MALHAM TARN HOUSE: ITS BUILDING MATERIALS, THEIR WEATHERING AND COLONIZATION BY PLANTS

By ARTHUR RAISTRICK and OLIVER L. GILBERT

I. Introduction

For nearly a century Malham Tarn House has been one of the best known houses in West Yorkshire, through its association with Walter Morrison and with Kingsley's "Water Babies". Nevertheless it has remained a remote building, seen by most people in its setting of trees on the far shore of Malham Tarn, while both visitor and local historian have known only that it was a house used for a time as a shooting lodge by Lord Ribblesdale, and later bought and rebuilt or extended by the Morrisons.

Of its architectural history no-one has written a word. Since its occupation as a Field Centre some 20,000 students have lived in the house, asked questions which could not then be answered, and have created the need for a definitive history based upon some serious research. A close examination of the building reveals that it has had three major periods of change, two by extensive building and the last by adaptation to new uses as a Centre for Field Studies. These changes have taken place at intervals of nearly a century—around 1780, 1870 and 1950—and have been associated with Lister of Gisburn, James and Walter Morrison, and the last one with the Field Studies Council and the National Trust.

The different periods of building have seen the use of different stones and these have responded in various ways to approximately dateable periods of weathering. Under the severe climatic conditions of the area, some very important aspects of the weathering of building stones can be demonstrated. The building has also been colonized by a variety of algae, lichens and mosses which show interesting relationships to the different stones, to their weathering and to climate. For these various reasons we have thought that a short account of the history of the house, and a study of the physical and biological aspects of it, would be interesting to many of the students who enjoy the shelter of its attractive structure and the beauty of its location.

II. Architectural history

The present Tarn House stands at 1,316 ft. O.D., about 87 ft. above and 200 yds. away from the north shore of the Tarn, and has behind it the high limestone crag of Highfolds Scar which reaches 1,500 ft. The house has a history of at least 350 years of occupation, possibly much more, and an analysis of the present building and of a few fragmentary manuscripts has enabled dates of high probability to be put on the important structural changes which can only be summarized here.

Malham Tarn House

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(i) *c.* 1600 (Fig. 1, Plan 1)

The cellars under the west wing of the present house represent the ground floor rooms of an earlier house, having mullioned windows and random masonry of the period 1570-1630.

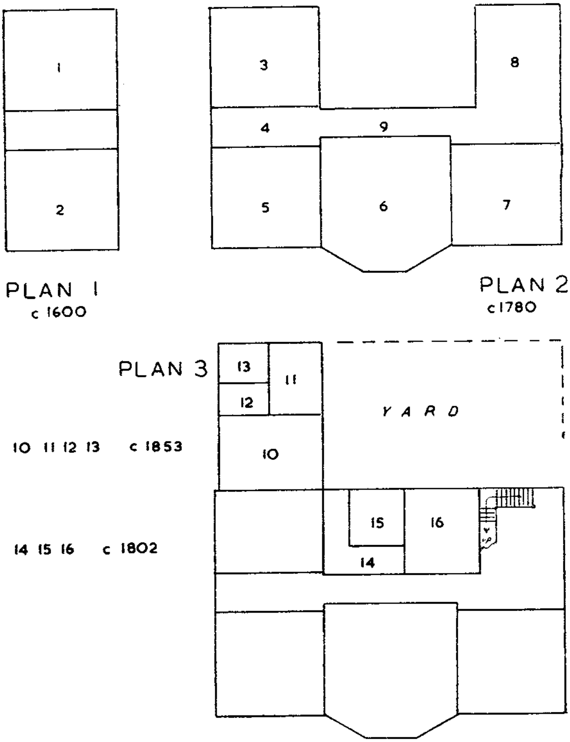

Fig. 1.
Plans of House development, *c.* 1600 to *c.* 1853.

(ii) *c.* 1780 (Fig. 1, Plan 2)

By the mid-18th century the Listers of Gisburn, who had inherited the estate, were becoming a wealthy and important family and the old house at Malham Tarn was soon replaced by something more in keeping with their social position. Thomas Lister, later to become Lord Ribblesdale, planned his new house to stand on a broad level platform which was made by digging into the scree foot behind the old house and building this material up in front, with a sharp slope which can be seen in the present lawn. The new level was made at about the first floor level of the old house, thus preserving its ground floor rooms as cellars for the new house. This was a gracious Georgian building, in carefully cut medium-grained sandstone, with large and well proportioned sash windows and a symmetrical front facing south across the lawn.

(iii) *c.* 1802 (Fig. 1, Plan 3)

An addition to the house was made by infilling the space at the back between the wings, to provide a passage and two rooms on the ground floor (14, 15, 16) and equivalent rooms above.

(iv) *c.* 1853-1855 (Fig. 1, Plan 3 and Fig. 2, Plan 4)

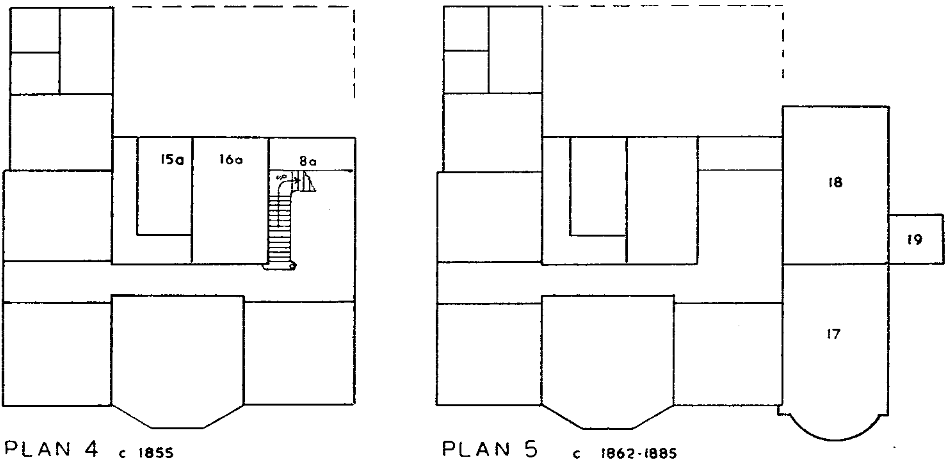

Fig. 2.

Plans of House development, *c.* 1855 and *c.* 1862-1885.

In 1852 Lord Ribblesdale sold his Malham Moor, Malham and Kirkby Malham estates to James Morrison, whose son Walter inherited them in 1857 and enjoyed them until his death in 1921. The Morrisons extended the house to its present size by two stages, neither of them easy to date exactly. The first addition was an extra kitchen-scullery block built as an extension backward from the west wing (Plan 3, rooms 10 to 13). The structure is in a new style with hammer-dressed limestone walls, with quoins, door and window framings in mason-cut yellow sandstone. This building is some inches narrower than the earlier wing on which it abuts with an unbonded outside joint. A high wall was built at the same time to enclose a small yard which completed the large rectangle of the whole house and gave room for some small service buildings. The large stable block behind the house, now laboratories and sleeping quarters, are identical in materials and style and are part of the same extension.

A year or two later, the back part of the entrance hall and rooms 15 and 16 were enlarged by taking the north wall eight feet back into the yard, thus lengthening the rooms and adding a small room to the hall (15a, 16a, 8a on Plan 4). Some of this work can be seen by a change of wall arrangement in the rooms, and to make the new room in the hall available as a cloak room it was necessary to take away the staircase which had risen along the north wall and to rebuild it to rise the opposite way.

(v) *c.* 1862-1885 (Fig. 2, Plan 5)

The last major addition to the house was carried out by Walter Morrison and consisted of a new east wing which included the present common room, library and tower (17, 18, 19). It was built with fine-grained dressed sandstone, in a style in which the influence of Ruskin, a frequent guest of Morrison, is clearly to be seen. The windows are larger and higher than in the rest of the house and the tower is in every feature suggestive of an Italian campanile. The rooms are higher also so that the first floor rooms of this new part are reached by four steps from the landing of the older part. The partition wall separating the library from the present passage to form an outer hall is comparatively recent and is seen to cut across and ignore the patterns of the floor tiling and the ceiling mouldings.

Where this new part joins the building at the back, the string course ends in a blank stop on a large block inserted into the limestone wall of the James Morrison extension, and on careful examination the bonding of the two parts of the house can be clearly seen. The glass-covered verandah across the front of the Georgian part was added during this period; the stonework of the plinth and the bases on which the cast iron columns rest are in the same stone as the east wing. The columns can be matched in pattern with many being made soon after the 1851 Great Exhibition, when firms such as the Coalbrookdale Company designed an amazing variety for the embellishment of houses and gardens, and for the rapidly growing railway stations.

(vi) 1948-1963

The house, the Tarn and its surroundings were given in 1947 by Mrs. Hutton Croft to the National Trust, who lease the property to the Field Studies Council. Minor changes only have been made to adapt Tarn House to its present use as a Field Centre and these are mainly internal partitioning, so that it remains almost as Morrison knew it. There have however been considerable structural alterations to the two stable blocks, both that near the house (now referred to as the North Wing) and the High Stables. In the North Wing the present laboratories, surrounding the main yard, were garages or stables when the Centre opened in 1948. The entrances to these have been walled up and large windows constructed in them, and additional windows made in the walls at the E and SW ends. In 1962 the archway was converted into a small laboratory and a new double garage made behind the North Wing.

