STONE PAVEMENTS IN SOILS OF CAERNARVONSHIRE, NORTH WALES

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Summary

In Caernarvonshire, North Wales, some soil profiles contain a concentration of stones as a layer, a single stone thick, which separates lower horizons of glacial drift from upper colluvial horizons. These layers, stone pavements, are believed to have formed as lag deposits (erosion pavements) on eroded drift surfaces which were then covered by colluvium. The formation and burial of the pavements may be attributed to periglacial and solifluction processes in the Late Glacial period. Local preservation of stone pavements suggests more widespread distribution of soils in which horizon differentiation results in part from depositional rather than pedological processes.

Introduction

CONCENTRATIONS of stones forming thin sub-surface strata in soil profiles have been described as *stone lines* (Sharpe, 1938), defined by Ruhe (1958) as narrow layers of coarse fragments, frequently one stone thick, within a soil profile. Ruhe stated that stone lines were generally overlain by fine-textured sediments. Parizek and Woodruff (1957) noted that the appearance of a stone line in cross-section was a partial exposure of a three-dimensional feature for which they proposed the name *carpedolith*. These features were ascribed to either sub-surface formation by soil-creep or to burial of former surface deposits. There are grounds for preferring the latter explanation for most examples, including those to be described here. The simpler term, *stone pavement*, is thought preferable to carpedolith, by analogy with *erosion pavement* (lag deposit), which was defined by Shaw (1929) as a surface covering of stone and gravel produced by sheet erosion.

Observations. Stone pavements have been seen in soil profile pits and sections at scattered sites in Caernarvonshire. In section they are a fairly closely packed line of stones forming a conspicuous concentration in a layer approximately parallel to the ground surface, long axes of individual stones being parallel to the general slope of the stone pavement as a whole.

Site and profile data for four stone-pavement sites are summarized in Table 1. The clearest exposures are found in long sections such as that of Site 1, of which a photograph is given in Ball (1963, pl. 12*a*). In soil-profile pits the pavement is found as a stratum of flat-bedded stones. The four pavements have some features in common (Table 1). They all overlie local Snowdonian boulder clay and are overlain by various deposits which can be broadly grouped as colluvial. There are, however, differences in the nature of the 'colluvium', in the size range of the pavement stones, in the Major Soil Group to which the profile which includes or overlies the pavement belongs, and in the slope and aspect

TABLE I

Site and Profile Summary for Stone Pavement Profiles

Site	*Grid reference (OS sheet 107)*	*Altitude, aspect, slope*	*Sub-pavement material*	*Depth and composition of pavement*	*Material above pavement*	*Major Soil Group and Soil Series*
1 Groes, *c.* 2¼ miles S of Conway on B 5106. Road-widening section now obscured, exposure length about 50 ft. (Pl. 12*a*, p. 95, Ball, 1963.	SH 777737	230 ft O.D. NNW Gentle (10–15°)	Local Snowdonian boulder clay with loam matrix and stones derived from Ordovician and Silurian sediments plus Ordovician igneous rocks. Boulder clay as pockets among shale *in situ*.	Depth: 20 in. Rounded stones, averaging 1–4 in. diameter, lithologically similar to stones in underlying boulder clay.	Loam to silty loam with relatively few stones, also rounded and drift-derived.	Brown Earth. Denbigh series (Profile Cn 71, p. 143, Ball, 1963).
2 Gorswen, Coed Gorswen National Nature Reserve,[1] *c.* 3¼ miles SSW of Conway. Profile pit.	759710	220 ft O.D. NE Gentle (5–10°)	Bouldery Snowdonian boulder-clay of loam texture, lithology as 1.	Depth: 16 in. Rounded stones, averaging 9–15 in. diam., lithologically similar to stones in underlying boulder clay.	Almost stoneless loam.	Non-calcareous Gley. Cegin series (Profile C, p. 35, Ball, 1960).
3 Bwlch y Ddeufaen, *c.* 5¾ miles SW of Conway. Profile pit.	719713	1300 ft O.D. SW Moderate (15–25°)	Bouldery Snowdonian boulder-clay of loam texture, stones being mainly igneous.	Depth: 24 in. Rounded and sub-angular stones, mainly rhyolite with veinquartz as present in underlying drift averaging 6–12 in diam.	Thin peat with tree remains immediately above pavement, and overlain by organic sandy loam.	Peaty Gley variant. In Ynys-Pentir complex, cf. Pentir series.
4 Llyn Dinas, *c.* 2 miles NE of Beddgelert. Small quarry, intermittently worked, described as exposed in 1958.	617498	250 ft O.D. SE Steep (30–40°)	Bouldery Snowdonian boulder clay of loam to sandy loam texture, derived from Ordovician sedimentary and igneous rocks.	Depth doubtful due to surface slips, but probably of the order of 5 ft. Very large rounded boulders up to 3–5 ft diam. lithologically similar to underlying drift.	Scree of angular stones of volcanic ash as outcropping on higher slopes with included thin buried organic horizons, and a matrix of sandy loam (*head*).	Brown Podzolic soil. In Cymmer-Peris complex, cf. Dolgarrog series.

