(3) Cakes of Bread Tors, situated on a spur-like feature on Derwent Moor.



(4) General view of white and Dovestone Tors, situated on the fringe of Derwent Moor and overlooking the deeply, incised valley of the Derwent.

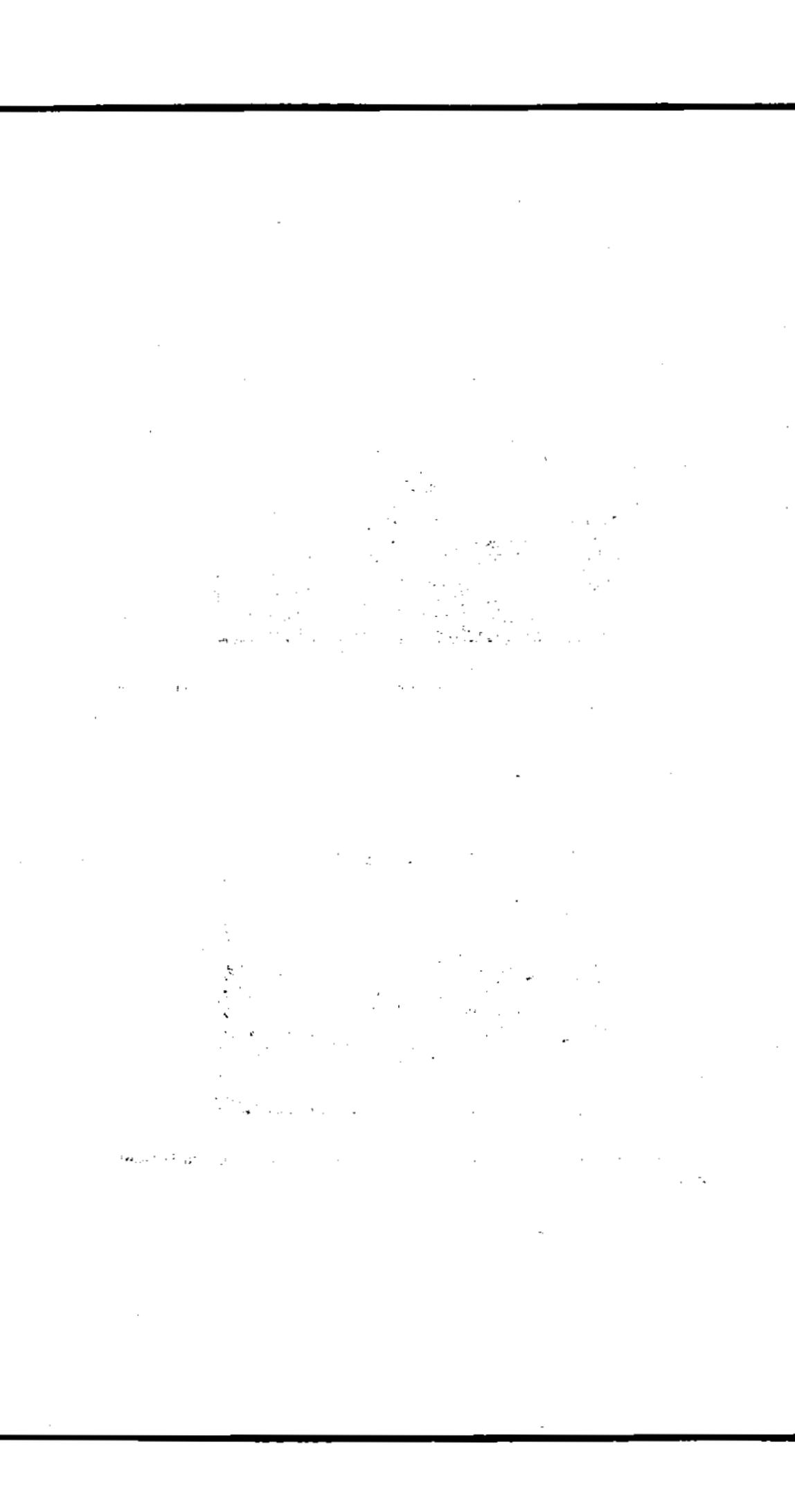




(5) A differentially weathered tower-like tor, at Back Tor, situated on the fringe of Derwent Edge.



(6) The White Tors, stand at a height of about 1530 feet O D., on Derwent Moor.





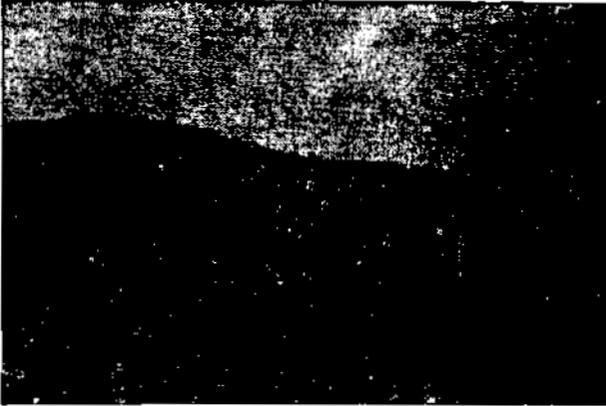
(7) A side view of the white tors, indicating the current bedding of the rocks and their modification by differential weathering..