Along with alterations and extensions to the house, the form of the roof has also been changed. The Georgian house of *c.* 1780 had the simplest form with a pitched roof over each wing, running north and south (Plan 2), connected by another roof over the central part (6 and 9) running east and west. When the space between the wings was filled about 1802, this new part was covered with a separate pitched roof parallel to the front (14, 15, 16). Morrison changed all this when the new east wing was added about 1870, by making a roof which was flat in its central area, with a very gently sloping surround leading to the outer portions of the earlier pitched roofs. The latter retain their slates while the rest is covered with lead. All the present roofing slates are of Silurian age and come from the Furness area of the Lake District.

III. The building materials—weathering and decay

In the course of giving expert evidence, Sir Frank Bains estimated in 1930 that in twenty five years the deterioration of buildings through the weathering of their materials by atmospheric pollution had cost various owners in this country between fifty-five and sixty million pounds. Much of this damage could have been avoided by the correct use of materials. At the Tarn House we have seen that different stones have been used in the building which vary in date by periods of up to a century, and it is possible to recognize about the house many blemishes which have arisen from the improper positioning of stone as well as from the nature of the stone and its exposure to atmospheric attack.

The materials we are to examine are the following:

(a) A medium-grained siliceous sandstone in which the grains of clear silica are cemented together by calcite and a small proportion of iron carbonate. This is used throughout the Georgian structures of *c.* 1780. The stone is very homogeneous and it is not easy to detect in it much trace of bedding or much difference in the texture of the different faces of corner stones. This stone when fresh is light creamy-grey with a pleasing and obvious granular texture. A hand lens will reveal a small proportion of iron oxides, seen in small red particles and sometimes forming small "nests".

(b) The sandstone used to frame all openings, and to make the corners, in the kitchen extension and North Wing stable block, provisionally dated to the 1850s. This is a soft, fine grained, yellow sandstone which often shows a clear bedding and in which it is easy to distinguish "side", "end" and "face".

(c) The sandstone used for the east wing extension of the house, which includes the tower, is finer-grained and a little softer than (a) and its bedding can generally be recognized. It is not so fine-grained however as (b), and has a smaller proportion of cementing material. Its porosity is not obvious; it contains numerous small pebbles of white quartz which are seen as white lumps on its cut surfaces, and by local masons these are often called "suet lumps", a good name for their appearance but totally unrelated to their hardness. This stone was used about 1870 and has had scarcely a century of exposure. Unlike the others it was used inside the house for the inner doorways of the tower and hall, in positions where it is exposed to view and has never been obscured by paint, colourwash or other treatment, so we can see it in its fresh and unweathered condition. It is a pleasant near-white stone, very different in colour from that which it assumes where exposed to the weather.

(d) Limestone has been used for the main structure of the back kitchen block, North Wing stables and the back wall of the house. It is a local, very compact, grey limestone, cut to shape with a hammer by what is called scapelling, dressing to proper rectangular shape, but leaving a surface of slightly conchoidal fracture planes which give a very attractive texture. It is free from visible fossils and large crystals or veins of calcite.

(e) A very important material is the mortar used in the different periods of building, which appears everywhere to be a normal sand-lime mixture. The thickness of the mortar between stones has been kept to a uniform and commendably thin amount, though not perhaps as thin in the newer parts as in the Georgian part of the house.

The term "weathering" is used to cover all the changes which are developed by the action of the weather on the materials of a building, and in a general sense these changes are more or less pleasant in effect, removing "rawness", developing textures in the stone, and giving an air of maturity. There are however some effects of weathering which are ugly, the more obvious being scabbing and crumbling of the stone surface, and a few which may be dangerous —loosening of undercut and carved work, breaking of cornices, and so on. These are usually spoken of as "decay" although they are only a special case of the general weathering.

If we assume that a building is made with a reasonably good stone, chosen in the first place with the necessary strength for the structure it has to support, then we can say that weathering, and particularly decay, may be caused by one or more of the following factors—atmospheric pollution, faulty handling of the stone i.e. poor craftsmanship, a design unsuited to the particular stone used, the wrong association of different stones in contact with one another, or the use of unsuitable mortars. The first element responsible for weathering is water, either as rainfall, as ground water, or as water occupying the porosity of the stone. Clean rainwater is beneficial by constantly washing the surface of a building and a very brief examination will usually show a great difference between the side of a building exposed to the prevailing wet wind and the sheltered side rarely lashed by heavy rain. The rain not only keeps the surface clean of accumulated wind-blown dust and soot, but it etches out and emphasizes a texture by carrying away some of the soluble cement in sandstones, or maintains a fresh clean surface on limestone by constant though very slight solution. The side exposed to heavy rain is also, generally, the one which gets most wind and so is rapidly dried. At Tarn House the south and west sides have most rain exposure, but they also get wind and sun and so have rapidly alternating conditions, very wet and very dry. On the north side towards the yard, there is not much direct impact of either rain or wind and no sunshine, so the conditions there are moist, with far less variation between wet and not very dry, with no direct sunshine and a lower light intensity. These are important factors in weathering and in the growth of the mosses, lichens and algae which cover parts of the building.

The most powerful ingredients in rain are due to atmospheric pollution—sulphurous and sulphuric acids from the sulphur dioxides and trioxides emitted with smoke from domestic and industrial fires which combine with the rain. Along with these there is a small content of tars and other chemical ingredients in the smoke, many of which are brought down with the rain and adhere to the stone surfaces with considerable affinity which makes them very resistant to rain wash.

This element of atmospheric pollution has been investigated at Malham Tarn, where measurements were recorded on the north shore of the Tarn from October 1957 to December 1960. A summary of the results for the year 1960 are given in Table 1, with those of selected large towns within thirty miles of the Tarn, and of Brixham in South Devon which is comparatively unpolluted. The sulphur dioxide in the air was measured by the rate of sulphation of a standard lead peroxide candle, so that the figures quoted are only empirical but are useful for comparisons. Rain collected in a standard atmospheric deposit gauge was sent away monthly for analysis and estimations were made of the dissolved and undissolved deposits in this. The totals are included in Table 1, with those from the other sites where available, and details of the deposits at Malham Tarn are shown in Table 2. The rain collected in the gauge during 1960 amounted to 51·6 inches compared to 61·8 inches in the nearby Met. Office gauge; and the pH of the rain varied between 3·8 and 6·2 with an average value of 4·6.

Table 1. *Atmospheric pollution at Malham Tarn and other localities in* 1960. (Sulphur Dioxide is expressed as mg.SO_3/cm.^{2}/day, measured by rate of sulphation of standard lead peroxide candle; deposits as tons per square mile per year.)

Site	Distance from Tarn House	Undissolved deposits	Dissolved deposits	Sulphur dioxide
Malham Tarn House	—	29·1	104·6	0·63
Leeds (Market buildings)	30 miles SE	163·3	95·6	3·37
Nelson (Walton Lane)	17 miles S	78·6	72·8	2·30
Blackburn (Daisy Street)	26 miles SW	99·1	115·0	3·13
Brixham, South Devon	—	—	—	0·28

Table 2. *Analysis of matter collected in atmospheric deposit gauge at Malham Tarn in* 1960.

	gms.	tons/sq. mile
Total undissolved matter	0·867	29·08
Soluble in CS_2	0·014	
Ash	0·341	
Other combustible matter	0·512	
Total dissolved matter	3·118	104·65
Ca^{++}	0·103	
Cl'	0·521	
SO_4''	1·056	
Total solids	3·985	133·73

The direction of the prevailing winds has some relevance to the amount of pollution in that the large industrial areas lie within thirty miles to the SW, S and SE, and in the ten years to 1961, 34% of all winds recorded at 0900 hours G.M.T. blew from these directions and can be regarded as smoke carriers. The yearly average for the period 1952 to 1961 was as follows:

wind direction	N	N.E	E	S.E	S	S.W	W	N.W	calm
days per year	16	24	40	36	34	54	90	36	36
percentage	4	6	11	10	9	15	25	10	10

As the house stands almost due north-south and east-west, we can regroup these wind directions into those which affect the different faces of the house.

winds on the north side	—	NW, N, NE	—	76 days per year
winds on the east side	—	NE, E, SE	—	100 days per year
winds on the south side	—	SE, S, SW	—	124 days per year
winds on the west side	—	SW, W, NW	—	180 days per year

We have already seen that most pollution comes from the SW, S and SE quarters and so the sides subject to these winds will receive the bulk of this.

