

HUMAN IMPACT ON LIMESTONE PAVEMENT

by Dr. H.S. GOLDIE *

Resum

Els paviments calcaris de les Illes Britàniques forneixen interessants exemples de l'activitat humana com a agent de canvi geomorfològic. Aquest article contempla la història de la influència humana en els paviments calcaris, especialment a l'Anglaterra nord-occidental, examina danys recents, i discuteix les accions realitzades per protegir aquestes formes paisatgístiques tan belles com fascinants. Han estat diverses les activitats que han afectat els paviments, i la importància de les activitats individuals ha canviat amb el temps. Darrerament la pressió s'ha incrementat i els organismes conservacionistes s'han interessat pel problema per tal de protegir els paviments de nous estralls. Durant els darrers 30 anys, molts pocs paviments calcaris de les Illes Britàniques han deixat d'esser afectats per agressions o alteracions, i alguns han patit molt seriosament.

Summary

The limestone pavements of the British Isles provide an interesting example of human activity as an agent of geomorphological change. This paper looks at the history of human influences on limestone pavements, especially in northwestern England, examines recent damage, and discusses the actions being taken to protect these fascinating and beautiful landforms. The activities which have affected the pavements have been varied, and the importance of any individual activity has changed over time. In recent decades the pressures have increased and conservation bodies have become concerned with the problem in order to protect pavement sites from further damage. Very few pavement sites in the British Isles have been unaffected by damage or alteration in the past 30 years, and some have suffered very severely.

Introduction

The effects of man as a geomorphological agent have been discussed in the literature at various times, for example Thomas (1956), Brown (1972). To elucidate these effects it is necessary to examine both field evidence and historical documentation of economic processes, as has been illustrated by Prince (1962).

In the case of limestone pavements field observation shows that the blocks or «clints» which compose them have in places been removed by man and used in various ways. Previous literature has briefly mentioned areas where this has occurred, and types of evidence for the damage and its dating (Sweeting, 1972; Goldie, 1973, 1976, 1981, 1986; Ward and Evans, 1976). In the present research the author has looked particularly at field evidence,

and at material made available by the Nature Conservancy Council, which is active in trying to protect limestone outcrops. This work comes at a time when there is an increasing need to conserve valuable landscape features, in the face of increasing environmental pressure. Other karst landforms, for example caves, have also been vulnerable to damage (Black, 1969; Stanton, 1982).

The evidence establishes that limestone pavements in the British Isles have been profoundly altered by human activities. Merely to observe the pavement outcrops and to conclude that their features are entirely natural could encourage erroneous ideas about their development. Analytical problems arise in situations where proof of human interference is not available, but where the field situation suggests damage. Older damage is more difficult to recognize in the field than recent. Further problems arise when trying to establish what effect in-

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direct activities have had on pavements. Direct effects have been so profound and extensive in some areas as to justify the legal protection of limestone pavements in Great Britain under the Wildlife and Countryside Act, 1981. No such protection exists in the Republic of Ireland, although clint removal is also very extensive there.

Man's influence on limestone pavement, particularly in Britain and Ireland, stems from several factors, including its proximity to settlements and communications, the value of the pavement areas to upland agriculture, and the value of limestone itself as a marketable commodity. Economic activities have directly or indirectly affected limestone pavement features and distribution for a long time. Areas where pavements are found have been grazed and cultivated since pre-historic times and these activities have affected vegetation and soil cover, thereby indirectly influencing pavement distribution. Other activities have directly affected pavement outcrops. These include limestone removal for roads, walls and buildings and their decoration; its burning for lime; its removal to improve pasture, and to supply garden rockery stone.

Sources and methods

Varied sources and methods have been used to obtain evidence for the effect on pavements of these activities. Field evidence has been the most important, especially as it shows exactly how the ground surface has been altered. But other sources are interesting and some supply information for sites lacking field evidence, whilst others give figures of quantities of stone involved. Local contacts, literature sources, examination and comparison of different map series, examination of aerial photographs, Inclosure Acts, estate records, local newspapers and Nature Conservancy Council files have all been used, in addition to field evidence, to compile a picture of what has happened to these landforms. The location map (fig. 1) indicates the main areas of pavements examined.

Local contacts have not been informative because there is great reticence in N.W. England over this question of pavement damage. The problem is over a clash in attitudes to the land which arises between different interests in a National Park, Site of Special Scientific Interest or other partly protected area of natural beauty. This is particularly so in the Yorkshire Dales National Park, where many important pavement sites are found and where they have been much damaged.

