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REGIONAL VARIATION IN QUARRIES

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Quarries are extremely diverse. We should therefore look briefly at the range of conditions found in them. Detailed research studies and practical reclamation schemes are tailored to particular sites and it is important to see how widely any particular interpretation or solution may apply. The following account draws on a survey of some 200 chalk and limestone quarries in England during 1974-6. Together, chalk and limestone are among the most widely used and heavily exploited minerals in Britain (Healing & Harrison 1975; Blunden 1975). They present major problems for restoration (Barratt *et al* 1970), but many old quarries have become naturally revegetated and now escape formal classification as derelict land. Chalk and limestone quarries therefore present both a considerable challenge and some encouragement to ecologists.

Many plant species grow on calcareous substrates. A sample of 48 quarries, ranging from 15 to about 100 years old and distributed through 21 English counties, contained 428 species of vascular plants. However, the main impression was of a strong underlying similarity in vegetation, based on the prevalence of species common to all age classes, all regions and all types of limestone (Table 6). Other widespread species were restricted to early, pioneer stages of colonisation or to older, well vegetated conditions. Less common plants were mainly local or regional species but some were quite rare (Davis 1979). The latter included species dependent upon open ground conditions such as matgrass fescue *Nardurus maritimus* and plants of closed grassland communities like perennial flax *Linum anglicum*. Ancient workings such as Barnack Hills and Holes in north-west Cambridgeshire are now amongst the best remaining examples of species-rich grassland in the county. However, early successional stages can also be of botanical interest for the large population of some species that they support; eg the Chiltern gentian *Gentianella germanica* in certain Bedfordshire and Hertfordshire chalk pits.

INFLUENCE OF QUARRYING TECHNIQUES ON TOPOGRAPHY AND THE DEVELOPMENT OF VEGETATION

Quarry floors

Until the introduction of steam power, quarries were worked by hand and mainly for local needs. Progress was therefore slow and intermittent and natural revegetation of worked-out areas was able to keep pace with new workings. Such methods lingered on until quite recently and one can still see examples in which all stages from bare ground to open grassland, scrub and woodland are compressed into a short distance on the quarry floor, eg at Claxby chalk pit, Lincolnshire which is now a nature reserve. Today, hand working is reserved for a few of the finest building stone quarries used for repair work such as those at Ancaster and Holywell in Lincolnshire (Plate 1).

Many quarries have had several growth phases associated with different markets and extraction techniques. Hopton Wood quarry, near Wirksworth in Derbyshire, illustrates these phases well as the Carboniferous limestone in the area occurred in three forms (Figure 1). A fine freestone was worked for many important buildings throughout the 19th century but the quarried area was small. It was absorbed in the early 1900s within the much larger scale extraction of chemically high grade limestone (99% $Ca\ Co_3$) for lime burning. This phase left very shattered faces, much talus and large quantities of

TABLE 6 The most common plant species in 48 chalk and limestone quarries in England. The quarry sample contains 12 in each of 4 age classes, <15, 15-35, 35-55, >55 years. Total records for each species followed by number of records in youngest age class.

