NATURE IN AVON

PROCEEDINGS OF THE BRISTOL NATURALISTS' SOCIETY, 1995

Proc. Bristol Nat. Soc.	55	Pp. xlviii+1-160	1997

This volume is dedicated to the memory of

V. D. DENNISON

1919 – 1996

former President of the Bristol Naturalists' Society

and Chairman of the Mendip Society

THE PROCEEDINGS OF THE BRISTOL NATURALISTS' SOCIETY

VOLUME 55 (for 1995)

Published by Bristol Naturalists' Society
c/o The Bristol City Museum & Art Gallery
Queens Road, Bristol BS8 1RL

Printed for the Society by Healey's, Fore Street, Ipswich

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VOLUME 55 (for 1995)

EDITED BY A. F. HOLLOWELL

ASSISTED BY A COMMITTEE

Printed for the Society by Healey's, Fore Street, Ipswich

ISSN 0068-1040

PAST PRESIDENTS

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T. E. THOMPSON	1987
Miss R. C. LEE	1989
R. G. SYMES	1991
D. A. WILSON	1993

VOLUME 55

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FRONT COVER The Cheddar Gorge, with a Cheddar Pink, *Dianthus gratianopolitanus*, in the foreground. Photographed by Dr K. C. Allen.

COUNCIL, 1995

President: Mr R. J. Barnett, MSc., FRES, AMA

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Hon Editor Proceedings:		Mrs A. F. Hollowell
Hon Publicity Secretary:		Miss M J. Marsh
Chairman, Field Committee:		Miss S. M. Garden
Secretary, Field Committee:		Miss R. C. Lee
Hon Conservation Liaison Officer:		Mr W. E. Dixon
Hon Librarian:		Vacant

Officers of Sections and Groups:

Botanical	President:	Mr A. C. Titchen
	Hon Secretary/Treasurer	Mr A. G. Smith
Geological	President	Mr D. W. Cope
	Hon Secretary	Dr P. R. Crowther
	Hon Treasurer	Mr S. Carpenter
Ornithological:	President:	Mr T. G. Evans
	Hon Secretary/Treasurer:	Mr R. G. Holmes
Mammal Group:	Leader:	Mr D. P. C.Trump
Invertebrate Group:	Leader:	Mr A. G. Smith

Other Members of Council:

Dr M. H. Martin   Mr B. M. J. Gray   Dr H. E. Rose

Past Presidents:

Mr V. D. Dennison   Mrs A. F. Hollowell

Miss M. H. Rogers   Mr D. A. Wilson

REPORT OF COUNCIL, 1995

It is pleasant to report an increase in membership. At the end of the year it stood at 574, including Honorary and Life members.

During the year the Society and its sections held 25 indoor and 49 outdoor meetings covering a wide range of topics and venues. The mammal group continues to flourish, and 20 members have requested the formation of an invertebrate group. The visit of Dr Algirdas Knystautas during his UK lecture tourto speak on "A naturalist's journey round Russia" was a successful event, resulting in a donation of £198 towards conservation in Russia. Council thanks those members who have entertained speakers on this and other occasions and have helped with the programme in many other ways.

During the year the Society produced ten monthly Bulletins, the *Proceedings* for 1993 (published in April) and a new publicity leaflet, and collaborated in producing the 1994 Avon Bird Report. Council records very grateful thanks to members who form the distribution network for these publications, thereby saving the Society much postage. Work proceeds on the 1994 Proceedings, which is nearly ready to go to press.

A Special General Meeting on November 9th agreed new rates of subscription from 1.January 1996; the subscription was last raised in 1993.

At the Buffet Supper, Dr Jon Gething, Director of the Wildlife Trust for Bristol, Bath and Avon, described progress in the restoration of Folly Farm, Stowey. The Society's Conservation Fund has supported tree planting at the Farm. There is continued liaison with the Trust and a reciprocal mailing of publicity literature was agreed for 1996.

Members have participated in survey work, management of reserves and liaison with the Bristol Regional Environmental Records Centre. Our Conservation Officer, besides keeping in touch with conservation matters in the area, is actively recruiting a team who could survey, at short notice, the wildlife of a threatened site.

The trustees of the Hector Hockey Memorial Fund have supported a study of small mammals and management of an ancient urban hedge, and made a further grant toward the cost of an interpretation board for a geological site.