The Chartulary of Fountains Abbey, which in Mediaeval times owned much of the land containing pavement in Craven, Yorkshire, offered no specific information on limestone use, but the evi-

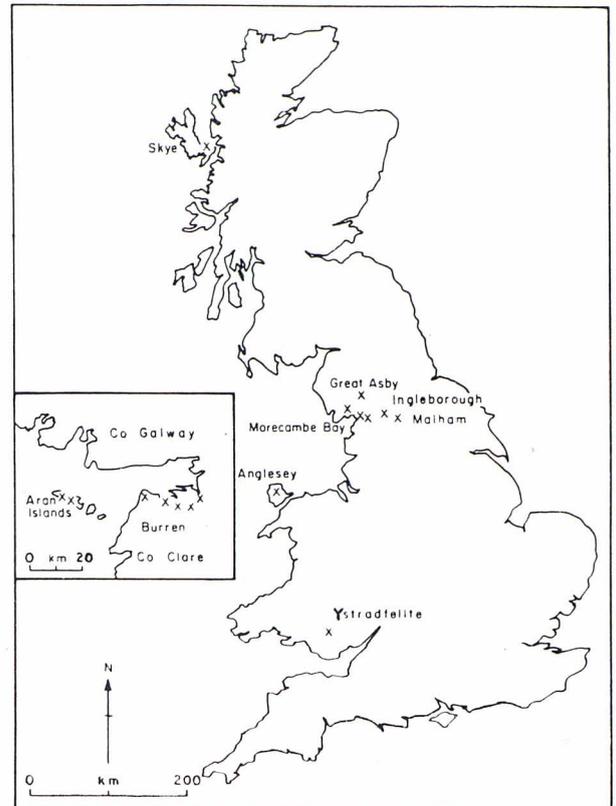


Figure 1. Location map of places cited in the text.
x = main pavement area examined.

dence it gave of the economic activities up to 1539 supports the idea of grazing pressure on soil and vegetation which might lead to soil erosion and exposure of pavement outcrops.

Archaeological literature confirmed some of the field evidence for clint use in building old structures, and confirmed general settlement pressure in pavement areas. Field examination of some sites in this literature shows that pavement was cleared and used in construction, for example the prehistoric standing stone circle at Knipe Scar near Bampton, Cumbria (Noble, 1907).

Maps might reveal evidence of recent changes in the pavement extent. The 1890's edition of the six inches to one mile Ordnance Survey maps of Craven was therefore compared with the most recent available. Unfortunately, this source was not fruitful, due to inaccurate mapping and differences in the representation of pavement; indeed there are differences in the cartographic representation within editions. Consequently, changes which appear to have occurred may not have, but merely reflect changes in cartographic method or accuracy. Six inch Ordnance Survey maps were also used to ascertain pressure on limestone from usage in walling, lime kilns, sheepfolds and quarries.

The Inclosure Awards of the late 18th and early 19th centuries for Craven show that pave-

ment was used in walling. The Malham Inclosure Award Map depicts limestone pavement outcrops with walls crossing them (Goldie, 1976). Walling pressure was greatest in the dales rather the moors, but in both areas pavement was used where it provided the most available stone. Calculation of quantities involved is difficult, as is assessment of the exact effect on the pavement. Grassy areas on either side of walls which cross pavement indicate removal, for example in Wharfedale above Chapel House Wood, and on Gauber Pasture on Ingleborough. Measuring wall length per kilometre square on the six inch maps indicates the scale and variation in pressure (Goldie, 1986). Densities as high as 8 km of wall per km² are found in Wharfedale and Ribblesdale. The majority of the walls involved are of limestone.

The Ingleborough Estate Cash Books document the amount of stone used on the estate for walling and lime in the early 19th century. Wall construction peaked in 1842, 1855 and the early 1870's. Most of the stone involved was limestone, though some was grit. Use of limestone for lime showed a very large peak around 1842.

Air photographs show examples of direct pressure on pavement from old settlements. One photograph in Raven Scar, Yorkshire (UH 93, Committee for Aerial Photography, Cambridge) shows how a space in pavement has been cleared for sheep-fold construction; another of Scales Moor, Yorkshire (UH 83, Cambridge) shows a further example of a sheep shelter using pavement. Photographs of old hut circles, settlements, small enclosures and field systems from the Iron Age, near pavement, indicate the possible pressure on outcrops at this period, for example on Cowside Flask, Malham Moor (BAQ 47, Cambridge).

Local newspapers in N.W. England, (Craven Herald and Westmorland Gazette) confirm the occurrence of removal and have reported on Public Inquiries into the problems. Information has also come from the Files and records of the Nature Conservancy Council (NCC) and discussions with

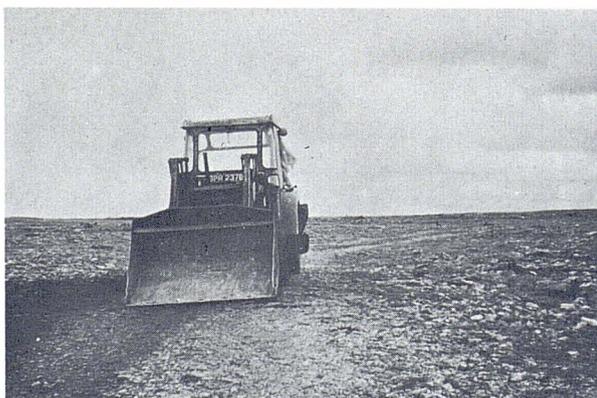


Photo 1. Heavy equipment on Gaythorne Plain, Cumbria.