HERBACEOUS PLANTS

Achillea millefolium	35	5	*Leontodon hispidus*	34	7
Bellis perennis	28	8	*Linum catharticum*	44	9
Carlina vulgaris	22	3	*Lotus corniculatus*	43	9
Centaurea nigra	37	7	*Medicago lupulina*	35	8
C. scabiosa	21	5	*Origanum vulgare*	22	6
Centaurium erythraea	24	8	*Pastinaca sativa*	18	6
Cerastium holosteoides	24	8	*Pimpinella saxifraga*	19	1
Chamaenerion angustifolium	38	11	*Plantago lanceolata*	40	10
Chrysanthemum leucanthemum	27	6	*P. media*	18	1
Cirsium arvense	22	7	*Polygala vulgaris*	17	2
Clinopodium vulgare	18	4	*Poterium sanguisorba*	23	3
Dactylorhiza fuchsii	23	3	*Primula veris*	17	2
Daucus carota	16	3	*Prunella vulgaris*	40	10
Epilobium montanum	19	7	*Ranunculus repens*	28	9
Euphrasia officinalis	27	4	*Senecio jacobaea*	38	9
Fragaria vesca	31	9	*Silene cucubalus*	18	4
Geranium robertianum	21	5	*Taraxacum officinale*	28	6
Heracleum sphondylium	21	2	*Thymus drucei*	19	2
Hieracium pilosella	37	4	*Trifolium pratense*	25	3
Hypericum perforatum	29	9	*T. repens*	17	3
Inula conyza	28	10	*Tussilago farfara*	39	11
Knautia arvensis	18	1	*Veronica chamaedrys*	20	3
Lathyrus pratensis	16	1			

GRASSES AND SEDGES			WOODY SPECIES		
Agrostis stolonifera	20	6	*Acer pseudoplatanus*	22	7
Arrhenatherum elatius	39	10	*Betula pendula*	16	5
Brachypodium sylvaticum	29	7	*Clematis vitalba*	22	6
Briza media	21	0	*Crataegus monogyna*	38	8
Carex flacca	23	2	*Fraxinus excelsior*	27	6
Catapodium rigidum	24	9	*Rosa canina* agg.	20	5
Dactylis glomerata	38	10	*Rubus fruticosus*	33	9
Festuca ovina	24	4	*Salix caprea*	28	10
F. rubra	36	7	*Sambucus nigra*	22	5
Holcus lanatus	38	9			
Poa pratensis	22	5			
Trisetum flavescens	31	7			

waste stone fragments which were tipped down the hillside like scree or heaped into large spoil banks (Plate 14). Similar results can be seen in Carboniferous limestone quarries worked in this way up till the 1950s in Derbyshire, Yorkshire, Cumbria and Somerset. The resulting topographical and microclimatic variability provides suitable conditions for many species of plants. However, the hard stone resists weathering and so a closed vegetation is slow to develop on such coarse substrates.

The third phase of development at Hopton Wood followed the enormous expansion of the aggregate market after the war, using the chemically less pure mountain limestone. More modern blasting and extraction techniques and visual sensitivities resulted in a concealed quarry driven diagonally