The sulphurous acid, though very dilute, will attack calcite cement in the sandstones and the face of the limestones, and produce the relatively insoluble calcium sulphate some of which occupies the pore-spaces. On drying this sulphate crystallizes and may form a hard skin which will burst or "exfoliate", or alternatively by its larger volume may burst the surface and disintegrate the stone, making a powdery surface that is easily seen if rubbed even with a finger. The sulphate will be drawn by capillary action to a drying surface and may form an unsightly efflorescence, though this will be washed off by the next heavy rain. There may be a sharp contrast between areas which are regularly washed free of sulphate by driving rain and those under deep recesses or cornices which are not so washed. This form of decay chiefly affects limestones and calcareous sandstones and is not widespread at Tarn House except in some of the yellow sandstone of the stable block.

An examination of the main entrance to the house will show something of this undesirable weathering. The small canopy over the main door projects slightly and its outer face has weathered uniformly and well. On the underside at the top of the doorway, which can never be reached by rain, the stone is decayed, with an ugly blistered and loose surface. This is caused by a combination of factors. The stone has some porosity and when rain drives on this side of the house the face of the stone is well washed, but the body of it is saturated by water which trickles down the building onto the projecting upper surface and may be drawn further into the stone by the porosity of the layer of mortar. This water carries into the body of the stone sulphates produced from the cement of the rain-washed sandstone above, and probably in some degree from the lime-sand mortar of the joint. The deep under-surface of this block is not wetted by the rain and the sulphated water will make its way through the stone to this drier face, where it is evaporated allowing the calcium sulphate to crystallize and to accumulate. This crystallization disrupts the surface layers of the stone and produces the ugly scabbing on the inner parts. It is difficult to suggest any remedy for this kind of decay. An impervious stone or a different stone and mortar would be needed for this position, or a complete lead flashing, or even an altered design to do away with the deep recess or the cornice. A far worse example can be studied on the underside of the stone arch leading to the new laboratory in the North Wing block. Here a stone, which is attractive where submitted to the regular driving rain, looks in the underside of the arch almost rotten and can in fact be peeled off with the fingers in scabby flakes, though this is a treatment and experiment never to be tried by the enquiring student.

If the surface of the stone in the library walls or the Georgian front of the house is examined with a lens, the surface texture produced by the cement being washed away by beating rain can be appreciated. Little or no cement can be seen except occasional "nests" of iron oxide, and the stone appears to be made up of nearly detached and very clean grains of quartz. The west end of the house, soon after it was built, was covered with a lime stucco, as protection from the weather and to prevent rain driving through any porous sandstones which may have been used. The rain has dissolved lime from the surface of this stucco and left a sandy residual layer which resembles a fine sandpaper. The lime carried down the wall in solution onto the sandstone lintels and sills of the window openings has there been redeposited as rippled stalagmite up to an eighth of an inch thick. This "lime-wash" can produce a serious form of deterioration like that which can happen when limestone and sandstone blocks are built against one another in the same wall. The lime solution washed down by rain penetrates the pores of the sandstone and then, when the rain has stopped, water evaporates and some of the lime crystallizes out as calcite within the pore spaces. Capillary attraction causes the solutions to be brought back towards the drying surface, and near this any cement in the sandstone is both weakened by penetrating water and further loosened by crystallization between the grains. The whole surface becomes loose and granular and sooner or later will scab off. Such a skin examined with a lens of high magnification can be seen to pass from compact and cemented quartz grain rock, through loose grains and fresh crystals of calcite to a stalagmite skin in regular layers (Fig. 3, *4*).

Where a sandstone block has been built in beneath a limestone one, as is the case all over the North Wing stable block on the corners of the buildings, the wash of limy water over the sandstone causes this kind of decay on the surface, and usually makes an obvious fringe along the top edge of the sandstone, which becomes crumbly and discoloured (Fig. 3, *1* and *3*). It is very difficult to find a sandstone whose properties are such that it can be used in this way, in intimate contact with a limestone or calcareous rock, without setting up this deterioration close to the contact. The quoins of the North Wing buildings, particularly those of the SW corners, should be looked at to see the extent to which this decay can proceed.

An effect of porosity is seen in the mullions and jambs, the vertical members, of the windows in most parts of the house. Rain running down these sandstone blocks, and more particularly that getting into the porous stone, drains to the lower part and keeps this wetter for a longer time after the upper part has dried out, so that there is an effective movement of water carrying dissolved materials out to the surface, at the bottom eight or ten inches. This results in the usual crumbling of the front face and some crumbling of the inner faces of the sides as well. The sharp corners of the mullions dry more easily from the two sides, and are less deteriorated (Fig. 3, *2*). A similar weathering is sometimes produced when very porous sandstones are built in with lime-mortar joints which are too thick or too "fat" with lime.

The newer portion of the Tarn House has some very fine string courses and plinths, projecting horizontal mouldings, which offer an interesting example of weathering by providing a good environment for lichen. Rain running down the plain wall surface is checked at the moulding and more time is given

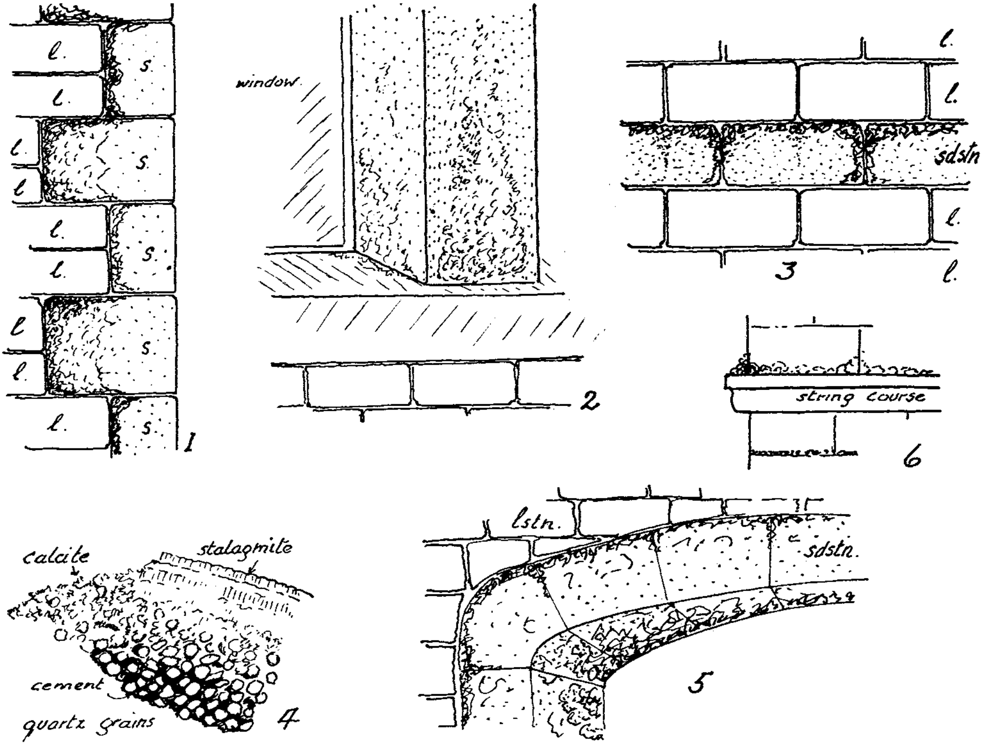

Fig. 3.

Examples of stone "decay".
1. Quoins of sandstone in a limestone wall, SW corner of stables (North Wing); *2.* Mullion, north window of Library; *3.* Course of sandstone in a limestone wall; *4.* Greatly magnified section of "skin" from sandstone sill near lime-rich stucco; *5.* Sandstone arch in limestone wall, North Wing; *6.* Lichens on a string course and on mortar joint, west wall.

for water to soak into the stone, and this may be helped by the layer of mortar at this position. The angle between the top face of the moulding and the wall thus becomes wetter and is slower to dry than the plain wall; wind blown dust accumulates and is helped to stick by the moisture, and any lichen growing there helps to perpetuate the conditions. It will be seen that many of the horizontal mouldings or slight projections carry a line of lichen which tends to spread up the face of the wall and so increase the area of moisture (Fig. 3, *6*). The lines of mortar are on some parts of the building, particularly the east front, picked out by a growth of lichen, but this is largely due to the lime content of the mortar plus the greater absorption of water.

There is another marked effect of water to be seen at the foot of the walls, particularly on the north and east sides of the house, where it is emphasized by a stronger growth of lichen. The porous sandstone of the wall base, bedded in the soil, may by capillary action draw ground water up above the ground level and this will occur particularly where soil banks up to the wall foot on the edge of the lawns. The water will rise in the stone until it reaches the level where its movement upward and its supply is balanced by evaporation. A zone at and just above ground level is thus kept wet and towards the upper limit, where evaporation is the most effective, salts will be deposited either as an efflorescence or in such a way as to form a skin and cause surface decay. On the south and east walls of the common room this area of ground water rises in some places a few inches and in some others a foot or a little more, and is clearly marked by discolouration and lichen. On the north wall of the library the ground water rises in parts above the level of the window sills, more than three times as high as on the south, and the upper limit is sometimes marked by crumbling of the stone. This difference is due to two factors: there is quicker evaporation on the south, and the principal drainage of both surface and sub-surface water is from the much higher ground on the north side and the north wall intercepts this water in its movement downhill towards the south. The porosity of the limestones is too small for this rise of ground water to occur. The ground water usually contains organic acids in solution and these can react in many ways with the cement of sandstones, and so produce a variety of decay effects. A good and properly designed damp course can prevent this water rising too far in the wall, but an attempt to make the outer wall waterproof by cement washes may turn the water to the inside where evaporation is assured by the warmer air of inside rooms. If ground water is rising at all, the wall needs to breath on the outside and keep the rise as low as possible.