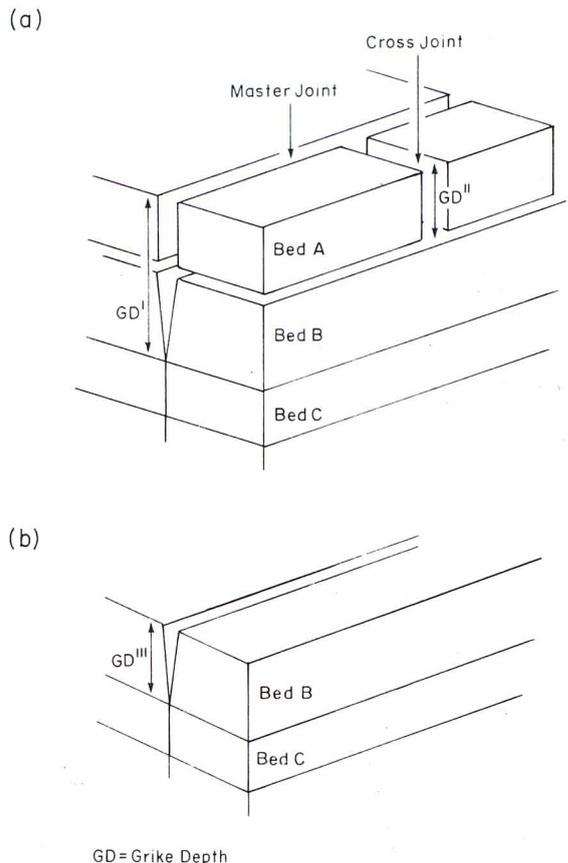


Figure 2. Diagram showing effect of clint removal on grike depth.

NCC officers have provided evidence. A comprehensive botanical survey of limestone pavements by Ward and Evans (1976) included assessments of pavement damage and is an important source of information for the NCC in its pavement protection work. There is approximately 2,150 ha. of limestone pavement in Britain and this survey detected damage to 97 per cent of the sites and regarded only 13 per cent of pavement sites as being 95 per cent or more intact. (Ward and Evans 1976; Frankland, 1980). The report estimated that about half of the total pavement had been damaged.

Field evidence of damage includes contractors' equipment, hydraulic shovels, heavy lorries and other equipment which have been seen by observers on damaged pavements (photo 1). Sweeting recorded an example on Graythorne Plain, Cumbria (Sweeting, 1972). Equipment has been seen on the same area more recently, and at Andrew Scar. Further features of damage have a geomorphological expression, such as access tracks onto pavement, and machinery and explosive marks in the rock. Track construction often involves filling in grikes with rubble, as at Gaitbarrows, Cumbria.

Geomorphological characteristics of limestone pavement damage

Geomorphological changes due to clint removal include obvious changes in rock level to the extent of the bed thickness removed and concomitant changes in pavement morphometry. After damage clints are in general longer and wider than before, and grikes shallower (figs. 2 & 3). The rock surface beneath clints is rougher than usual on pavement surfaces which have been scoured by glaciers and affected by solution, probably under a soil and vegetation cover, for a lengthy period (photo 2). Removal also produces much small debris, which can be seen on damaged surfaces, filling remnants of small solution features, with larger material blocking the grikes. Clints can be found wedged in grikes, or left in heaps. Observation of this depends on the stage of removal when the site is examined but at Hampsfield Fell (photo 3), removal was stopped by legal action so clint heaps remain on the site. There is also a lack of lichen growth on freshly damaged pavements. Study of this phenomenon could produce useful evidence for dating damage areas where no other precise information is available, similarly to the way lichen studies have been used to date exposure due to soil erosion (Trudgill, Crabtree and Walker, 1979).

Damaged limestone pavement looks very different generally and in detail from undamaged pavement. The geomorphological effects at a freshly damaged site are clear, but problems arise when trying to interpret field evidence in areas of old damage with its effects obscured by the passage of time.



Photo 2. Gauber Pasture, Ingleborough, with damaged pavement (foreground) and intact pavement (background).

Destinations of clints removed from limestone pavements

One of the clearest types of evidence for clint removal comes from seeing them at their destinations. Though some uses totally destroy the limestone, for instance lime making, the use of clints for construction and decoration of buildings and gardens can clearly be seen. Not all limestone blocks used in limestone areas for constructions such as walls, roads and buildings will be clints, some will be loose surface stones, or from quarries. But there are many occasions when the state of a pavement, and its proximity to settlement strongly suggests that its clints have been used in construction. This is confirmed when the characteristic runnel markings of clints are seen on building stones. Some buildings use trimmed clints in their construction, others contain whole clint blocks. Ob-