Plate 1 Overburden and face of Glebe quarry, Ancaster, Lincolnshire in 1975

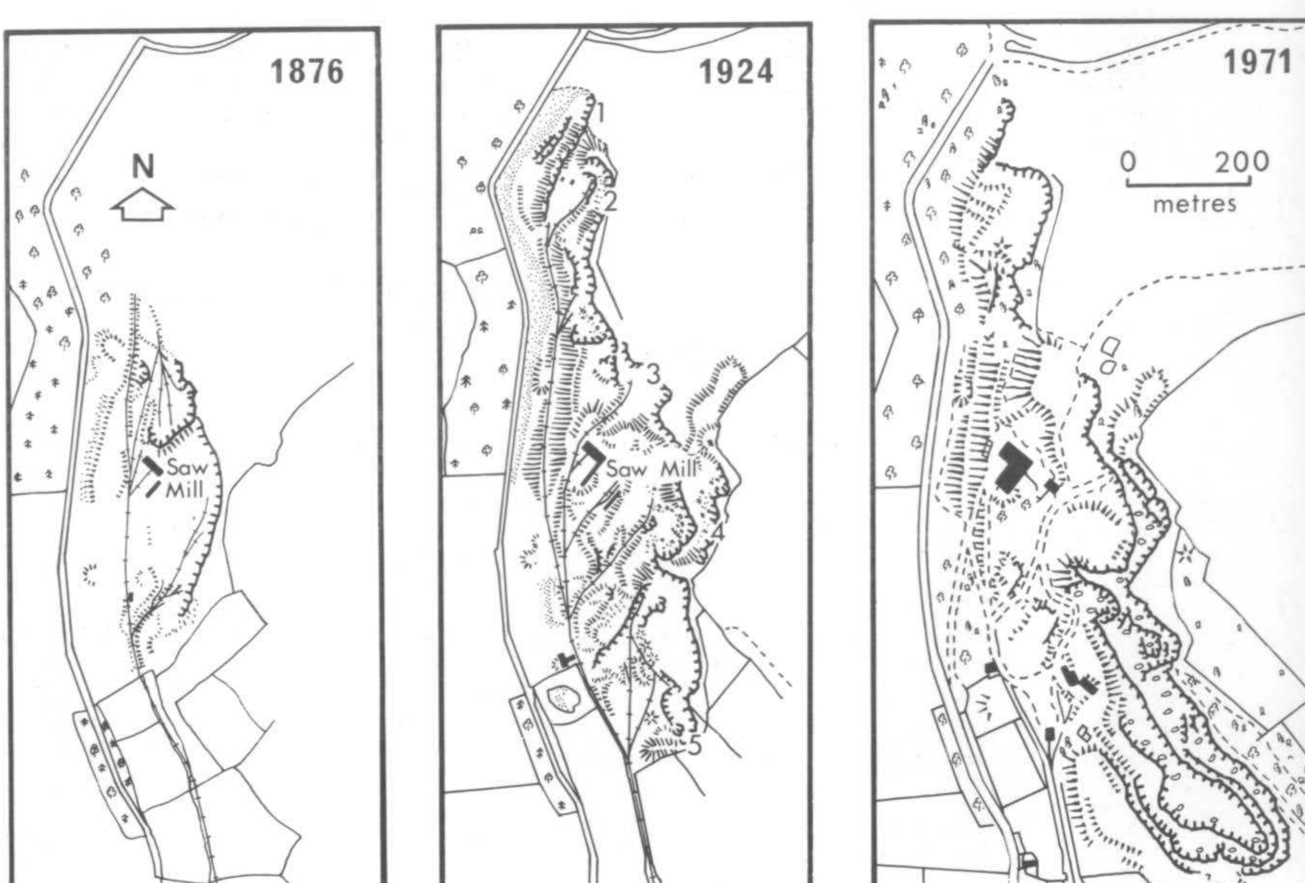

Figure 1 Hopton Wood quarry, Wirksworth, Derbyshire 1876-1971. Crown copyright reserved.

into the hillside in place of the earlier "bluff" quarrying along the side of the hill. The floor and terraces left in 1964 are relatively flat and free of coarse stone waste and have gained a 50% vegetation cover with an average of 20 species/m^2. This density of species is comparable with the much older but rougher quarry floor at the northern end of the complex which is now a nature reserve.

Similar species densities occur in some 30-40 year old chalk and Magnesian limestone quarry floors in Kent and Co. Durham (Table 7) (Plate 4). The highest density I have found was on the floor of a Jurassic limestone quarry at Clipsham, Leicestershire where work finished in 1941. In 1980, an experimental area of 150m^2 contained a total of 77 species at a mean density of 30.3/m^2 and mean cover of 21.4%. The low nutrient levels (Table 8), low annual rainfall (ca 570mm) and rabbit grazing are probably responsible for the slow development of vegetation cover here.

TABLE 7 **Total and mean numbers of plant species in 8 random m^2 quadrats on quarry floors with approximate dates of closure and present day adjacent land use. The quarries were virtually devoid of spoil material except at Hopton Wood (old quarry) and Ferriby Cliffe.**

	DERBYSHIRE		KENT	
	Carboniferous Limestone		Chalk	
	Hopton Wood	Hartington Station	Gt. Culand	Cliffe
Last worked	1920s	1955	1941	1970
Total species	38	29	42	27
Mean species/m^2	17.4	11.0	19.6	10.1
Mean % cover	66	27	76	91
Adjacent land	grassland/wood	grassland	arable/ grassland	arable