Special mention must be made of Mr C. S.Carlile, a former Honorary Secretary and our oldest Honorary Member, who reached his century on November 19th. A special message of congratulations was sent to him and a warm reply received.

The family of the late Mr A. P. Richards donated money to the Society in lieu of flowers. A substantial legacy was received under the will of former member Mrs I. C. I. Milton, who died in 1980; the estate was complex and the final figure is not yet known.

Council records with regret the deaths during the year of Mrs B. D. Bell and Messrs S. C. Lawrence, H. E. R. Rideout, H. R.Hammacott, A. P. Richards, A. R. Cook and R. Bassindale (President in 1956-57), and of Mrs Eleanor Vaughan Davies on January 3rd 1996.

Sylvia P. Kelly, *Hon. Secretary.*

GENERAL MEETINGS, 1995

27 Jan.	Annual General Meeting & Presidential Address – "A visitor to Shetland" by Mr D. A. Wilson.
11 Feb.	"Avon's Levels and Moors", by Mr S. Christian.
4 Mar.	Flora of ancient woodlands", by Dr G. Peterken.
12 Oct.	"A naturalist's journey across Russia", by Dr A. Knystautas.
9 Nov.	"Kenfig National Nature Reserve", by Mr P. Jones.
7 Dec.	"Alien Empire – the world of insects", by Mr S. Nicholls.

GENERAL FIELD MEETINGS, 1995

These meetings were organised by officers and members of the General Field Committee – President, Miss S. Garden; Hon. Secretary, Miss R. C. Lee; members, Mr D.A. Cullen, Miss S. McCarthy and Miss M. Morris.

25 Mar.	Miss S. Garden. The Natural History Museum, London
14 Apr.	Miss R. C. Lee. Horner Hill and Horner Water, Exmoor. On a glorious spring day, there were many flowers to see and members also had good views of a male Pied Flycatcher and a Treecreeper.
13 May	Miss M. Morris. Hinton Charterhouse and Wellow. This was a return visit to an area of of flower-rich meadows and woodlands where the spring flowers included Bath Asparagus. A nightingale was among the many birds present and members were able to observe some butterflies.
17 Jun.	Mr S. Howe. Pontneddfechan, Neath Valley. Despite poor weather, members saw many birds and flowers. An interesting visit to the waterfall area, where the leader ably described its geology and history .
22 Jul.	Dr N. Webb. Fontmell Down, near Shaftesbury. A circular walk over chalk downland where the abundant flowers together with the birds and butterflies helped to make this a very rewarding day.
9 Sept.	Mr A. C. Titchen. Forde Abbey Gardens, near Chard. The leader identified the many trees and other plants and gave details of their histories, making for a very informative tour around these fine gardens.
21 Oct.	Miss R. C. Lee. Savernake Forest, near Marlborough. On two short walks, many trees were identified, a heavy crop of beech- mast, acorns and chestnuts noted, and a number of fungi and woodland birds seen.
18 Nov.	Mr D. A. Cullen. The Wildfowl and Wetland Trust, Slimbridge. The leader led an interesting tour round the collections and identified all the birds seen, including also the many species observed from the hides.

RACHEL C. LEE, *Hon. Secretary, Field Committee.*

REPORT OF THE BOTANICAL SECTION, 1995

At the Annual General Meeting held on 18 January, the President, Mr A. C. Titchen and the Hon. Secretary / Hon. Treasurer, Mr A. G. Smith were re-elected and the following were elected or confirmed in office as members of the Committee: Miss I. F. Gravestock, Mr C. Hurfurt, Mrs C. Kitchen, Mr M. Kitchen, Dr N. Malcolm, Mrs P. Millman, Mr. L. Taylor, Mrs M. Titchen, Mrs M. Webster and Mrs N. Vaughan Davies. New recording cards were available to facilitate forwarding of members' records to Professor Willis at Sheffield University for the compilation of "Bristol Botany".