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[1] Permits are required to visit this Reserve, to be obtained from the Regional Officer, The Nature Conservancy, Penrhos Road, Bangor.

1 in. = 2·54 cms, 1 ft = 0·305 m, 1 mile = 1·61 Km.

of the site. Table 2 gives soil texture and organic matter data for horizons immediately above and below the stone pavements. At Site 1 these properties do not change sharply at the stone pavement, but at the other sites there is an increase in clay and a fall in sand below the pavement, together with a sharp fall in organic matter. The pavements especially mark discontinuities in properties for which quantitative data are not available, in particular consistency and structure, together with quantity and/or lithology of stones. Above the pavement, structures are crumb or cloddy and consistencies generally friable, but below the pavement structures are weak and the material is initially massive and either sticky or indurated. Stones above the pavement are either of similar lithology to those below but greatly reduced in quantity, or they are equally abundant but of different lithology (e.g. site 4, Table 1).

TABLE 2

Texture and Organic Carbon in Stone Pavement Profiles

(Values for horizons immediately above and below the stone pavement)

Site	(1) *Groes*		(2) *Gorswen*		(3) *Bwlch y ddeufaen*			(4) *Dinas*	
Mechanical composition (per cent)	*Above*	*Below*	*Above*	*Below*	*Above*		*Below*	*Above*	*Below*
Clay	21	23	10	22	8	<1[1]	13	4	10
Silt (Int.)	27	29	25	29	21	14	28	17	22
Silt (Amer.)	38	33	41	39	37	22	38	25	33
Total Sand (Int.)	52	48	65	49	71	85	59	79	68
Organic C	1·2[2]	0·2	3·7[3]	0·8	15·0[3]	30·4	1·5	3·5[3]	0·3

[1] Peaty Horizon.
[2] By calculation from Loss-on-Ignition (Ball, 1964).
[3] By Tinsley's method.

Interpretation and Discussion

Three questions particularly require consideration. How were the stone pavements formed? When did they develop? What is their geological or pedological significance?

Mode of formation of the stone pavements. The stone pavements described from Caernarvonshire are of a different origin to other concentration layers of coarse particles recorded in British soils. The concentration of fine (*c.* 6 mm diam.) gravel in a horizon of 'pea-grit' at textural discontinuities in free-draining gravels of the Thames Valley has been ascribed to earthworm activity by Webster (1965). Thin horizons of sandy gravel which may in part have their origin in earthworm activity have been seen in some Caernarvonshire soils but are distinct from the stone pavements described here which are obviously not formed in this way. The junction between colluvial upper horizons and underlying drift, of 'Northern' and Snowdonian origin respectively, in two adjacent soil profiles, Cn 53, Aber series and Cn 54, Sannan series (Ball, 1963), is marked by a thin (*c.* 6 mm) horizon of sandy gravel. This may be, in part, an earthworm concentrate but because this junction is a preferred zone of lateral water movement in these footslope soils the gravel horizon has probably been produced largely by this water movement. The stone pavements are concentrates of much coarser material and do not have a sandy or gravelly matrix which acts as a preferred channel for water movement.

The formation of stone pavements has, in previous work, been ascribed mainly either to sub-surface development as a result of soil creep, or to the burial of a surface stone-accumulation. Sub-surface creep has probably operated in cases where trains of angular stones clearly lead upslope to buried outcrops but cannot explain the orientation of lines of drift-derived stones. Ruhe (1958) discussing his and previous work concludes that most often the stone lines (pavements) were produced through erosion by running water which removed finer material and allowed stones to accumulate as a protective lag-deposit, which was later buried. This explanation is considered to account for the stone pavements described here.