	DURHAM			HUMBERSIDE	
	Permian Limestone			Chalk	Jurassic Lst.
	Wingate	Mill	Trimdon Grange	Ferriby Cliffe	Maws
Last worked	?1947	1948	1944	1964	1934
Total species	52	55	47	28	28
Mean species/m^2	19.3	20.9	15.5	9.8	12.0
Mean % cover	70	n.d.	n.d.	39	56
Adjacent land	arable	quarry/ grassland	arable	arable/wood	arable

n.d. = no data

TABLE 8 Levels of plant nutrients in the top 5-6 cm of quarry floor at Clipsham, Leicestershire after 40 years, compared with the levels in an old pasture nearby. (Means ± standard deviations).

	Total %	Extractable ppm		
	N	P	K	Mg
Clipsham quarry	0.08 ±0.02	3.2 ±1.1	55.4 ±9.6	79.1 ±7.0
Old pasture	0.79 ±0.06	23.5 ±2.6	268 ±124	213 ±26

Overburden

The depth and nature of overburden can also influence greatly the methods of working and the final land form. In modern large quarries, such material is usually sold, utilised in some subsidiary process or used for planned landscaping of worked-out areas. Formerly, however, it was simply a waste material which had to be carried away and dumped. Often this covered up older areas of working so that little or none of the underlying rock remained exposed. Considerable depths of clay overburden were encountered in some of the Jurassic limestone quarries of Northamptonshire, Leicestershire and Lincolnshire (Plate 1). A large spoil bank at Clipsham quarry is now about 50 years old and fully vegetated with more than 100 species of plants, including 14 species of shrubs and trees (Davis 1981). Here the species density was about 20/m^2 though this was reduced in areas of denser scrub.

In Warwickshire, the depth of sandy clay and shale overburden above the Lias limestone reached ten metres in the Harbury and Stockton area (A.P.C.M. 1952). Draglines were used in the early 1950s at Ufton to remove the clay and they created large areas of "hill and dale" like those in the ironstone workings of Northamptonshire. At Harbury, the use of a conveyor belt fed by a walking dragline produced massive spoil mounds (cf. Plate 2). The most striking vegetational features of Harbury were the exceptionally large populations of kidney vetch *Anthyllis vulneraria* and narrow-leaved birds-foot trefoil *Lotus tenuis* in the newer area and butterfly orchid *Platanthera chlorantha* in an older area. The latter two species are rare in quarries. The hawkweed *Hieracium strumosum* was abundant at Stockton. This is one of 11 species found to be early and abundant colonists of quarry spoil whether of limestone, chalk marl or clay (Davis 1977). Some of them are more common in man-made habitats such as quarries and railways than in natural habitats.

At Betchworth in Surrey, the too pure Upper Chalk had to be removed to obtain the clay-rich Lower Chalk used for building lime from the mid-nineteenth century (Searle 1935). Work continued here until 1968 and several very large spoil heaps were produced with the aid of steam power and narrow gauge railways. These have become colonised by a typical species-rich chalk quarry flora with over 80 species of plants (Plate 3). Some areas are becoming dominated by hawthorn *Crataegus monogyna* and dogwood *Thelycrania sanguinea* scrub whilst others are in various stages of development towards birch *Betula pendula* or ash *Fraxinus excelsior* woodland. As in the adjacent downland itself, this development has accelerated since the loss of rabits in the 1950s.

Plate 2 Limestone face, spoil mound and lake at Stockton quarry, Warwickshire in 1975

Plate 3 Face (right) and spoil mound (left) at Betchworth quarry, Surrey in 1975

Water table

Water shortage is often a limiting factor for plant growth in chalk and limestone quarries except where quarrying extends to near or below the water table. This is becoming a more common practice in large scale modern workings and will probably develop considerably in the future. There are deep pools at the Harbury and Stockton cement workings mentioned above with fringing lesser reedmace *Typha angustifolia* and other aquatic plants at the foot of the spoil mounds (Plate 2). At Ufton Fields, the hollows in the hill and dale are largely flooded and have developed a rich flora and fauna. It is now a statutory Local Nature Reserve.