A serious misplacing of some individual stones has caused a few very unsightly blemishes on the kitchen and North Wing buildings—this is what is sometimes called "face bedding". The yellow sandstone in these buildings is finely bedded, and has a quantity of mica flakes whose thin flat sheets have settled horizontally along the bedding layers. If a cube is cut from the rock in its natural position in the quarry, the bedding will be parallel to the basal and top surfaces. The four sides will form two pairs of faces or surfaces which can be called "end" and "side" and which will be at right angles to the bedding. If such a block is examined carefully it will be found that the individual layers composing it are not identical, some may be slightly larger grains, some have more mica and some may have a higher proportion of cementing material. It will be found that the porosity is generally greater along the bedding direction than across it, and also the strength of the rock in compression is much greater across the bedding. This is the simple difference between pressure put on the edges of a book and pressure placed evenly on the covers. In the first case the book would fail by the pages bending and opening out; in the second case it would merely become more and more solid and compact. When a bedded building stone is used it must be laid "on bed" though the smooth and even surface of the bed may tempt a thoughtless builder to place it on edge and so secure a smooth outer surface to his wall, without the trouble of a lot of tooling. The whole pressure of the load which the wall is carrying will tend to force open the bedding planes in such a position—water will have much easier passage vertically through this block, and any expansion of salts under the "face" or surface, will lever the whole off in large scabs or sheets. This is a surprisingly common fault in many buildings. It can be seen to a very serious extent in some of the blocks of yellow sandstone which form the surrounds of windows and doorway in the end wall of the kitchen which forms part of the main yard and in the south end-wall of the large laboratory. Some of these blocks are both scabby and recessed from the wall face, and it is often possible to see that they have been placed with the bedding vertical—a reprehensible practice which no good mason would ever allow.

There is still another defect of workmanship which can be illustrated, though fortunately not to any great extent. This is seen in some of the window framing and mullions round the back of the North Wing block. A soft sandstone, the one already referred to so often as the yellow sandstone, has been tooled to give a fancy surface, by "boasting" with a punch—a narrow pointed chisel—or with a comb—one with several points. The edges of the stone are tooled to a straight edge or narrow border and inside this the whole surface is roughened in an approximate pattern of chisel marks. Even with the sharpest tool, the jarring of a heavy hammered tool on the sandstone will produce a "star" of microscopically fine cracks through the cement and even through some of the quartz grains. Frost, water, lichen and all sorts of undesirable elements make an entry to the surface by these, and sooner or later the surface begins to crumble and lose its sharpness, producing what can only be called a shabby appearance.

IV. THE ECOLOGY OF TARN HOUSE

This large man-made habitat in the middle of great areas of semi-natural vegetation has during the last few centuries been colonized by many Bryophytes, Lichens and Algae. It was thought interesting to discover which species out of the extremely rich natural flora of the surrounding countryside have found a home on it and whether their distributions on the buildings could tell something about the conditions of moisture, pH, pollution and decay to be found there. There is probably a fairly uniform plant succession on such buildings of which we are recording a reasonably advanced, but by no means final, stage. The house is surrounded by cliffs, screes and pavements of bare limestone while the nearest appreciable exposures of sandstone and slate are over two miles away.

Lists of species or genera will be found in the Appendix, and the following frequency symbols are used throughout: a abundant, c common, f frequent, o occasional, r rare.

(1) *Bryophytes*

The annual rainfall of 58 inches keeps parts of the house damp enough for Bryophytes to grow luxuriantly. Twenty-three mosses and two liverworts have been found on it. These are reliable indicators of certain habitat conditions, the species changing in response to aspect, rock type and height above ground level in a well defined pattern. The details and significance of their distributions will be discussed.

The north face of the library is a 28 ft. high wall of cut medium-grained sandstone rising up from the gravel of the drive. The wall has a sandstone plinth which provides a two inch ledge at 6 inches and there are other ledges at 2 ft. 6 in., 12 ft. and 19 ft. Bryophytes are concentrated on the plinth where ten species can be found, some of them abundantly. Elsewhere on this face they are sparse and only on the two lowest ledges.

Sandstone plinth		*2 ft. 6 in. & 12 ft. ledges*	
Amblystegium serpens	o	Barbula rigidula	o
Barbula rigidula	c	Brachythecium populeum	r
Bryum argenteum	o	Bryum capillare	o
Bryum capillare	f	Cratoneuron filicinum	r
Bryum pseudotriquetrum	o	Ditrichum flexicaule	r
Ceratodon purpureus	o	Tortula muralis	o
Grimmia apocarpa	r		
Mnium hornum	o		
Tortula muralis	c		
Marchantia polymorpha	o		

This distribution pattern is largely controlled by ground-water which rises up the wall by capillary action keeping the lower parts damp long after the rest has dried out. Where a grid leading down to a coke hole abuts against the plinth, the action of ground-water has been eliminated and here the plinth is completely bare. A large paving-stone set against the base of the wall has had a similar effect by keeping the ground under it dry (Fig. 4).

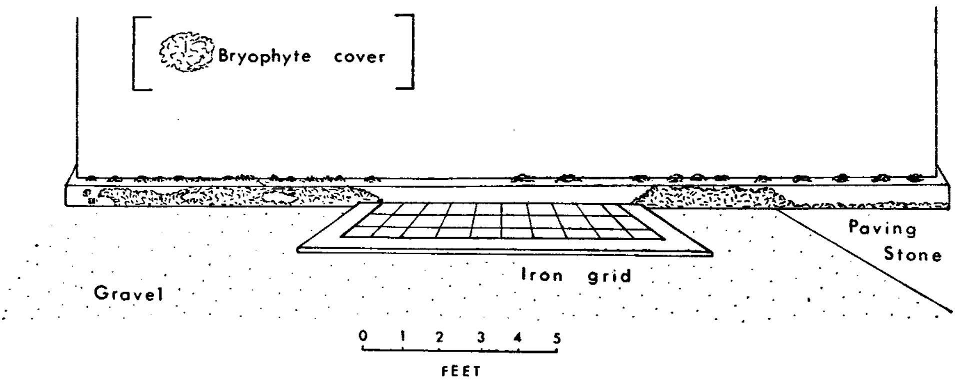

Fig. 4.

Lower part of north face of library, showing distribution of Bryophytes on the sandstone.

The influence of rising ground-water can be seen in many places round the base of the buildings. The east wall of the North Wing, and north wall of the kitchen block show its effect on limestone. Here a Bryophyte line occurs at 2-3 ft., below which mosses are frequent. The highest parts of this Bryophyte zone are the dryest and are occupied by cushions of *Bryum capillare* and *Tortula muralis*. The *Bryum* needs a largish ledge or crack in the mortar, while *Tortula* is chiefly on the smaller steeper ledges. Lower down these two mingle with *Barbula rigidula*, *Cratoneuron filicinum* and *Bryum argenteum*, both the ledges of the mortar and the vertical faces of the limestone blocks being occupied.

On south facing walls ground-water effects are reduced by the more rapid evaporation, so that Bryophytes are rare on the kerb of the verandah and the base of the common room. Much of the north wall of the house is partially protected from capillary rise by closely laid paving-stones, which in the kitchen yard bring the Bryophyte line down to only a few inches. Here the splash zone round drains is carpeted with the moisture-loving *Bryum pseudotriquetrum*, *Cratoneuron filicinum* and various others.

The buildings provide only two places suitable for calcifuge mosses. Out of sight to most people, many large yellowish-green mats of the upland moss *Rhacomitrium fasciculare* flourish on the sandstone flags which cap the wall on the south side of the main yard, and just as secretly large cushions of *Pohlia nutans* are growing anchored between the slates of the North Wing roof. *Pohlia* grows well on the decaying peat of Tarn Moss 600 yds. away, but *Rhacomitrium* will have had to travel much further. These are the only strongly calcifuge mosses on the buildings. Other places where they might be expected, such as the base of the sandstone walls, are rendered less acid than they would otherwise be by water rising out of the limestone drift which is banked all round the house. *Mnium hornum* is a mildly calcifuge moss restricted to such positions. The sandstone plinth along the west side of the house is rendered slightly more alkaline by flushing from the stucco faced wall above. This brings a few calcicole elements, such as *Plagiochila asplenioides* and *Cratoneuron filicinum* into its Bryophyte cover.

The presence of calcicole mosses such as *Ditrichum flexicaule* and *Cratoneuron filicinum* high up on the ledges of sandstone faces was at first puzzling. Investigation showed however that they were anchored in the thin line of mortar at the back of the ledges. The accumulation on these horizontal surfaces of a little soil formed by particles of stone, lichen and dust weathering off the faces above helps to make such habitats less xerophytic.