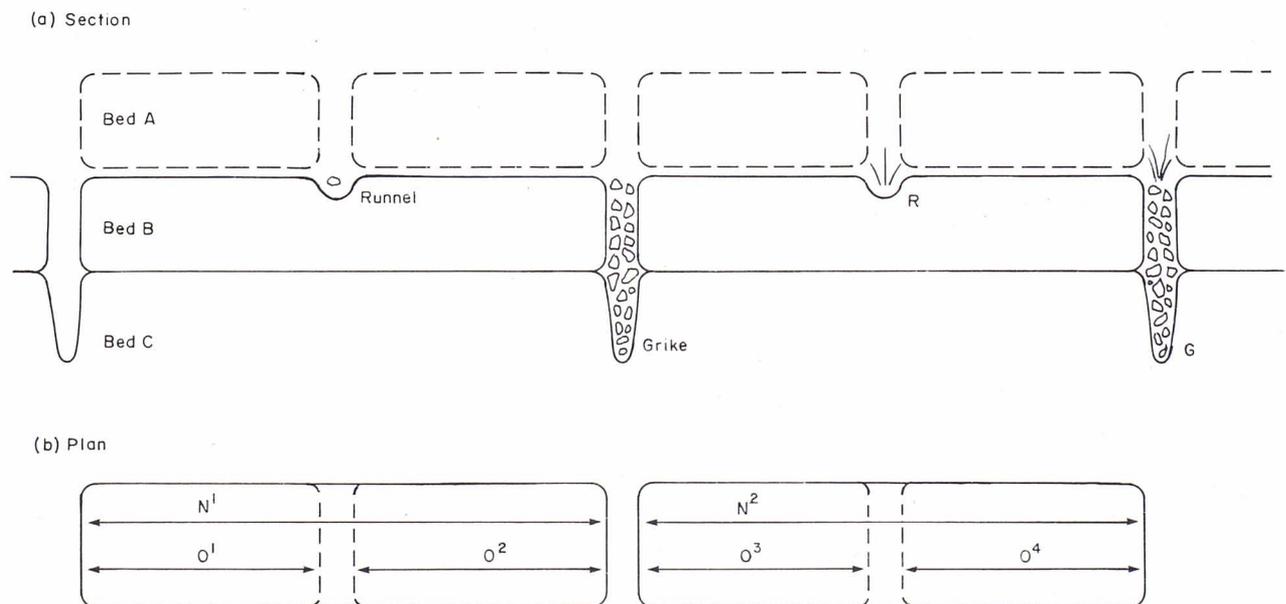


Figure 3. Diagram showing effect of clint removal on clint size.



Photo 3. Hampsfeld Fell, damaged pavement, debris in background.



Photo 5. Poul nabrone Dolmen, Burren, Eire.

vious instances of the latter are ancient structures such as the remains of hut walls in Oxenber Wood, Yorkshire and at the 4th century A.D. village at Din Lligwy, Anglesey. At Din Lligwy there is a clearing of c.o.2ha for the village between two wooded areas of limestone pavement (Craster, 1953). The hut walls' bases are clints in situ, and other blocks and gateposts are displaced clints (photo 4).

Other ancient structures constructed of clints include Plas Lligwy burial chamber, Anglesey; the dolmens of Burren, Eire, for example Poul nabrone Dolmen (photo 5); and other smaller burial chambers in Burren.

There is also evidence of indirect effects on pavement distribution. Raistrick and Holmes (1962) drew attention to the Iron Age field boundaries on Malham Moor, which indicate settlement pressure on the environment as the fields would have originally had soil in them, where now they are bare rock. Drew (1983) discusses the evidence for deforestation and soil erosion in Burren in the late Bronze Age, which supports the idea that limestone pavement has been increased in extent by indirect human effects. It also confirms that the rock was used to build structures in this period.

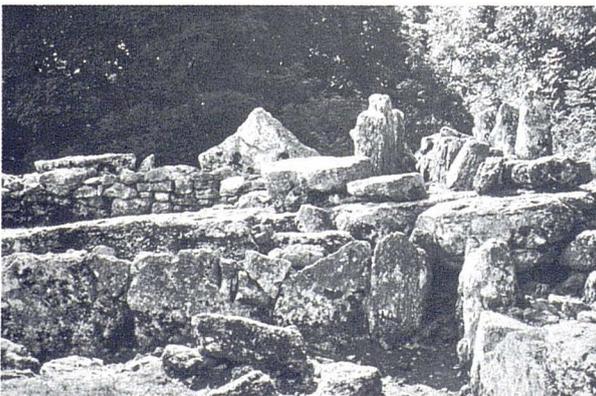


Photo 4. Din Lligwy, Anglesey.

A frequent modern use of broken pieces of well-runnelled clints is for decoration on garden walls. This is a common feature of villages and towns in N.W. England, for example Horton-in-Ribblesdale, Tebay, Bowness-on-Windermere, and Kendal (photo 6). It is systematic along whole streets and in some cases is added to by using large clints (C. 1.5m by 0.5m) for gate posts. In one suburban road in Kendal 42 such clint posts have been counted (photo 7), and neighbouring roads have the same feature. This housing development is early 20th century and the gate posts were probably put in when the houses were built. At a minimum these posts account for the damage of 30 m² of pavement, excluding allowance for grike widths. The clints would have been selected carefully for this use as their size and shape was important, so a much larger pavement area would have been damaged to obtain them. Other examples of the decorative use of clints includes toppings for gateposts, and doorways, and as a shield to municipal waste bins.