The following indoor meetings were held:

18 Jan.	Annual General meeting and members' slides.
7 Feb.	Dr M. H. Martin. The ecology of Mediterranean plants.
7 Mar.	Dr M. Simmonds. Plant defences against insects.
23 Oct.	Mrs M. Webster. Bulgaria in August.
20 Nov.	Members' slides.
28 Dec.	Mr N. Wray. Flora of the Western Cape. (S. Africa)

The following field meetings were held:

23 Apr.	Mr P. Martin. Osleworth Bottom - Bryophyte foray.
10 May	Mr A. G. Smith. Wickham Glen, Stapleton.
13 May	Miss I. F. Gravestock. Pitch and Pay Lane (Stoke Bishop) and environs.
28 May	Mrs P. Millman & Mr A.G. Smith. Cadbury Camp and Limebreach Wood
4 Jun.	Mr A. G. Smith. Green Down, Charleton Mackrell.
14 Jun.	Mr. L. Taylor. Frenchay.
25 Jun.	Mr A. C. Titchen. Bishops Knoll, Sneyd Park.
4 Jul.	Mr A. C. Titchen. Clifton Downs & Observatory Hill.
9 Jul.	Mrs P. Hill-Cottingham. Catcott Nature Reserves SSSI.
15 Jul.	Mr P. M. J. Nethercott. Leigh Woods.
23 Jul.	Mr R. Higgins & Miss D. Lawrence.Dolebury Warren.
2 Aug.	Mrs P. Millman. Weston Big Wood.
28 Aug.	Mr M. & Mrs C. Kitchen. Aust in August.
1 Oct.	Mr J. Keylock. Great Breach Wood - Fungus foray.

The year was a very interesting one.. The good attendance at indoor meetings showed that the speakers and their subjects were of real interest to members. All walks were well supported and many interesting finds were made. Field meetings were all within our catchment area, except for two in Somerset, for which car-sharing was organised, so there were no coach trips. The Committee thanks all members for their support.

A. G. SMITH, *Hon. Secretary.*

REPORT OF THE GEOLOGICAL SECTION, 1995

At the Annual General Meeting, held on 18 January, Mr D. Cope was elected as President, in succession to Dr M. J. Simms. The Hon. Secretary, Dr P. R. Crowther, the Hon. Field Secretary, Mr S. C. Carpenter and the Hon. Treasurer, Mr V. D. Dennison were all re-elected. Other members elected to the Committee were Mrs M. Poolman, Mr P. Stephenson, Dr M. J. Simms and Mr D. A. Wilson.

At the end of March, Dr Crowther resigned on taking up an appointment at the National Museum of Ulster and Dr Simms took over the duties of Hon. Secretary. Thanks were expressed to Dr Crowther for all his valuable work for the Society and for the advancement of geology in the Bristol District.

The following indoor meetings were held:

18 Jan.	Annual General meeting and Presidential Address: "Geology and landscape in Ireland" by Dr M. J. Simms
15 Feb.	"A geologist in the Andes", by Dr M. Bell.
15 Mar.	"The Severn Bore" by Dr G. Steel.
18 Oct.	"Avon RIGS Project" by Ms S. Myles and Ms P. Burrell.
15 Nov.	"The building stones of Clifton" by Prof. R. J. G. Savage.
20 Dec.	Annual Members' Evening, including a display by Mr S. Carpenter of his recent finds of reptile bones.

Two fascinating lectures, by Professor Savage and Dr Steel, were very well supported, with around 50 people present at each meeting. However, attendance at the members' evening was affected by the proximity of the date to Christmas. The launch of the Avon Regionally Important Geological Sites (RIGS) Project on 23 October made the talk given in that month particularly appropriate; the speakers described how these sites are designated, documented and conserved.

The Department of Geology of the University of Bristol is thanked for allowing us the use of the excellent facilities there.

During 1995, four outdoor meetings were held, in April, May, August and October, respectively.

MICHAEL J. SIMMS, *Hon. Secretary.*

REPORT OF THE ORNITHOLOGICAL SECTION, 1995

At the 71st Annual General Meeting, held on 13 January, the President, Mr T.G. Evans and the Hon. Secretary and Treasurer, Mr R. G. L. Holmes, were re-elected. Dr and Mrs T. N. P Wilton retired from the Committee by rotation, Mrs J. M. Lance was elected and Mrs J. Fowles and Mr and Mrs J. Prince were re-elected.

The following indoor meetings were held:

13 Jan. Annual General Meeting, with a video presentation, by the President, of two films on the identification of British waders.

