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DRY VALLEYS IN THE CHALK SCARPS OF SOUTH EAST ENGLAND

Dry valleys, usually referred to as coombes, are characteristic of the Chalk scarps of England. They vary in shape from shallow scallops to deeply incised flat-floored trenches. The problems of their age and, in particular, their origin have sustained a continuous thread of discussion for over 75 years. The more spectacular examples such as those at Pegsdon (Sparks & Lewis 1957), Ivinghoe (Brown 1964) and Devil's Dyke (Small 1962) have become much quoted examples of their kind. Explanations proposed include erosion by glacial meltwater (Sherlock 1929), nivation (Bull 1936), if not quite true corrie erosion, the collapse of joint-controlled sub-surface water courses (Oakley 1936) and headwater erosion by springs (spring sapping) (Sparks & Lewis 1957; Small 1958). Another view sees the scarp as having been inherited from a former valley side, complete with short tributary valleys, consequent upon scarp retreat (Fagg 1954).

A recent study by Kerney, Brown and Chandler (1964) of the Devil's Kneadingtrough and associated coombes cut into the south facing Chalk scarp of the North Downs near Brook, Kent, suggests that they originated in large measure through niveo-fluvial action in Late Glacial times (pollen Zone III, Younger Dryas). Full details are given elsewhere but it is thought that a summary of the results of this investigation will be of general interest.

There are seven coombes, the largest extend back half a kilometre into the scarp. All have rather flat or very slightly concave floors in cross section and very steep, straight sides which vary in angle between 20° and 34°. Their long profiles are smooth concave curves. Two coombes have springs at their lower ends occupying marshy amphitheatres 5 m below the general level of the floor.

Broad tongues of superficial deposits occupying the floors of the coombes and up to 5 m thick extend, stream like, out on to the plain ahead of the

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scarp where they coalesce and broaden into two lobes. Overall, the superficial deposits extend to a distance of 1.5 km from the scarp foot and reach depths of up to 4 m.

These fans of chalky debris are of Late Glacial age. At the base are up to 1 m of deposits dated as Zone I (Older Dryas). They consist largely of reworked Lower Cenomanian and Albian rocks with very little material from higher divisions, this points to erosion from the scarp foot rather than from the coombes which were conceivably not then in existence. There is no evidence of spring action and this may indicate the existence of deeply frozen ground. Analysis of overlying thin organic deposits shows that during the relatively mild Zone II (Allerød), processes of physical weathering ceased, or were greatly retarded. These have yielded a Carbon 14 date of 9,860 $\pm$ 180 years. The pollen and molluscan content of the deposit lead one to visualise wide expanses of marshy ground mantled by herbaceous vegetation and bearing scattered birch trees, interspersed with small pools. The deposits culminate in a rendsina-like marsh soil containing charcoal fragmants.

When the climate deteriorated at the beginning of Zone III (Younger Dryas), chalk debris was carried from the escarpment onto the plain, burying the Allerød marsh soil. In places temporary pools developed. Local areas periodically dried out and small thicknesses of windblown chalk silt accumulated. The bulk of this material is from the Upper Cenomanian and Lower Turonian stages of the Chalk; i.e. on the scarp face. One third or more of the chalk eroded from the coombes is still present within a radius of less than 1.5 km. In view of the not inconsiderable amount of calcium carbonate which must have been carried out of the area in suspension and solution, or which has been lost by weathering subsequently, this ratio is unexpectedly high. It suggests strongly that the major part of the erosion of the coombes was accomplished during Zone III. Earlier than this, the coombes, although possibly existing in some form, must have been much shallower and smaller than we now see them.

It would appear then that the climate of Zone III in south-east England must have been exceptionally conductive to rapid physical weathering of the Chalk. The factors responsible appear to have been a relatively high humidity coupled with temperatures hovering for long periods around freezing point. Cryoturbation structures have been described from Zone III deposits at Upper Halling, Kent, by Kerney (1963) and by analogy with similar structures in the Netherlands (van der Hammen & Maarleveld 1952) it was suggested that permanently frozen ground (*perennial tjaele*) may have occurred locally in patches. At Brook, smaller-scale structures in the Allerød soil are not conclusive evidence of similar frost action, but from the prevailing climatic conditions it is clear that at least a seasonal freezing of the ground, *annual tjaele*, must have occurred, alternating with cold, wet summers. During the winter, freeze—thaw action would have been especially active on the south-facing escarpment. Winter snowfall would not have been inconsiderable in this damp environment and early falls in the winter may have done much to limit the depth of *tjaele*. Snowdrifting by north-easterly winds probably built up large accumulations of snow on the scarp crest and more especially just in the lee of the height of land as happened during the severe winter of early 1963. Although most of the debris at Brook is poorly graded, the presence locally of bedding and of seams of washed chalk gravel suggests transport by surface meltwaters, released from snowfields, sweeping away the accumulated products of frost-shattering in the coombes over still frozen ground. Such deposits may be termed *niveo-fluvial*, and are of importance in the Late-Glacial in the Netherlands (van der Hammen 1953; van der Hammen & Maarleveld 1952).

The scarp foot springs were probably active throughout Zone III. The depth of frozen ground could hardly have been sufficient to cause the groundwater to freeze and the springs to cease flowing. The addition of spring flow would greatly facilitate the transport out onto the plain of the chalk slurry, brought down from the coombes by niveo-fluvial processes. This supplementation makes it easier to understand the considerable distance travelled by the slurry away from the scarp face and its low lobate form when finally deposited.

At Brook, the Devil's Kneadingtrough, and probably also the series of associated coombes, were cut in very large part during the comparatively short period, in the 500 or so years between about 8,800 and 8,300 B. C. (Godwin & Willis 1959); one must infer that only then did the climate offer a certain critical combination of humidity and repeated freezing and thawing, in contrast to the rather drier and certainly much colder conditions existing during most of the preceding 15 to 20,000 years of the Last Glaciation.

It does not follow from this that all scarp face coombes are of a similar Zone III age. In the Medway gap (Kerney 1963, p. 210), on Beachy Head (*ibid.* p. 221) and at Ivinghoe (Brown 1964) it can be shown that the coombes themselves contain deposits belonging to Zones I, II and III; they must, therefore, have been cut during or before Zone I of the Late-Glacial.

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