At the Cliffe cement works on the Thames estuary in Kent, the chalk was excavated by face shovels to a depth of about 15m - about sea level. The pits were kept dry by pumping water to the works but the damp conditions were evident in the older disused pit from the presence of reed *Phragmites communis* and willow carr. The northern pit was abandoned in 1970 and plant colonisation here has been rapid. By 1978, most of the floor had 100% vegetation cover dominated by creeping bent *Agrostis stolonifera* and false oat-grass *Arrhenatherum elatius* with much grey willow *Salix cinerea* and a showy profusion of spotted and marsh orchids *Dactylorhiza fuchsii* and *D. praetermissa*. The species density, however, was only 10/m^2 (Table 2). Was this due to the lack of natural chalk species in the surrounding agricultural land or the effect of competitive exclusion resulting from the unrestricted growth of grasses?

A much more varied vegetation occurs in the similar but older chalk quarries in Essex such as Grays and Warren pits. Interesting communities are also developing in some of the Bedfordshire chalk quarries worked close to the water table. They include the unexpected occurrence of flattened meadow-grass *Poa compressa* as a dominant coloniser in damp areas (Dony, *pers. comm.*). It occurs in a similar situation in a limestone quarry near Clitheroe in Lancashire. The species is normally associated with dry banks and walls.

SURROUNDING LAND AND SUCCESSION

Many of Hodgson's comments on colonisation and succession in quarries in the Sheffield area apply throughout the country. Salt Lake quarry in North Yorkshire has acquired, over 80 years, many of the species characteristic of the limestone in the Ingleborough area, including bird's-eye primrose *Primula farinosa* in exceptional density. Likewise, several of the older Magnesian limestone quarries of Co. Durham contain communities derived from the grassland that was formerly widespread in the area (Richardson *et al* 1980). In contrast, many active or recently worked quarries are now surrounded by agricultural land (Table 2). Both initial colonisation and succession may therefore be very different from what occurred in the past. Ferriby Cliffe chalk quarry, near Barton-upon-Humber, is surrounded by arable land and lacks 25 of the most common quarry species in Table 1. These include early colonists such as common centaury *Centaurium erythraea*, perforate St. John's-wort *Hypericum perforatum* and rough hawkbit *Leontodon hispidus*. The quarry was worked for the Scunthorpe steel industry until 1968 and large quantities of coarse chalk waste have been levelled off and left. There is now a 20-50% vegetation cover but an average of only 10 species/m^2 (Table 2). Wild strawberry *Fragaria vesca* is dominant. Older areas suggest that succession leads directly to hawthorn/rose scrub with ash and sycamore *Acer pseudoplatanus* without an intermediate closed grass/herb stage. Experiments would show whether dispersal or chemical/physical properties of the chalk spoil are limiting factors for the "missing" herbaceous species.

INTRODUCED SPECIES

Several introduced plants have colonised quarries. One of the most striking examples is *Buddleja davidii*. This has spread from gardens since the war and now occurs in chalk and limestone quarries from Surrey to Norfolk and Dorset to Derbyshire. At Betchworth quarry described above, it has invaded an area of open ground and now forms an impenetrable monoculture. A similar garden escape that has established itself on quarry faces and spoil is red valerian *Centranthus ruber*. It occurs in profusion at Grays pit in Essex and in quarries in Humberside, Somerset, Gloucestershire and Co. Durham. Of the hawkweeds mentioned earlier, several species including *H. strumosum* are introductions into this country. The ability of species to establish themselves rapidly on nutrient poor and physically hostile media is useful in reclamation. We need to explore further and perhaps exploit the properties of naturally good colonists including non-native species if only as an initial phase in re-establishing vegetation.

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