On Arainn, Eire, clints are used to make water-troughs found in many of the very numerous small fields. These troughs and their catchment slopes are constructed from limestone pieces cemented together. General clint clearance is common in Burren, Co. Clare, Eire, and appears to have increased in frequency recently. Pavement is cleared by bulldozer, any soil left grasses over quickly, and the area becomes good grazing. However, the Irish have not developed a taste for decorating their gardens with water-worn limestone, hence the clints bulldozed aside are abandoned around the field edge. In Ireland clints have also been used for construction and many damaged pavement sites near settlements testify to this, for example near Ballyvaughan and Kinvarra. In England abandoning clints is fairly rare as they have horticultural value. Nevertheless at Little Urswick, Cumbria, clints were seen cleared, heaped up with vegeta-



Photo 6. Decorative clints, Kendal, Cumbria.

tion, and burned by a farmer to increase pasture.

Finally, the use which has caused most of the damage to pavements in the last twenty or thirty years, particularly in Cumbria and Yorkshire has been of 'water-worn' limestone for garden rockeries. 'Water-worn' limestone means the solution runnelled clints. These attractive features have been much sought after in the horticultural trade. The efforts of the NCC and other bodies have prevented this in some areas, for example, the Yorkshire Dales, but the figures quoted earlier indicate that possibly over 1000 ha. of pavement may have been damaged by removal. Accurate figures are hard to obtain as removal was a casual industry, but table I quotes figures from the Public Inquiry in 1962 on removal from Scales Moor, showing that much water-worn limestone had been removed from the pavements around Ingleborough.

British Rail estimated that between 1947 and 1955 a maximum of 300 tons p.a. of rockery limestone was forwarded from Ribbleshead, Horton and Settle stations. This is a small amount, consisting of odd loads picked up by farmers to enhance their

<i>District</i>	<i>Approx. period</i>	<i>Approx. quantity removed</i>
Gauber Pasture	1910 - 56	20,000 - 25,000 tons.
Ingman Lodge Hall & High & Low Pasture	1927 - 35	7,000 - 8,000 tons.
Ashes Shaw Pasture	1945 - 50	4,000 - 5,000 tons.
Philpin Sleights	1954 - 58	3,000 tons.

(source Ward and Evans 1976 vol. VI)

Table I. Estimates of quantities of clints removed from limestone pavement, presented to the Scales Moor Public Inquiry 1962.

livelihood. However, removal was more commercial on Gauber Pasture and on Scales Moor. According to the Dalesman (Oct. 1956), 8,000 to 14,000 tons of clints were removed from the area each year, by rail and lorry, clearly for several years. Accessibility almost certainly influenced the extensive removal from Scales Moor.

Rockeries made from clints are fairly common in N. England (photo 8). Sometimes the blocks are well-runnelled, especially in older, larger gardens. In the early days of clint removal for rockeries it was done carefully, by crowbar, and for a specialized market. Such activity, though causing damage did not produce the devastation seen more recently. The modern mechanised methods, sometimes even using explosives, damage the clints and break up the runnel patterns, the very feature which attracts people to this particular rockery stone.

There are well-known gardens which contain water-worn limestone rockeries; some are open to the public, or are featured in magazines, thus encouraging demand (Minney, 1983). One well-known example is Sizergh Castle, Cumbria, a National Trust property. It contains a large clint rock garden with a stream. It was built at the turn of the century, before present concern about pavement damage,

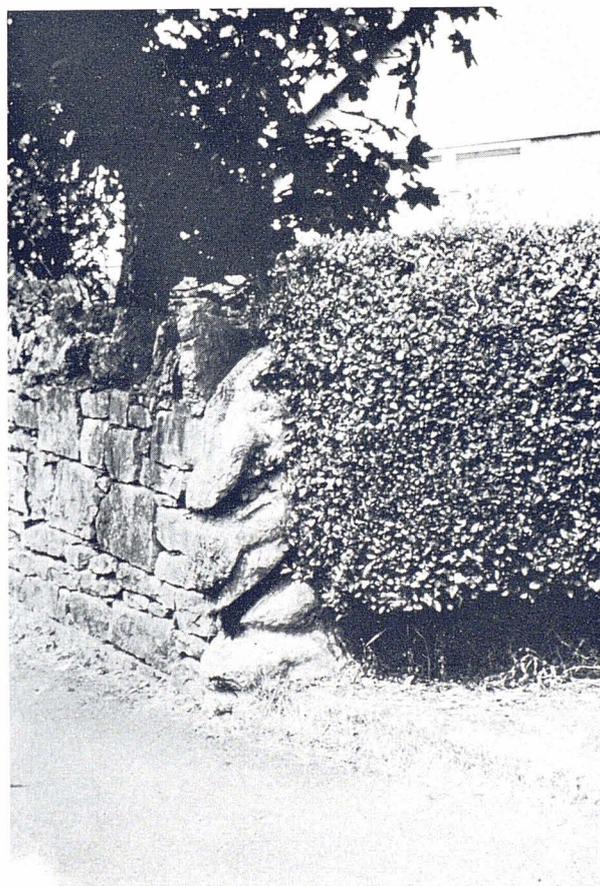


Photo 7. Cornerpost, Kendal.

indeed it would not have been built by the castle's present owners. Limestone pavement rockeries were displayed at the 1863 and 1911 exhibitions at Crystal Palace, and at the 1951 Festival of Britain. The limestone at Crystal Palace was obtained from Gauber Pasture, Ingleborough. Such rockeries were destroyed at the end of the exhibitions! The use has continued recently, for example at the 1981 Chelsea Flower Show (NCC NE 6/5/7/2). In the nineteenth century runnelled limestone from the Ingleton area was even exported to South America for garden rockeries on coffee plantations (Anon, 1956).