The walls of the main buildings, backed often by centrally heated rooms, constructed of cut or well-shaped stone and bound with hard smooth mortar, are not ideal for Bryophtes as they dry out first and offer few places for anchorage. In contrast the 10 ft. high wall between the main yard and the kitchen yard is of roughly hewn limestone and the coarse mortar has crumbled back to provide numerous ledges and recesses at all heights. On its northern side twelve species of Bryophyte occur, some of them abundantly.

South Wall of main yard

Barbula convoluta	Ceratodon purpureus
Barbula cylindrica	Cratoneuron filicinum
Barbula recurvirostra	Encalypta streptocarpa
Barbula rigidula	Seligeria sp.
Bryum capillare	Tortula muralis
Bryum pseudotriquetrum	Marchantia polymorpha

Commonest is *Encalypta streptocarpa*, which has rosettes of light green, tongue-shaped leaves giving it the appearance of a minute lettuce. Loose tufts of it are abundant on the crumbling mortar everywhere. It is a strict calcicole which likes shelter. *Tortula muralis* looking like a very small *Encalypta* but with hair points to its leaves is common on the limestone and mortar low down. Above 2 ft. it is only on the mortar and above 3 ft. it peters out. This moss, the commonest on the house and one of the commonest on walls throughout the country, is curiously restricted away from man-made habitats. The other Bryophytes are all concentrated on the lower third of the wall and these chiefly on the mortar. Most are small acrocarps which need shelter and a high concentration of nutrient salts. *Barbula recurvirostra* is only where a little soil has accumulated on ledges. *Marchantia*, *Bryum pseudotriquetrum* and *Cratoneuron* like the wetness at the very base. From the distribution patterns on this wall it appears that water is absorbed, held and conducted better by mortar than by Great Scar Limestone, hence the limestone faces except at the very base are free from moss.

On the exposed sandstone ridge tiles of the North Wing roof grows an assemblage of mosses with a weedy flavour, more typically found in and around a town or village. It is strongly influenced probably by smoke from the house chimneys and dust kicked up in the yard.

Ridge tiles of roof

Barbula rigidula	Grimmia apocarpa
Bryum argenteum	Grimmia pulvinata
Bryum capillare	Orthotrichum diaphanum
Ceratodon purpureus	Tortula muralis

The main ridge of this roof, 76 ft. long and pitching north and south at 29 degrees, provides an opportunity for the investigation of aspect on the Bryophyte cover. Dense silvery-grey patches of *Bryum argenteum* dominate the south side, filling the cracks in the stone and creeping a little way down the slates. It is commoner up here on the roof than for some distance around the Tarn; the north side of the ridge has only minute traces of it. Another moss which prefers the warmer south side is *Grimmia pulvinata*. Both species have a mainly lowland distribution and at this altitude are successful only in the warmest and driest places. *Bryum capillare* and *Barbula rigidula* are predominantly on the north side where they appreciate the extra dampness. The other four species appear to be indifferent to aspect, but *Tortula muralis* fruits best on the northern side. Small fragments of this community can be seen around the tops of used and disused chimney stacks where smoke pollution is intense enough to blacken the stone. *Bryum argenteum*, *Ceratodon* and *Tortula* seem to be especially tolerant of this factor.

The surfaces of slate roofs are not suitable for Bryophytes which prefer a softer more porous stone. Although they can find anchorage in the cracks between the slates, such places are usually too dry and the huge areas of slate on the roof of the main house are completely devoid of Bryophytes. The slate roof of the North Wing however does support a moss flora. It is overhung by a larch tree, the short needles of which are shed annually choking the gutters; some become lodged between the slates and over the years there has been a considerable build-up of organic matter under them. By holding moisture during long dry spells this humus makes the habitat less extreme and several mosses, *Pohlia nutans*, *Bryum argenteum* and *Tortula muralis*, find a home there. Later these mosses by their own decay contribute to the humus under the slates. The older *Pohlia* cushions become quite spherical and high, and as they have only a small area of attachment many must eventually be blown away or swept off by sliding snow.

Bryophytes show a great diversity of growth form and can be divided very roughly into cushions, carpets, mats, wefts, canopy formers and thallose forms (Gimingham and Birse, 1957). Cushions predominate on roof tops, high ledges and southern aspects where their compact growth and crowded leaves hold water well, maintaining the turgor of the actively assimilating leaves of the whole cushion for long periods. All mosses on the house above 2 ft. 6 in. (with three exceptions) have this habit. The chief exception is *Brachythecium populeum*, a mat-forming epiphyte from the plantations which has become established on some of the higher ledges. *Orthotrichum diaphanum* is another epiphyte which finds high exposed ledges, especially west-facing ones, a substitute for tree trunks. On plinths and wall bases the cushions are joined by mat-formers (*Cratoneuron filicinum*, *Amblystegium serpens*) and wefts (*Eurhynchium confertum*). These growth forms hold water less well than the cushions. Carpets, such as *Mnium hornum*, *Encalypta* and *Bryum pseudotriquetrum*, are less easily dried out than the pleurocarps and extend a greater distance up the walls. *Marchantia* with its broad flat thallus is very closely restricted by its need for a constantly damp niche and all its stations are on the lowest inch or two of walls which get no direct sunlight. Several mosses are plastic and can produce neat cushions on the dry ridge of the North Wing roof and carpets on the plinths: *Tortula*, *Bryum capillare*, *B. argenteum*.

It is puzzling that none of the large calcicole mosses so abundant on cliffs, screes and drystone walls near the Tarn (Proctor, 1960) are found on the house. The absentees include *Ctenidium molluscum*, *Camptothecium sericeum*, *Hypnum cupressiforme*, *Neckera crispa* and *Tortella tortuosa*. The north-facing wall of the yard would appear suitable for all these and also for the small shade-loving *Fissidens cristatus*. Another problem is the absence of Bryophytes on the plinth of the east wall of the common room. It is unlikely to be due to excess evaporation as the sun leaves this face before mid-day. Possibly in its more affluent days the house was demossed from time to time, a process which is continuing in an unsuspected way. Soon hot car exhaust will have spoilt the fine display on the library as it has done a few yards away on the east wall of the kitchen yard.

(2) *Algae*

Most algae are invisible to the naked eye and so it was impossible to study their distributions as thoroughly or by the same methods used for the other groups. Small areas of the different stones were scraped with a penknife and the scrapings were then examined in water. In this way all the major habitats of the house were sampled. Sometimes a green tinge to the stone indicates the presence of algae, but more often a surface quite rich in them looks bare. It emerged that water conditions are far more important than any other factor in determining the distribution of the algal genera; had identifications been made to specific level, variations in pH might be more influential.

South-facing walls are subject to violent rain-lash alternating with long periods of drought. This produces conditions too extreme for most free-living algae. Scraping the coarse sandstone at a height of 6 ft. on the south face of the common room produced only pollen grains, fungal spores, pieces of quartz, zircon and garnet, small fragments of lichens and a few cells of unidentifiable green and blue-green algae.

Exposed south-facing limestone at the SW corner of the North Wing was equally barren, a scraping of about 4 sq. ins. yielding a few little green cells and a trace of *Trentepohlia*. Under the foliose colonies of the lichens *Physcia* and *Xanthoria* which grow on this limestone face, diatoms were found to be very abundant. This was totally unexpected since the bare limestone had been so unproductive. Further lines of investigation suggest themselves: does the lichen help in the nutrition of the algae or is it purely physical benefit like shading?

The base of the mossy north-facing walls, around drains and behind leaky pipes are the richest places on the buildings for algae. They are also the dampest. The lists below are from the sandstone plinth along the north face of the library and from sheltered limestone on the south side of the main yard. Both scrapings were from an area of about 1 sq. inch.

Damp sandstone		*Damp limestone*	
Chlorella	Nitzschia	Aphanothece	Protococcus
Coccomyxa	Protococcus	Cylindrocystis	Trebouxia
Gloeocapsa	Stichococcus	Hormidium	Trentepohlia
Gloeothece	Trebouxia	Navicula	Vaucheria
Hormidium	Trentepohlia	Nitzschia	Phormidium
Mesotaenium	Vaucheria		

These lists cannot be used to make any valid comparisons between the two habitats as the scrapings were from such small areas. It can be seen however that both sites are rich in algae and that several are common members of the soil flora (*Vaucheria*, *Nitzschia*, *Hormidium*, *Stichococcus*).

High up under the projecting eaves of the North Wing block and of the kitchen extension, thick deposits of *Protococcus viridis* Ag. lie on the ledges of the mortar and in the deeper scallops of the limestone. This pale green blanket extends for 8 ft. down north-facing walls and 2 ft. down south-facing ones, which illustrates its preference for reduced illumination and freedom from direct rain. It is able to obtain its water from vapour. In summer there were many diatoms mixed up with the *Protococcus* but these died down to insignificant proportions in winter.