22 Feb. "Wildlife of the Grand Teton and Yellowstone", by Mr and Mrs J. G. Prince.

17 Mar. "Birdwatching in Israel", by Mr A. Hawkins.

11 Oct. "The Natural History of the Wyre Forest", by Mr J. Robinson.

17 Nov. "Galapagos, in the footsteps of Darwin", by Mr A. Cleave.

6 Dec. "Seventeen years of the Blaise Woods Common Bird Census", by Mr J. Tully.

There were 20 field meetings. Once again, the longer-range weekend excursions were less well supported than the weekday evening walks nearer home.

During the year, members participated in the quinquennial rookery survey and continued to contribute to the following local and national surveys: Birds of Estuaries, Wetland Species, Birds in Gardens, Overwintering Warblers and Breeding Birds (in which 92 one-km squares were covered). Many nest record cards were completed.

RICHARD HOLMES , *Hon. Secretary.*

REPORT OF THE PUBLICATIONS COMMITTEE , 1995

The Committee met three times during the year. Matters discussed included the production of an index for the *Proceedings*, covering the issues for the years 1971 to 1995.The beginning of the year saw plans well advanced for a special issue of the *Proceedings* for 1995, to be devoted to"The Mendips". The retiring Hon. Editor, Dr P.R. Crowther had worked with the Committee to compile a full range of contributions, all agreed with the Mendip Society, which had pledged support for this issue.

Meanwhile, Dr Crowther, before leaving Bristol, generously completed work on the *Proceedings* for 1993, which was published at Easter, 1995. The Committee expressed the Society's thanks to Dr Crowther for his excellent work as Hon. Editor from 1990 to 1995, during which period five issues were published, including a special issue for 1990 on "The Coast of Avon". In January 1995, Mrs A. F. Hollowell was elected Hon. Editor, *Proceedings* ,and worked on the issue for 1994, which was originally scheduled to appear in the autumn of 1995 but is likely to be issued at the beginning of 1996.

ANNE HOLLOWELL, *Hon. Editor, Proceedings.*

REPORT OF THE LIBRARY COMMITTEE, 1995

The post of Hon. Librarian was not filled by election but Mrs. A.F. Hollowell was subsequently co-opted into the post by Council, a most welcome appointment. Roger Symes was elected as Chairman of the Library Committee for 1995.

This was a year of consolidation. After the installation of some new shelving last year it was necessary to enter or alter shelf marks in many of the books. Steady progress has been maintained with this work and with the accessioning of the many volumes generously donated to the library by members. For the gift of over 50 books and journals we are indebted to Dr. L. C. Frost, Mr. H.R. Hammacott, Mrs. A. F. Hollowell, Mr. R. G. L. Holmes, Mr. P. J. M. Nethercott, the estate of the late Mr L. T. Jones, Mr A. P.Richards, Mr. R.G. Symes, Mr. S. M. Taylor, Prof. A.J. Willis and Mr. D. A. Wilson. Special name plates are added to books given to the collection by members. It is normal practice that most books and journals received as gifts are retained in the Library collection, but in 1995 some little-used library books and journals were sold; the substantial proceeds will be used for library purposes. During the year three books were purchased, 31 journals were received by subscription, 46 by exchange, and five journal runs as gifts. The Committee commends to members the improvements which have been achieved in the Library. Any further suggestions are always welcomed.

The Library Committee met four times during the year, and one working party was held. Mr. P. S. H. Boyce resigned from the Committee at the end of the year after serving for eleven years as a Committee Member, and his work for the library during this time has been much appreciated.

Members of the Committee continued to staff the Library from 12.30 to 1.30pm on Wednesdays, and from 10.15am to 12.00 noon on Saturdays. During the year 190 visits were made by 30 members who borrowed 130 items. There were 34 visits by members of staff of the City Museum and Art Gallery, a welcome increase.

The Society thanks Mrs Hilary McGowan, Divisional Director (Museums and Heritage), Leisure Services, Bristol City Council for the continued use of the Library room and for the assistance given to members during the year by Museum staff.

R G. SYMES, *Chairman, Library Committee*

OBITUARY

VIC DENNISON, 1919-1996

With the death of Victor Douglas Dennison in April 1996, the Bristol Naturalists' Society, together with the Mendip Society and the Geographical Association, among others, lost a valued and well-respected member and many of us a well-loved friend.