Even local authorities are known to purchase water-worn limestone and blocks can be found in such strange places as a York traffic island, and the garden of a York museum. Private examples include the landscaped garden of a London hotel, clint rockeries on the Calthorpe estate in Birmingham, similar rockeries in Leeds, Grassington (photo 8) and other towns and a rockery which decorates a factory at Netherton near Dudley, W. Midlands. This illustrates the wide range of destinations of clints.

A further threat to limestone pavements is incidental to commercial limestone quarrying. In Britain an estimated 26 per cent of the aggregates used are crushed limestone (NCC file S601/5/1). Large limestone quarries even in national parks, such as that at Horton-in-Ribblesdale in the Yorkshire Dales, testify to this their economic importance. Some quarries are in limestone hillsides surmounted by pavements, which will be chewed into as the quarry expands. Table II lists those identified by the NCC as threatening limestone pavement, some of which have already removed large amounts of pavement. For example Holmepark quarry, Cumbria, has destroyed pavement which had unique geomorphological features. The quarry now surrounds a pavement site (Clawthorpe Fell) which has been protected from further inroads under a National Nature Reserve agreement with the ow-



Photo 8. Garden rockery, Grassington, Yorkshire.

ners, but which could be threatened again. Some pavements affected by quarrying are good and important for their botanical and geomorphological features, for example Kilnsey in Wharfedale and Blindcrake Clints, Cumbria. At other quarries, such as at Strath Suardal on Skye, the pavement has not yet been damaged but could be, if not protected, due to proximity.

<i>Name</i>	<i>Location</i>
Maeshafn	Clwyd
Haverbrack Bank	Cumbria
Middlebarrow	Cumbria
Holmepark	Cumbria
Blindcrake Clints	Cumbria
Crosby Ravensworth	Cumbria
Gaythorne Plain	Cumbria
Ribblehead	Yorkshire
Horton-in-Ribblesdale	Yorkshire
Skythorns	Yorkshire
Strath Suardal	Skye

(Source: NCC file S601/5/ pt 3)

Table II. Location of limestone quarries adjacent to limestone pavement outcrops.

Problems in interpreting the field evidence

Virtually no pavement site in the British Isles visited by the author appears to be completely free of damage. However, there are cases where field evidence is ambiguous, especially if the limestone is well-fractured and the clints therefore small and easily displaced by natural processes and grazing animals. There are areas where the pavement's natural state is very disturbed and where it is virtually impossible to assess damage if no independent evidence exists. So the assessment of damage by Ward and Evans (1976) may be an overestimate for some areas. When there is independent material, such as walls and cairns made of limestone on fractured pavements, for example at Ystradfellte in South Wales (photo 9) this is evidence of human involvement, though not proof that all the apparent 'damage' is artificial. The field evidence is more convincing on pavements with clints too large for animals to dislodge, and where natural processes are possibly the main cause of dislodgement, aided by human interference. For example on the west-facing scar of Hampsfield Fell clints of approximately 1m to 3m in dimensions have been displaced downslope, and frost action, joint opening aided by pressure release, and gravity could all be involved. If blocks are obviously missing from such



Photo 9. Clints near Ystradfellte, S. Wales.

a site then human removal is likely to be involved, but this would need careful field checking. Documentary evidence (NCC files) shows that human interference has affected much of this area, and so the displacement here is probably due to a combination of human and natural processes.

Problems can arise in interpreting older damage, for instance at Gauber Pasture, Ingleborough. The apparently older damage here fits the known usage of clints from this area in the nineteenth and early twentieth centuries. There is lichen regrowth on lowered clints, and solution features are reforming. Further evidence are the clints used in old walls and sheep shelters. In the western part of Gauber Pasture extensive damage appears to be fairly recent compared with further east (photo 2). Removal in the whole area was facilitated by proximity to roads and a railway-station. In other areas though, similar evidence may lack independent corroboration of human influence.

Case studies

1. Hampsfield Fell

Extensive limestone pavement occurs on Hampsfield Fell, north-west of Grange-over-Sands. The area is popular with walkers, and has excellent views towards the Lake District. The pavement has been severely damaged, mainly on the eastern side, and is now subject to the first limestone pavement protection order under the provisions of the 1981 Wildlife and Countryside Act. The pavement is good, though not unique, and it displays varied massive and undamaged pavement and many runnel features.

Damage has occurred over many years but increased in 1968 when it became the concern of protection bodies. Efforts were made to safeguard the site and enforcement procedures were im-

posed which limited damage to the removal of 10 to 20 tons of limestone pavement blocks per week (NCC fill (c) SD 38/2 part 3). Operations in the 1970s involved the removal of blocks as large as 200 kg, c. 0.5m by 1m, by a single operator. Attempts to increase the scope of the removal were unsuccessful. In 1982 a Public Inquiry confirmed a ban on limestone removal and this was upheld by the Environment Secretary. Thus there should be no further stripping of clints here.