The most conspicuous alga on the house is *Trentepohlia*, which has a brick red or orange thallus and is often so abundant that it gives a distinct red colour to whole walls. This is a filamentous green alga in which the green colour is masked by a red pigment, haematochrome, and it is easily identified under the microscope by the branched filaments of short cells packed with red oil globules. It is common on all but south-facing limestone and reaches its maximum development on the north faces. Here most of the stones are encrusted with its crumbly almost yeast-like thallus. On the dry limestone under glass at the back door it forms a beautiful pattern of red on the stone, alternating with pale green *Protococcus* on the mortar. It is also frequent on lime-rich stucco where it produces circular dark red colonies. *Trentepohlia* appears to demand a fairly high concentration of nutrient salts, but is not a strict calcicole as it is widespread on slightly flushed sandstone where the growth form is more fluffy and the colour bright orange. Sites on sandstone include the doorway under the bell, top of the archway, base of the library wall and all window frames set in limestone walls. Other algae found on flushed sandstone include *Phormidium* and *Synechococcus*.

Algae of various kinds are present in all lichen thalli. The algal species is usually constant in a given species of lichen and it must normally be present in a free-living form before a lichen can develop, so that a knowledge of the algal partners in the various lichens of the house can give additional information about the normal algal cover. The following eight species occur on the buildings as lichen symbionts.

Cyanophyta	*Chlorophyceae*
Nostoc (Leptogium)	Chlorella (Cladonia)
Scytonema (Placynthium)	Coccobotrys (Verrucaria nigrescens)
	Trebouxia (various)
	Palmella (Crocynia)
	Protococcus (various)
	Trentepohlia (Gyalecta cupularis)

Lichens containing green algae (Chlorophyceae) are usually grey in colour and have a firm consistency when moist. Those employing blue-green algae (Cyanophyta) are black or brown and gelatinous when wet. There is still disagreement concerning the identity of the unicellular green alga so common in the majority of lichens. British authors (Smith, A. L., 1921; Duncan, 1959) regard it as belonging to the *Protococcus* group, while in America it is believed to be *Trebouxia* (Hale, 1961). Eight lichen species from the house, representing five genera (*Candelariella*, *Evernia*, *Lecanora*, *Lecidea*, *Platysma*) all contained *Trebouxia* as the algal partner. Occasionally Protococcus cells were present on specimens from sheltered walls, but they were never associated with hyphae nor could they be found after the lichen had been washed.

To sum up, the algal cover of the house is fairly complete, but thins out on slate roofs and southern aspects. Below the capillary damp line they are plentiful and in great variety, above it unicellular forms predominate with the exception of *Trentepohlia* on the limestone. This species together with *Protococcus* and diatoms are the dominant algae on the building.

(3) *Lichens*

Lichens, having a thallus composed of algal and fungal cells, are able to grow in places which are quite unsuitable for other forms of plant life. Their unique physiology gives them a special ability to survive desiccation and accumulate nutrients from very dilute solutions, and they have no problems of attachment to vertical surfaces; all factors which combine to make them the most successful colonizers of the house. Over thirty species occur on the buildings, including some which are such sensitive indicators of habitat conditions that the slightest changes of pH can be traced, and one—*Lecidea lucida*—can distinguish between the sandstone used in the 1852 constructions and the others. Enough descriptive notes are given here for the non-specialist to identify the majority of the species.

Lime Stucco. The lime stucco on the western side of the house supports a very simple community of three calcicole species. The general surface is thickly covered with white colonies of *Lecanora albescens f. dispersa* (f), chaffy yellow ones of *Caloplaca citrina* (f) and groups of reddish-brown apothecia which mark those of *Protoblastenia rupestris* (a). These three lichens, common on lime stucco and concrete fence posts throughout the country, total over 99% of the lichens on this face. The yellow colonies of *Caloplaca* are especially conspicuous on the big rain track which leads down from a leaky gutter, and below the capillary damp line which here has a height of about 1 ft. 6 in. This it marks very accurately showing the sudden dips in response to cellar grids and a rise over the kitchen drain (Fig. 5), indicating that *Caloplaca* can tolerate damper situations than the other two species, which below the damp line are only occasional (*Protoblastenia*) or rare (*Lecanora*).

The latter grows best around crumbling holes in the surface and where parts of the wall have been refaced with new stucco. These places have a better supply of calcium and are white with abundant fruiting colonies of *Lecanora*. The largest patch of new stucco is below the landing window and there are others where pipes come through the wall. *Protoblastenia* prefers the original, by now somewhat leached, surfaces. Tests showed that the old stucco has a lower pH than the new and in the future this lichen will probably increase on such areas, as leaching reduces the vigour of its more robust associates.

Limestone. The North Wing block and kitchen extension provide limestone faces over 100 years old. There is abundant colonizing material blowing on to them from the surrounding lichen covered cliffs, screes and pavements (Sinker, 1960) and they were expected to have a rich flora. South faces have a sparse cover which includes eleven of the commonest species of the natural limestone. This is a good variety but the colonies are mostly small and widely spaced. The most abundant lichen is *Lecanora albescens f. dispersa*, which from experience gained examining gravestones is the first lichen to colonize fresh limestone surfaces. It is much commoner on the house than on the surrounding hills and probably needs a chemically unweathered surface. *Caloplaca citrina* is also common but chiefly on the mortar. In exposed places the mortar has become so leached that *Candelariella vitellina* can grow on it. This species, usually on sandstone, has a yellow thallus and fruits which can be separated from *Caloplaca citrina* by a chemical test. A drop of 50% KOH will turn the *Caloplaca* red (K+r) and leave *Candelariella* unaffected (K–r). Under natural conditions Great Scar Limestone becomes covered with crustose *Lecidea* spp. and *Verrucaria* spp. especially those with immersed fruiting bodies. Such types which represent an advanced stage in the lichen succession are still infrequent on the house and probably need a surface which is chemically well-weathered to enable the fungal hyphae to penetrate. The following species can be found: (a) *Verrucaria sphinctrina* with a thin chalky white thallus into which are sunk numerous minute perithecia. On decaying they leave neat round holes in the rock. (b) *Lecidea immersa* is superficially similar but has larger, more widely spaced apothecia which leave deeper pits. (c) *Verrucaria nigrescens* and *Placynthium nigrum* (mainly on west-facing limestone) form circular dull black colonies.

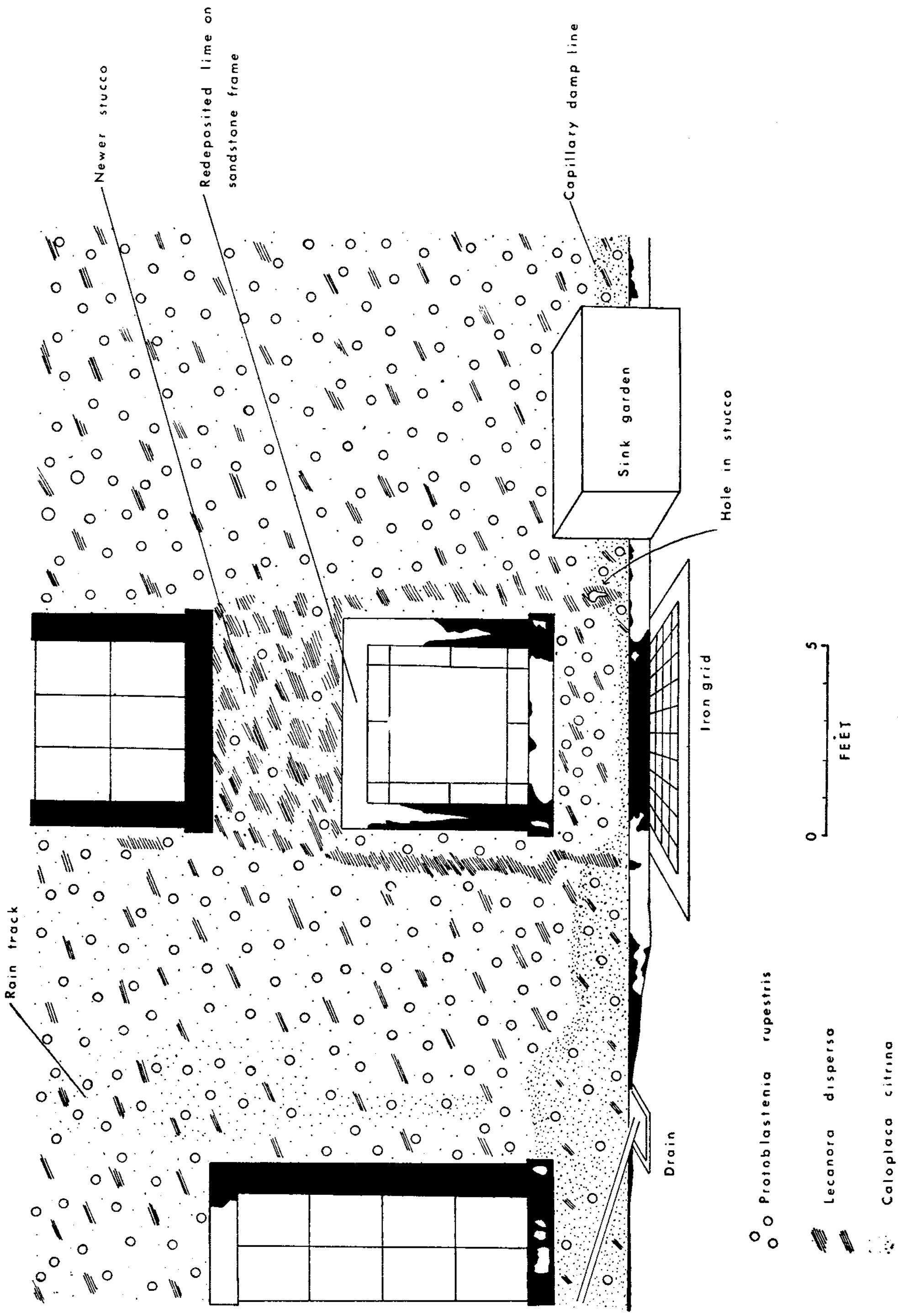
Newer stucco
Redeposited lime on sandstone frame
Capillary damp line
Sink garden
Hole in stucco
Iron grid
0
5
FEET
Rain track
Drain
Protoblastenia rupestris
Lecanora dispersa
Caloplaca citrina

FIG. 5

When moistened with a finger, the surface of the latter feels slightly gelatinous as it contains the blue-green alga *Scytonema*.