Development of the pavements. It is possible that not all the pavements are of the same age but to assume comparable ages is a reasonable working hypothesis. No absolute dating can be given although this might be obtained from ^{14}C or pollen data. The two most probable periods of formation are Late-Glacial or early Post-Glacial. There is no evidence of recent disturbance of upper horizons at the four sites. The soil profile types have a degree of profile development in their respective Major Soil Groups similar to that found at comparable sites in the area without stone pavements. Burial of the pavement must have rapidly followed formation because it is unlikely otherwise that a thin horizon of pavement type would remain well defined. At Site 4 (Table 1) the stone pavement occurs beneath head that may be dated as Late-Glacial, there being no evidence to show that massive frost-shattering and solifluction movements have accumulated material of this type in the Post-Glacial period. Glacial drift sections examined by Dr. J. Whittow and the writer in Anglesey and SW Caernarvonshire have contained stone pavements marking erosion surfaces beneath uppermost solifluction deposits (not necessarily of the same date as the Snowdonian uppermost periglacial solifluction horizons). Such sections confirm that, during thaw periods under periglacial conditions, stone pavements can be produced. The size of the boulders and stones in the pavements, especially at Sites 2–4, would demand strong surface run-off to remove finer material and allow this accumulation. This is likely only in periods when frozen subsoil prevents normal drainage. Solifluction was active in Snowdonia during the Late-Glacial pre- and post-Allerðd periods (Zones I and III) as shown by Seddon (1962) from lake sediments and pollen data. In the intervening Allerðd interstadial (Zone II) a marked spread of tree birch occurred which may be significant in relation to the thin peat with twigs which overlies the pavement at Site 3 (Table 1). Evidence has been given (Ball, 1966) that mass-movement in terms of scree-formation by periglacial frost-shattering was important in N Caernarvonshire during the Late-Glacial period. In other areas of Britain some mass-movement has been Post-Glacial (e.g. Galloway, 1961, Dimbleby, 1965) in the Pre-Boreal, Atlantic, and Sub-Boreal periods

Zones IV, VII*a* and VII*b*) so that a Post-Glacial origin cannot positively be dismissed for at least some stone-pavement sites such as Sites 1, 2, 3. When the stone pavement was originally recognized at Site 1 (Ball, 1963, p. 52) it was assumed to be Post-Glacial.

Geological and Pedological significance. On balance a Late-Glacial origin is preferred. If this is accepted, stone pavements are another feature of periglacial morphology, the recognition of which emphasizes the importance of Late-Glacial periglacial processes in distributing the surface mantle of detritus on which soil formation has proceeded over much of glaciated upland Britain. That stone pavements should be rarely preserved and found only as small patches rather than as extensive continuous features is not surprising because preservation demands a favourable interaction between erosive force and size of stones available to allow initial accumulation of an erosion pavement; rapid covering of the pavement as a protection against destruction (the circumstances which allow an almost stoneless material, poorly sorted at < 2 mm, to be deposited above the pavement at some sites are the most difficult to visualize in the whole process although most pavement sites are at or near the foot of slopes); the failure of later erosion to disturb the colluvium–pavement–boulder clay sequence; and finally, the exposure of the site accidentally in sections and profile pits. Within the limitations for discussion of such a small number of randomly located sites there appears to be a correlation between site and size of stones in the stone pavement. Site 4 where boulders are very large is in a narrow central Snowdonian valley, where scree, solifluction, and permafrost features are developed and where heavy run-off would have occurred from the Late-Glacial cwm glaciers (Seddon, 1957) of Snowdon. Sites 2 and 3 are in the upper and lower reaches respectively of a broad N Snowdonian glaciated valley, lateral to the Conway. Site 1 where the stones are of smaller size occurs more centrally in the Conway Valley on a site of gentler slope with a smaller catchment area during the postulated erosion period. Relative intensity of Late-Glacial erosion in the area may thus be suggested from these pavements in the order $4 > 2\text{–}3 > 1$. A clearer understanding of the rate and nature of these erosion processes might be obtained if further sections showing stone pavements could be located and studied in more quantitative detail.

Pedologically the interpretation of these stone pavements as erosion surface makes it clear that the profiles in which they occur are geologically complex, rather than derived simply *in situ* by pedological processes acting on a uniform deposit. Such soils, in which the result of pedological processes are superimposed on composite depositional profiles have been long recognized in North Wales, e.g. the Aber series where hill-wash of one derivation overlies lithogically dissimilar boulder clay. However, in profiles such as that at Site 1, without the presence of the stone pavement, *in situ* formation from the underlying drift would be accepted. The evidence of the stone pavements suggests that soils in which horizon differentiation results from primary depositional features as well as from pedological processes, are widespread in North Wales and probably also in other upland areas.

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