Clints removal has left very clear geomorphological effects. On the fell top there is a small area of damaged pavement and a pile of rubble, in addition to good intact pavement on the damaged part there is grass growing where the grikes of the top clints would have been or where deep runnels cut through the top bed and begun to etche into the bed below. One possible effect of removal is to leave larger clints beneath and this is illustrated by measurements (Table III and Fig. 3).

	<i>'Before'</i>	<i>'After'</i>
Clint 1	1.50	7.5
	0.90	N.B. 'Before' clints marked on this larger clint beneath by 4 areas of gravel and grass across its width
	1.15	
	1.55	
	2.40	
Clint 2	1.05	3
	1.95	N.B. 1 gravel and grass mark
Clint 3	1.30	2.5
	1.20	N.B. 1 gravel and grass mark

Table III. Clint sizes 'before' and 'after' damage, measured on Hampsfield Fell, Cumbria (in metres).

Figure 4a illustrates what was found in the field, and Figure 4b illustrates the possible interpretations. Measurements were made of undamaged pavement at Hampsfield Fell on the same stratum and very close to the damage site. The clints at the undamaged sites are well and deeply runnelled, suggesting that the clints at the damaged site could have been similar. If so the clints removed would have been arranged in the possible options of A, B or C (fig. 4b) rather than D.

2. Great Asby Scar

Limestone pavement removal near Great Asby Scar, Cumbria, took place «on an organised basis for many years» (NCC file 81-AS2). The operation was small-scale, but over a period of years the damage was widespread. Nothing remains of the original pavement surface in some areas, for example Gaythorne Plain (photo 1), and elsewhere pavement is partially damaged. NCC files on the Asby pavements show that planning permission for sur-

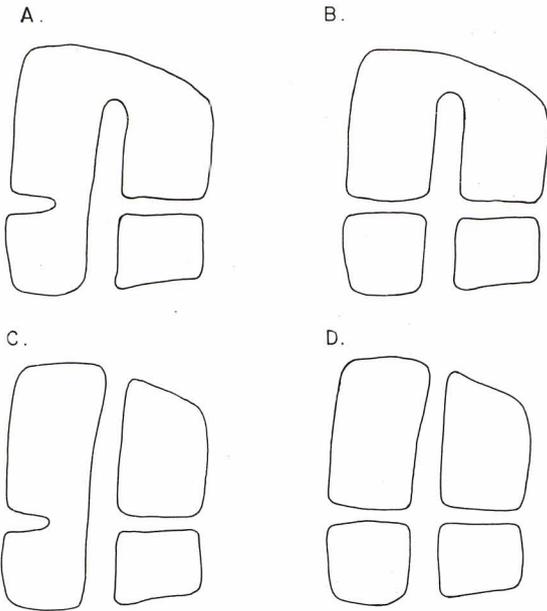
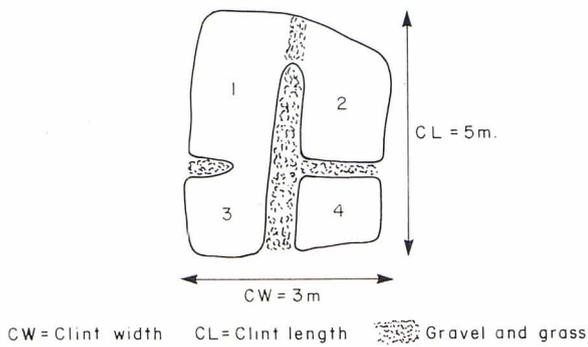


Figure 4. Possible interpretations of damage at Hampsfield Fell.

face limestone removal was refused. However, in spite of this, removal occurred, action was therefore taken in 1970 and 1971 to prevent it. It was difficult to control the removal of loose rock, however, as a legal problem concerning ownership of the loose rock complicated matters.

In the early 1970's the area was described as possessing a number on fine pavements with well-

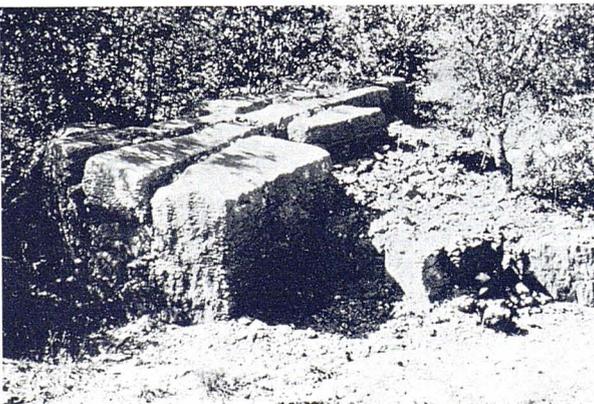


Photo 10. Lowered clint surface, Gaitbarrows, Cumbria.