North-facing limestone is poorer in species than south-facing, but being more sheltered it has some special lichens of its own. The pink cups of *Gyalecta cupularis* are almost restricted to mortar on the north side of the yard wall, where the conditions of dampness, shade and high pH suit it. On the same wall orbicular felty white colonies of the sterile lichen *Crocynia membranacea* can be found. It also occurs abundantly inside dry stone walls. Another sterile species of sheltered limestone is *Caloplaca xantholyta*. There is a huge patch of its powdery, dull yellow thallus on the wall to the west of the new garages. Shade lichens like these are rare because the amount of chlorophyll in a typical thallus is only one tenth to one quarter that of a green plant (Hale, 1961), so to attain even a slow growth rate they must be well illuminated. It used to be thought that carbohydrate metabolism was the limiting factor imposing a slow rate of growth on lichens, but recent work suggests that protein synthesis is more limiting.

Sandstone. There are large sandstone walls facing north, east and south. A verandah has been built against one and others are flushed by limey water, so that their uniformity is broken and they provide more varied conditions than can be found on the limestone. The nearest areas of similar rock are several miles away but there appears to be no lack of colonizing material. Some species, such as *Lecanora atra*, will have come from afar, but others such as *Lecanora conizaeoides* grow abundantly only a few yards away on tree trunks in the plantation.

Rising ground water keeps the lowest parts of north-facing walls too damp for lichens. The success of lichen symbiosis depends upon a delicate balance of relatively prolonged desiccation alternating with brief periods of moisture. If kept wet and in an active metabolic state for too long the fungus overwhelms the algal host, and left without a source of carbohydrate the lichen dies (Hale, 1961). A few species with blue-green algae prefer damp situations; one of these, *Leptogium lichenoides*, grows among moss in the main yard.

Above this wet zone on the north face of the library are thick, pale grey, powdery masses of *Lepraria incana*. It is dominant for about three feet up the face, where it is still in the capillary damp zone. The only other lichen here, *Lecanora conizaeoides*, is abundant below eight feet but above this its greenish grey, crustose thallus becomes thin and diffuse. The paucity of lichens on the vertical sandstone parts of this sheltered face—two species—requires explanation in view of the twelve or more species on sandstone with a southern aspect. The limey mortar between the sandstone blocks is fairly thickly encrusted with *Lecidea lucida*, *Crocynia membranacea* and the alga *Trentepohlia*. *Lepraria incana* and *Crocynia membranacea* are two difficult lichens of sheltered habitats. All sterile grey powdery lichens on sandstone have been placed under the former, the white more or less determinate ones on basic substrata under the latter species.

Fig. 5. (opposite)

Part of west side of Tarn House, showing diagrammatically the distribution of lichens on the lime stucco. Black represents sandstone without redeposited lime on it.

Included as south-facing sandstone is the bow-shaped end of the common room and the rest of that side of the house above the verandah. This is the most exposed stone in terms of wind, rain lash and sun. *Lecanora conizaeoides* is very common, occupying faces and ledges right up to the top; it produces abundant irregular apothecia especially on the window mouldings. The granular, mustard-yellow thallus of *Candelariella vitellina* is most abundant low down but gets on to all the first floor window sills. It thrives best where it has slight contact with alkaline water from the mortar. *Lecanora atra*, *L. intricata*, *L. polytropa*, *Lecidea leucophaea* and *Acarospora fuscata* are all scattered over the face. *Lepraria* is present only in the very deepest recesses, sheltered places usually occupied by the ubiquitous *L. conizaeoides*. Add to this numerous colonies of *L. albescens* on the mortar and six foliose and fruticose species on the upper parts of the face and some idea is got of the tremendous differences between north and south aspects.

It is well known that lichens grow most luxuriantly well away from smoky towns where atmospheric pollution, especially in the form of sulphur dioxide fumes, are absorbed and concentrated in the algal part of the thallus till it becomes lethal. A few lichens are tolerant of sulphur dioxide poisoning, among the best known being *L. albescens*, *Candelariella* and *L. conizaeoides* (Jones, 1952), the three commonest lichens on the house. The amount of pollution which reaches the house is considerable (see Tables I and II). It affects all aspects, but quickly gets washed off the exposed ones by the rain which averages 58 inches in a year, falling on about 220 days. On very few days does it come from the north, and so pollution accumulates on this aspect, severely restricting the lichen flora. The effect is not so marked on limestone or mortar where the sulphur dioxide is neutralized to form calcium sulphate.

A community of foliose and fruticose lichens similar to that growing on some of the older trees in the plantations occurs on the most exposed sandstone:

Hypogymnia physodes	Parmelia saxatilis
Platysma glaucum	Parmelia sulcata
Evernia furfuracea	Cladonia coniocraea

It is well developed high up on the SSW-facing arc of the common room bow, on the very exposed ridge-tiles of the North Wing roof and the top of the yard wall. It is easier to describe its distribution than to explain it. Possibly the propagules of these species have difficulty landing on the house and can achieve this only by impaction at high speeds or by settling on horizontal ledges during very calm nights.

East-facing sandstone carries an impoverished flora of the south-facing type. With the exception of *Lecanora conizaeoides*, lichens over most of the face are markedly restricted to the mortar where calcium can be found and acidity will be neutralized. The yellow to brown convex apothecia of *Lecanora polytropa* are commoner here than elsewhere on the buildings and a new species is *Bilimbia sabuletorum*.

Viewed from a distance the clean buff sandstone under the verandah contrasts sharply with the wall above it which is covered with the grey-green *Lecanora conizaeoides*. Few lichens have overcome the severe drought, accumulated pollution and lack of nutrients which prevail there. Those which have

—*Candelariella*, *L. albescens* and *L. conizaeoides*—are depauperate and seem dependent on the thin lines of mortar for their nutrients. They are only on the lowest three feet of the wall, where suitable rain-bearing winds occasionally saturate them with water (Fig. 6). Under the verandah at the back door, yellow-green streaks of *Lecidea lucida* are conspicuous on window frames.

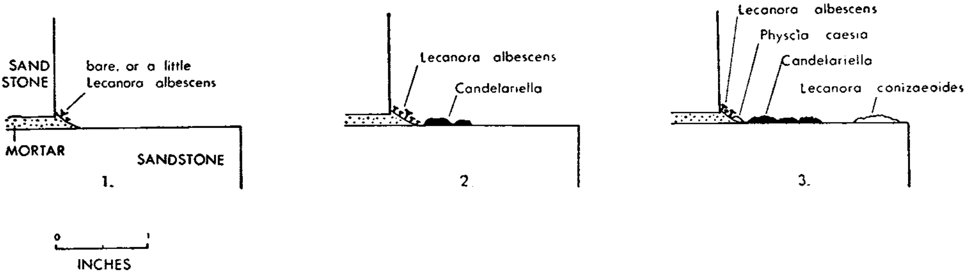

Fig. 6.

Diagrammatic sections across the 2 in. wide ledge, three feet above ground level, under the south verandah.

The biggest problems faced by lichens in dry places are the need for an appreciable supply of water for normal metabolism and growth—*L. lucida* must by reason of its sheltered position be able to obtain sufficient from vapour —and the difficulty of getting sufficient nutrients, as most of these are obtained from the very small amounts in rainwater. On average, rain in 1962 contained 0·7 p.p.m. of ammonia nitrogen (expressed as N) and 0·03 p.p.m. of soluble phosphorus (expressed as P). Taken over the year the amount of ammonia nitrogen is appreciable, whereas the amount of phosphorus is very low but over the life span of a lichen this might be the major source of this essential element. Where a leak of water and nutrients has occurred down the back of the south verandah there is a streak of *L. conizaeoides*, a cluster of *L. atra* and some algae.