War service interrupted Vic's education at the London School of Economics, to which he had won a scholarship to read geography, but it led to his being able after the war to complete his geographical and geological studies at Cambridge. Here he developed a deep interest in geomorphology, the main area of overlap between his chosen subjects. After graduating he became a teacher of geography and geology, at first in Lincolnshire but then, in the early 1950s, he came to Bristol where he taught first at the College of Commerce, then at Queen Elizabeth's Hospital and finally at Filton Technical College.

In 1955, soon after coming to Bristol, he joined the Bristol Naturalists' Society and became involved with its Geological Section. He was elected to its committee in 1956 and served, in some capacity, almost continuously until his death. He was Honorary Field Secretary from 1957-1961 and Honorary Treasurer, 1991-1996. He was Vice-President of the Section in 1980 and 1981 and President in 1978 and 1979, and an ordinary member of its committee in almost every intervening year. He led the first of several geological field meetings in 1961, to Winford. He regularly attended field and indoor meetings of the Section, and made many contributions to the members' evenings. His Presidential addresses to the Section, in 1978 and 1979, were on 'The Holford Stream' and on 'Iceland'. Vic was also active in the wider affairs of the Society. He was a member of Council, 1959 -1961 and a wise President in 1983 and 1984, when his addresses were on 'Landscape' and on 'Volcanoes and Glaciers.'

On moving to live in Churchill in 1966, Vic soon became involved in the Mendip Preservation Society, later the Mendip Society. He was on its Management Committee from 1969 to 1996, was Honorary Treasurer for six years, Newsletter Editor for nineteen years and Chairman for five years, retiring only one month before his death. Such a bald recitation of the facts does little to illustrate his deep, continuous and caring involvement with all aspects of the Society's affairs. He became, as his son Edward has written elsewhere, very much a 'Man of Mendip', a region he knew intimately and which he loved promoting and talking about.

On a national level, Vic was a long-time member of the Geographical Association and was for some years a member of its education sub-committee, in recognition of his particular interests in the teaching of geography in schools. He was elected national President in 1980-1981, and in 1994 he was made an Honorary Member in recognition of fifty years of valuable service to the Association.

Also in the wider sphere, he was passionately concerned about the environment and its conservation and was a member of Friends of the Earth and the Somerset Wildlife Trust. He had a genuine concern for the under-dog, as exemplified by his sympathy for the oppressed people of Tibet which was consequent on a visit he made to that area.

The local community benefited from his move to Churchill. He was deeply interested and involved in village affairs – cricket club, photographic society, anything that needed organising – and was a Parish Councillor for seventeen years.

Vic was widely travelled. He paid many visits to Canada to see his daughter and took the opportunity to study some of its marvellous geology. He attended field excursions run by the Department of Continuing Education of Bristol University, the Geographical Association, the Geologists' Association and the Royal Geographical

Society, going to Japan, Iceland, Cyprus, Sierra Leone, the United States and many other countries. He was always well-prepared beforehand, so that if the leader was a narrow specialist, unable to integrate the geology into the local landscape, history and traditions, Vic would often be able to answer some questions and supply the background.

Particularly after his retirement, he attended several university Extra-mural classes, which, on occasions, dealt with topics on which he was expert. If the lecturer strayed beyond his competence and made some questionable statement, Vic would sometimes make a gentle but not intrusive intervention and with a few wise words provoke a lively discussion. His presence kept at least one tutor on his toes!

Vic Dennison's quiet, caring, helpful and friendly manner touched the lives of many people, who were glad to be considered his friends and he and his influence will be sadly missed. It is fitting that this number of the Proceedings, which he inspired and whose production in conjunction with the Mendip Society he facilitated should be dedicated to him in recognition of his valuable contributions to the two bodies.

This obituary is based in large part on an the Appreciation by his son Edward, which appeared in the *Mendip Newsletter* No. 88, for December 1996.

R. BRADSHAW

H. R. HAMMACOTT, 1908-1995

We record with regret the death of H. R. Hammacott ("Steve" to his many friends) on July 20th 1995, in his 87th year. He was a fine example of the stalwart, unassuming supporter so valuable in Societies like ours but whose work so often goes unrecorded.