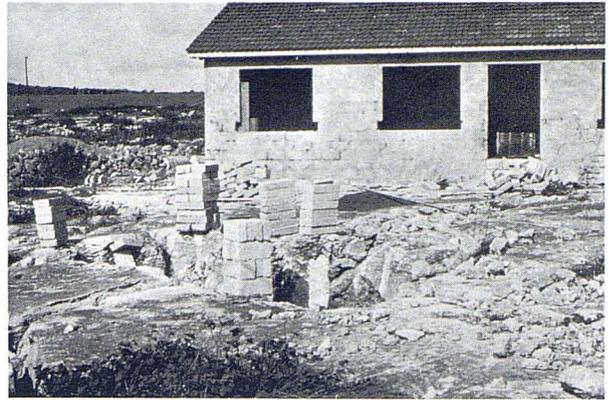


Photo 11. Limestone pavement near Carron, Burren, being built on in 1980.

developed clint and grike structures and an abundance of lime-loving plants. Simultaneously though, tractor-mounted power shovels were seen on these pavements, removing clints (photo 1). The surface is now typical damaged pavement: rough, lacking surface solution features and with much small limestone gravel. Gaythorne Plain is probably the most extensively damaged pavement in N.W. England.

The NCC pressed for the cessation of removal, and purchased some of the land for a Nature Reserve at Asby Scar.

3. Gaitbarrows

Ratcliffe (1977) refers to this pavement in Cumbria as being the most important single example of limestone pavement in Britain. Its botanical importance is very great; it is top of Ward and Evan's floristic assessment of pavement sites in Great Britain. It is also very interesting geomorphologically, showing a wide range of surface solution features. As an example of the problems involved in trying to protect valuable scientific sites from clint removal its history is sobering. Concern began in the 1960's when damage became obvious (removal had occurred as early as 1912). Being private, wooded land, it was extremely difficult for NCC officers to gather information about illegal clint removal, and they were acutely conscious of the potential dangers of the legislation process. The site was eventually made into a National Nature Reserve in 1977. Despite removal of about 50 % of the original pavement Gaitbarrows is still extremely important scientifically, with about 5 ha. of intact pavement. The effects of clint removal are clear (photo 10), with lowered clints, rubble strewn surfaces and access tracks across pavement with grikes infilled with rubble. Heavy machinery and explosives were used at Gaitbarrows and an important lesson learnt here was that even thickly-

bedded and large clints are not safe from such modern extraction methods.

4. Eire

In Burren, Eire, many pavement sites observed show evidence of damage. At various places, e.g. in the north near Blackhead, there are lowered surfaces near intact pavement; and at other sites, e.g., Burrenwee, pavement is smashed and messy. Near both of these particular sites there are walls and buildings made of limestone. Elsewhere there are bulldozed sites, e.g. near Kinvarra; sites cleared and manured for agricultural improvement, e.g. near Corcomroe Abbey; and pavements broken by tracks cut through them, e.g. above Aillwee cave. At Corcomroe Abbey damaged pavement shows grikes averaging 0.68m deep, whilst on intact parts they average 1.0m deep. In the Carron depression grikes on damaged pavements average 0.28m deep, in undamaged 0.6m. Stone-working for tombstones was observed here, nearby a limestone pavement was being built on in 1980 and 1983 (photo 11), and all over N. and E. Burren there are field boundaries made from clints.

Limestone pavements on the main island of the Aran Islands, Arainn, also display damage. This is not surprising as the extensive bare limestone makes life extremely hard for farmers, who literally make soil by scraping the meagre soil from the pavement, and adding sand and sea-weed to it. Many fields have been cleared of limestone, the rock being used to build the numerous walls. Arainn shows some interesting types of damage, including clearance of clints to construct several stone forts of Iron Age period (Robinson, 1980). These involve huge amounts of the rock in their walls, for example, Dun Dubhcathaire and Dun Aonghasa (photo 12). In addition to this, jagged clint blocks were used to form defensive lines or 'chevaux de frises' beyond the walls. Pavements near these forts



Photo 12. Dun Aonghasa stone fort, Arainn, Eire.



Photo 13. Displaced clints near Dun Dubhcathaire stone fort, Arainn.

show the expected effects of damage (photo 13). Lastly, near Mainistir, an area of several hectares of pavement was seen being destroyed for gravel, with the crushing machinery on site.

Conclusion

This paper has drawn attention to the effects of human activities on limestone pavements. It has shown that these activities have been extensive and damaging to these landforms. There are areas where the effects have been the understandable result of a landscape having an overabundance of surface limestone, for instance on Arainn and in Burren. Here human effects have largely been the consequence of farmers' attempts to increase their grazing areas. But clints from limestone pavements have also been deliberately used in structures of many kinds both in Britain and Ireland. In many parts of Britain large areas of clints have been exploited for their horticultural value and for other decorative purposes. This has caused extensive and serious damage, sufficient to require legal protection for limestone pavements.

The evidence for these effects has been varied, including historical sources as well as field evidence. There are circumstances where it is necessary to look beyond field evidence to other material to elucidate what has happened in the field. The combination of evidence from a variety of sources is essential if a full picture of the effects of man on these landforms is to be obtained.

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