Other sandstones include door and window frames, quoins and the top of the yard wall. In the last-named habitat, large mats of *Rhacomitrium fasciculare* support several fruiting patches of *Cladonia coniocraea*, though this moss is frequently stated to be uncongenial for colonization by other plants (Watson, 1955). Window sills on the west side of the North Wing have communities of the nitrophilous lichens *Physcia caesia*, *P. adscendens*, *Xanthoria parietina* and *Candelariella*. These are quiet window sills much used by birds from the plantation. Water entering window jambs and mullions gravitates to the bottom where it drains out of the mortar joint (Fig. 3, *2*), keeping a small part of the sill wetter and slightly less acid than the rest. Such sites are frequently occupied by *Candelariella* and occasionally *Lecanora albescens*. The quoins on the North Wing and kitchen extension are made of the fine-grained sandstone of *c.* 1853, the surface of which is much affected by weathering when sheltered, becoming crumbly and quite unsuitable for lichens. *Lecidea lucida* is found only on the highest quoins, where it is sheltered from direct precipitation by a northern aspect and the projecting eaves. Exposed quoins on the SW corner of the

North Wing show the effects of lime-flushing (Fig. 3, *1*); the projecting parts which receive a limey wash have a greater variety of lichens than the rest, notably *Lecanora atra*, *L. intricata*, *L. polytropa*, *Candelariella*. The brown, cracked thallus of *Acarospora fuscata* is restricted to the acid parts.

One of the finest examples of lime-flushing can be seen on the sandstone frame of the big coke hole which has been built into the damp limestone wall on the south side of the main yard (Fig. 7). The upper parts of the lintel are encrusted with stalagmite on which grow the calcicole lichens *Protoblastenia*, *Verrucaria sphinctrina* and *Lecanora albescens*. Below this is a zone of algae, covered with red *Trentepohlia* mainly and at some seasons a gelatinous stratum of other genera. This area of porous sandstone is too wet for most lichens. The lowest part of the lintel, which is furthest removed from the limestone, has powdery masses of *Lepraria incana;* this is the typical species of sheltered sandstone, which but for the flushing would cover the whole surface. *Lepraria* is similarly restricted on the projecting parts of the framework where it faithfully marks out the limits of the flushing.

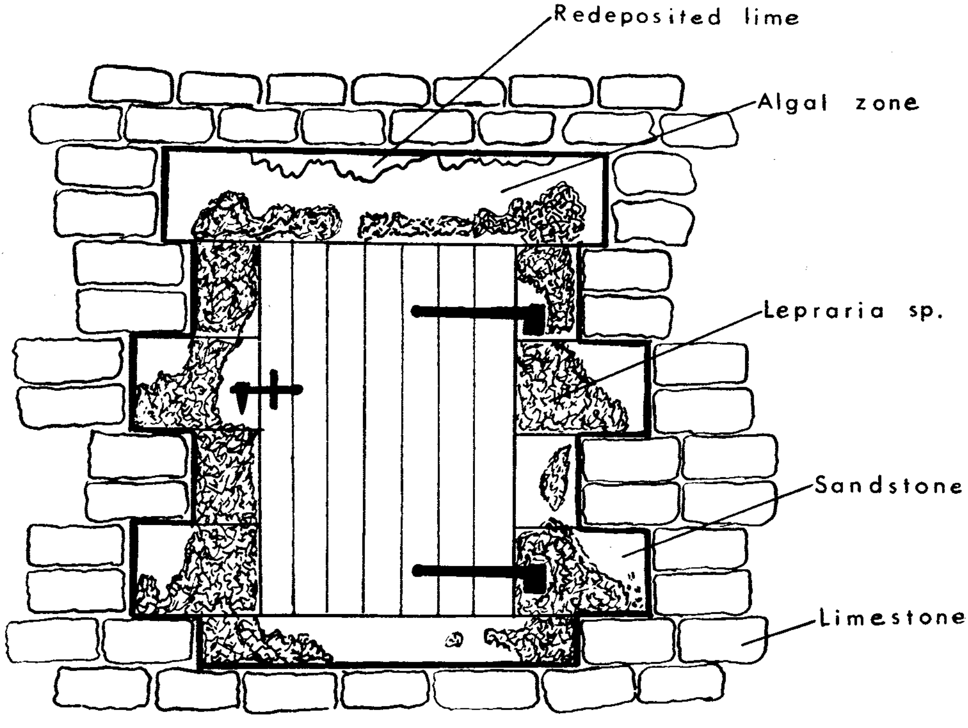

Fig. 7.

Coke hole in sheltered limestone wall, south side of main yard. Flushing with lime-rich water has restricted *Lepraria* on the sandstone framework. Constant use prevents its establishment on the sill.

Slates. Several kinds of roofing slates have been used on the buildings. All are hard, well-cleaved, purple-grey or greenish lower Palaeozoics, silicious and acid, but much finer grained than any sandstone. The nearest outcrops of similar rocks are several miles away in Ribblesdale.

The purple-grey slates on the North Wing have a thin covering of *Lecanora conizaeoides*, broken only where wedges of lead, zinc or copper sheeting project from under the tiles or where lead has been fastened round chimney bases or skylights. The rain tracks below these pieces of metal are completely devoid of plant life and show up as clean streaks on the slate. Lichens have a special ability to concentrate large amounts of ions in a very short time from water trickling over them (Smith, D. C., 1961), and although the metals must be present in extremely small quantities they can be concentrated in the thallus until they become toxic. *Aspicilia sp.*, common all over the roof but especially on the north side, is affected in the same way. Curiously *Lecidea lucida* can be seen growing on lead on the north wall of the pantry. *Squamaria muralis* is present on dry south-facing slates, and *Lecidea goniophila* can be found on the mortar of the ridge.

Large amounts of lead have been used in constructing the roof of the main house and this severely restricts its lichens. On the south side, rainwater runs over ten feet of lead before flowing down the purple slates which are consequently bare. Large green slates used over the east wing have numerous small black colonies of *Buellia aethalia* on all but northern aspects and also a little *Lecanora conizaeoides*. *Buellia* also grows on the smaller flaggy green slates on the west end of the roof.

Occasionally a green slate has been used to repair the purple roof on the south side and some of these bear a trace of *L. conizaeoides*, which shows that the green slates are inherently more suitable for lichens.

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APPENDIX

Species or Genera lists

The nomenclature of Bryophytes follows Jones (1958), and Richards and Wallace (1950), in *Transactions of the British Bryological Society*. With a few minor exceptions Lichen nomenclature is that of Watson (1953), *The Census Catalogue of British Lichens;* and Algal nomenclature follows Fritsch and West (1927), *A treatise on the British Freshwater Algae.*

BRYOPHYTES

Amblystegium serpens
Barbula convoluta
Barbula cylindrica
Barbula fallax
Barbula recurvirostris
Barbula rigidula
Brachythecium populeum
Bryum argenteum
Bryum capillare
Bryum pseudotriquetrum
Ceratodon purpureus
Cratoneuron filicinum
Ditrichum flexicaule
Encálypta streptocarpa
Eurhynchium confertum
Grimmia apocarpa
Grimmia pulvinata
Mnium hornum
Orthotrichum diaphanum
Pohlia nutans
Rhacomitrium fasciculare
Seligeria sp.
Tortula muralis

Marchantia polymorpha
Plagiochila asplenioides

ALGAE

CHLOROPHYTA
Chlorella
Coccobotrys
Coccomyxa
Cylindrocystis
Hormidium
Mesotaenium
Palmella
Pleurastrum
Protococcus
Stichococcus
Trebouxia
Trentepohlia
Vaucheria

CYANOPHYTA
Aphanocapsa
Aphanothece
Gloeothece
Nostoc
Phormidium
Scytonema
Synechococcus

CHRYSOPHYTA
Navicula
Nitzschia

LICHENS

The following abbreviations are used to indicate the habitat preferences of species: sil = silicicolous, cal = calcicolous, sax = saxicolous (indifferent), N = nitrophilous, soil = soil or moss, P = reasonably tolerant of pollution.

Acarospora fuscata	sil	Lecanora sulphurea	sil
Aspicilia sp.	sil	Lecidea leucophaea	sil
Biatorina lenticularis	cal	Lecidea lucida	sil
Bilimbia sabuletorum	soil	Lecidea petrosa	cal
Buellia aethalia	sil	Lecidea macrocarpa	sil
Caloplaca citrina	cal, N	Lepraria incana	sil
Caloplaca xantholyta	cal	Leptogium lichenoides	sil
Candelariella vitellina	sil, N, P	Parmelia saxatilis	sil
Cladonia coniocraea	soil	Parmelia sulcata	sil
Cladonia pyxidata	soil	Physcia adscendens	sax, N, P
Crocynia membranacea	cal	Physcia caesia	sax, N, P
Evernia furfuracea	sil	Physcia orbicularis	sax, N
Gyalecta cupularis	cal	Placynthium nigrum	cal
Hypogymnia physodes	sil	Platysma glaucum	sax
Lecanora atra	sil	Protoblastenia rupestris	cal
Lecanora conizaeoides	sil, P	Squamaria muralis	sil, P
Lecanora albescens f. dispersa	cal, P	Verrucaria nigrescens	cal
Lecanora intricata	sil	Verrucaria sphinctrina	cal
Lecanora polytropa	sil	Xanthoria parietina	sax, N, P