He was born in February 1908 near Plymouth. From boyhood he was a keen amateur naturalist, particularly though not exclusively interested in birds. In 1930 he graduated in English at Exeter, then spent his working life in Bristol state schools (to which he introduced the game of Rugby Football). He retired in 1968, after 17 years as the first head of the new Romney Avenue Junior School on Purdown.

He joined our Society in 1953 and was soon active in the Ornithological Section. He and his wife moved to West End, Nailsea in 1955 and he rapidly gained a detailed knowledge of Nailsea and Kenn Moors, daily walking his dog over them He organised our surveys of Lapwings and Yellow Wagtails there. He made friends with farmers, workers and neighbours, who for the rest of his life brought him news and specimens of animals and birds. He served on the Editorial Committee of the Bristol (and then Avon) Bird Report, compiling the passerine section from 1965 to 1982 and acting as Committee Secretary for 15 years. His detailed records, kept from his editorial duties, are now a unique source of data from those years. Already a major contributor to the BTO's Nest Record Scheme (he had an uncanny knack for finding nests), in 1962 he succeeded the late M. A. Wright as the BNS' local organiser, issuing and collecting record cards, abstracting the basic data for local use and encouraging recruits. He continued this task until early 1995. The 1986 Avon Bird Report contains his findings from 10,000 nest summaries.

Having qualified as a bird-ringer, he developed a special interest in Swifts, Swallows and House Martins. His 16 years' work on one Swift colony is described in "Swifts in a Bristol Roof" in the 1985 Avon Bird Report. He regularly contributed to local and BTO surveys, serving as "steward" of one 10-km square, and much enjoyed our five-yearly rookery censuses. Having entered a nursing-home at the end of 1994, he missed the 1995 census but still found a small new rookery from his window. Among other bird-related activities, he was a voluntary warden at Chew Valley Lake from the inception of the scheme in 1967 until the autumn of 1994.

Aside from birds, all aspects of natural history interested him. He contributed to our Mammal Section and to the working parties which prepared the guides for the Ashton Park and Frome Valley Nature Trails, and was active in our Conservation Committee. A skilled bee-keeper for many years, he later became an inspector for foul-brood. He enjoyed fly-fishing, and followed the Clifton Foot Harriers until well into his eighties. He grew superb vegetables organically, and cultivated shrubs destined to be planted surreptitiously at Chew Valley Lake.

One anecdote will illustrate his willingness to help others. In 1962 a Sunday working party went to Bristol City Museum to set up part of our Centenary Exhibition. Tools and materials that had been promised us were not to be found; I telephoned Steve and with only mild persuasion he left his potato patch in Nailsea, drove to Bristol, took me back to Nailsea to raid my workshop, brought me back to Bristol, then returned to his garden – a total of over 40 miles and two hours. The displays were completed; his help was never publicised.

He was a pleasant, generous, unassuming man, widely read and excellent company, as those who travelled with him in search of birds or churches at home and overseas will testify. His wife died at the end of 1994; they had no children. We extend our sympathy to his step-son and his family.

S. M. TAYLOR

ERRATUM AND APOLOGY, 1994 PROCEEDINGS

After our 1994 *Proceedings* had been prepared for press and all editorial checking had been completed, in the effort to meet a deadline an out-of-date version of a file was accidentally transmitted to the printers. In consequence the Income and Expenditure Account and Balance Sheet as published were actually early draft copies. We apologise to the Hon. Editor, the Hon. Treasurer and especially the Hon. Auditor for this error. The correct versions are published on pages xiv and xv.

STATEMENT OF ACCOUNTS, 1994

1993	*INCOME*	1994
4139	Subscriptions	4174
202	Donations	142
195	Bank Interest	310
201	Supper profit	38
149	General Field Meetings surplus	220
983	Proceedings - Grants 200, sales 255	455
168	Sale of surplus books & journals	1
6038	*TOTAL*	5340

1993	*EXPENDITURE*	1994
85	Bank charges	57
21	Donations	27
1966	Proceedings & Bird Report	2435
208	Library: books	239
279	subscriptions & journals	293
138	fire insurance	148
42	fittings	33
25	committee room hire & sundries	11
690	General postage and telephone	738
1070	General printing and stationery	1171
481	Meetings expenses	555
130	Section grants	132
904	Surplus (deficit) on year	(498)
6038	*TOTAL*	5340