(8) Dovestone tor, situated on the fringe of Derwent Moor.

- Notes:*
- a) Differential weathering and erosion of the tors.
 - b) The characteristics of the interfluvial and valley side's slope profiles.

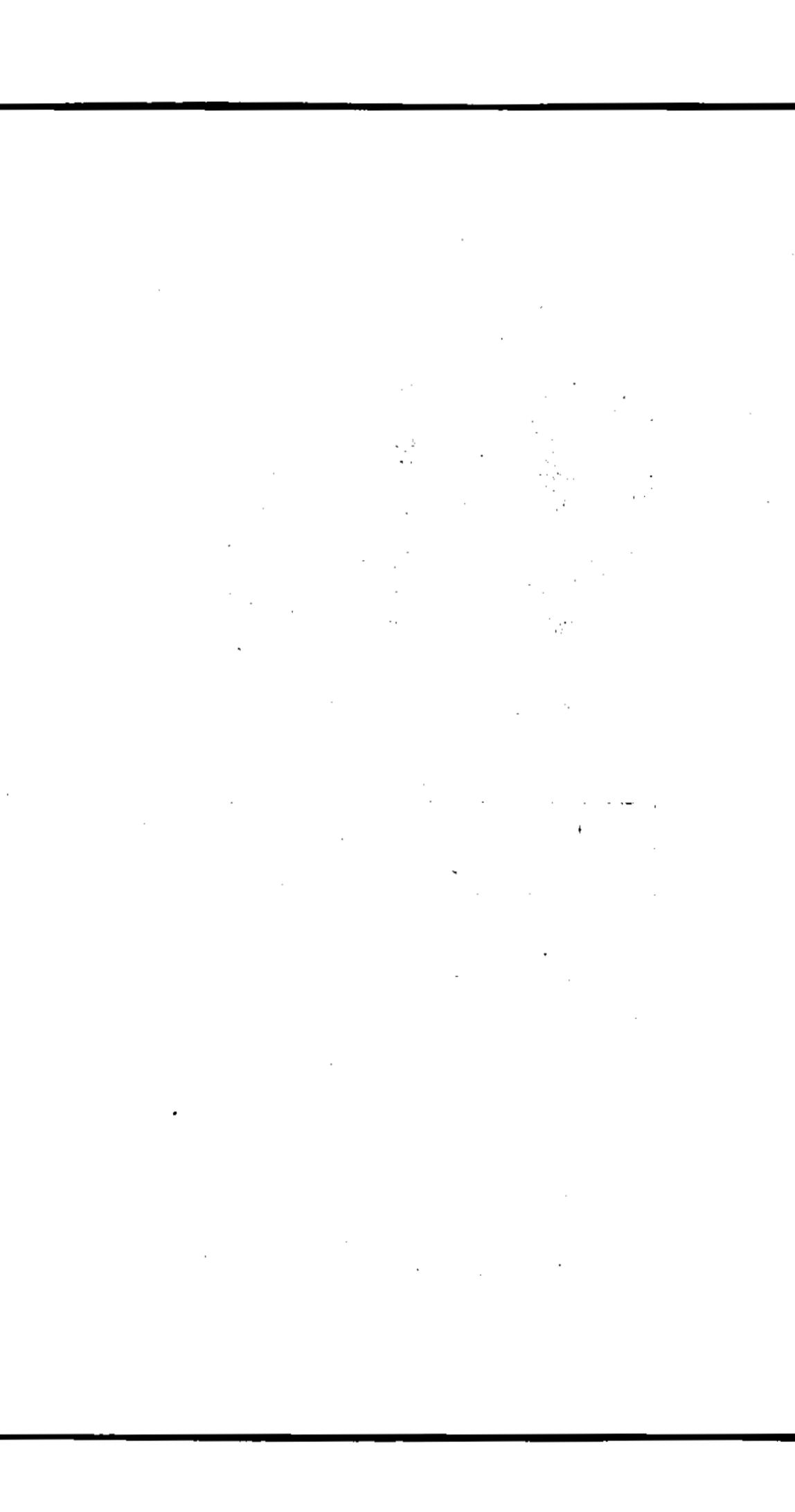




(9) Tor-like features on Derwent Moor, occupying the convexities of the structural rock benches.



(10) A tor-like feature, near to Back Tor on Derwent Moor, exhibiting furrows and pot holes.





(11) Wheel Stone Tors on Derwent Moor.



(12) Ox Stone Tors, situated on a spur at 400 yards to the south of Ringinglow.

- Note :*
- a) The current bedding of the rock.
 - b) The occurrence of a pot-hole on the top of the tor.