BALANCE SHEET at Dec. 31, 1994

1993	*ASSETS*	1994
6000	National Savings Income Bonds	6000
581	National Savings Bank	817
827	Cash at bank - currrent accounts	734
9393	Cash at bank - high interest account	9347
2	Cash in hand -Treasurer	68
108	Prepayments (journals 71, other 4)	75
	Debtors	152
(1,903)	LESS Creditors (advance subscriptions 323, room hire 170, Proceedings for 1993 1799, insurance 148, other 22)	(2,412)
15008	*TOTAL*	14780

1993	*REPRESENTED BY*	1994
6693	General Fund at Dec. 31st 1993	7597
904	Add surplus (deficit) on year	(498)
	Benefactors' Funds:	
290	Harry Savory Illus. Fund	153
185	Conservation Appeal	255
459	R. G. Williams Memorial Fund	459
6580	Hector Hockey Memorial Fund	6817
15008	*TOTAL*	14780

BENEFACTORS' FUNDS

1993	*RECEIPTS AND PAYMENTS DURING THE YEAR*	*1994*
	Harry Savory Illustrations Fund	
193	Fund at Dec. 31st 1993	193
	Additions to it in year	60
	Less grant made	(100)
193		153
	Conservation Appeal	
185	Fund at Dec. 31st 1993	185
	Additions to it in year	120
	Less grants made	(50)
185		255
	R. G. Williams Memorial Fund	
459	Fund at Dec. 31st 1993 and 31 December 1994	459
		-
459		459
	Hector Hockey Memorial Fund	
6,950	Fund at Dec. 31st 1994	6,580
424	Year's investment income	437
(794)	Less grant made	(200)
6,580		6,817

NOTES

1) No value is placed upon the contents of the Library nor on stocks of publications

2) These accounts do not include any balances held by Section Treasurers nor the Ornithological Section's Special Fund of £761.29

3) The Hector Hockey Fund is represented by the Income Bonds and the National Savings Account. The grant made in 1994 was towards the cost of an interpretation board at a geological site.

Signed:

S. M. Taylor	T. B. Silcocks
Hon. Treasurer	Hon. Auditor
Jan. 20, 1996	Jan. 23, 1996

STATEMENT OF ACCOUNTS, 1995

1994	*INCOME*	*1995*
4,174	Subscriptions	4,188
142	Donations	10,773
310	Bank Interest (incl. Field C'tee £3.12)	554
38	Supper profit	128
220	General Field Meetings surplus	93
455	Proceedings - Grant £100, sales £78.95	179
1	Sale of surplus books & journals	3,337
5,340	TOTAL	19253

1994	*EXPENDITURE*	*1995*
57	Bank charges	52
27	Donations	397
2,435	Proceedings & Bird Report	2,436
239	Library: books	99
293	subscriptions & journals	288
148	fire insurance	148
33	fittings	0
11	committee room hire & sundries	64
738	General postage and telephone	697
1,171	General printing & stationery less 188 grant	1,040
555	Meetings expenses	672
132	Section grants	200
(498)	Surplus (deficit) on year *	13,160
5,340	TOTAL	19,253

*surplus nett of special receipts (see Note 2) (140)

BALANCE SHEET at Dec. 31, 1995

1994	*ASSETS*	*1995*
6,000	National Savings Income Bonds	6,000
817	National Savings Bank	1,239
734	Cash at bank - currrent accounts	1,399
9,347	Cash at bank - high interest account	21,317
68	Cash in hand -Treasurer	40
75	Prepayments (room hire)	139
152	Debtors	
(2,412)	LESS Creditors (advance subscriptions 414, Proceedings for 1994 1666, meetings 38, subscriptions 23, library fire ins. 148, printers 188)	(2,478)
14,780	TOTAL	27,656

	REPRESENTED BY	
7,597	General Fund at Dec. 31st 1994	7,098
(498)	Add surplus (deficit) on year	13,160
	Benefactors' Funds:	
153	Harry Savory Illus. Fund	68
255	Conservation Appeal	235
459	R. G. Williams Memorial Fund	342
6,817	Hector Hockey Memorial Fund	6,752
14780	TOTAL	27,656

BENEFACTORS' FUNDS

1994	*RECEIPTS AND PAYMENTS DURING THE YEAR*	1995
	Harry Savory Illustrations Fund	
153	Fund at Dec. 31st 1994	113
60	Donations received in year	56
(100)	Less grant made (towards 1995 Proc.)	(100)
113		68
	Conservation Appeal	
255	Fund at Dec. 31st 1994	325
120	Donations received in year	237
(50)	Less grants made (see Note 3)	(325)
325		235
	R. G. Williams Memorial Fund	
459	Fund at Dec. 31st 1994	459
-	Donations received in year	72
-	Less grant made (cost of prospectus)	(188)
459		342
	Hector Hockey Memorial Fund	
6,580	Fund at Dec. 31st 1994	6,817
437	Year's investment income	422
(200)	Less grants made (see Note 4)	(487)
6,817		6,752

NOTES

1) The accounts do not show balances held by Section Treasurers nor the Ornithological Section's Special Fund of £791.27p
2) The special receipts referred to in connection with the Income Account are the bequest of £10,000 from Mrs Milton and £3,300 from sale of surplus Library material.
3) The grants made from the Conservation Appeal were £100 to Avon Wildlife Trust and £225 to Dr Knystaustas' Russian Wildlife Trust.
4) The Hector Hockey Memorial Fund is represented by the Income Bonds and National Savings Account. The grants were £155 towards cost of a geological site interpretation board, £115 to fund a Survey of Small Mammals and £217.50 towards the restoration of an ancient hedge.

Signed:

S. M. Taylor,
Hon. Treasurer, 1995
24 Aug. 1997

T. B. Silcocks, Hon. Auditor
24 Aug. 1997

INSTRUCTIONS TO AUTHORS

1) The editor welcomes original papers on the natural history of Avon and surrounding areas for consideration for publication in the *Proceedings*. Inexperienced authors may obtain advice from members of the Publications Committee. Authors should bear in mind that their readers will not usually be specialists in the particular subject, and that unnecessarily technical language can be a barrier to understanding.

2) All PAPERS for consideration should reach the editor by the end of August in each year. If there is likely to be a problem with this target date please contact the editor in advance. All SOCIETY REPORTS etc should reach the Editor by the end of February in the next year.

3) Manuscripts should be double-spaced, with wide margins, and on one side of the paper only. The author should retain a copy.

4) The wording should follow the style and format of the Proceedings. Abbreviations should not normally be used, especially in the references. An abstract should be supplied, and the text should be broken up by appropriate headings and sub-headings and accompanied by relevant illustrations. Captions to illustrations should be given separately at the end of the text.

5) Originals, not copies, of photographs, slides, line drawings, diagrams and maps should be submitted - returnable on request. Drawings and other diagrams should not be more than twice final size, and made in black medium. Photographs and slides may be submitted as prints, positives or negatives, preferably in monochrome. Graphs, charts and simple diagrams may most readily be produced by computer graphics; advice and help with this are available.

6) References should be listed at the end of the text in alphabetical order of the first author's name, and should take the following form.

Book: AUTHOR (DATE). *Title.* Place of publication: Publisher. E.g.,

RACKHAM, O. (1986). *The history of the countryside.* London: J. M. Dent.

Paper: AUTHOR (DATE). Title. *Journal name,* **volume**, (part), page nos. E.g.,

ROSS, S. M. & HEATHWAITE, A. L. (1986). West Sedgemoor: its peat stratigraphy and peat chemistry. *Proceedings of the Bristol Naturalists' Society,* **44**, 19-25.

7) It is very helpful if the text can also be submitted on a magnetic disk readable under MS-DOS (any version) or *Windows*, either as an ASCII ("text" or "print" file) or as a formatted file produced by any well-known word processing software. A formatted version is especially valuable where many scientific names are involved.

8) The copyright of all published material will belong to Bristol Naturalists' Society, whose Council may authorise reproduction.

Proceedings of the Bristol Naturalists' Society (1995), **55**:xix-xxvii

BRISTOL & DISTRICT INVERTEBRATE REPORT, 1995

Compiled by R. J. BARNETT

City Museum & Art Gallery, Queen's Road, Bristol BS8 1RL

INTRODUCTION

During 1995 four field meetings were held during the summer, as follows:

Site	*Date*	*Leader*
Middle Hill Common	3 June	Bill Dixon
Dolebury Warren	24 June	Justin Evans
Goblin Combe	16 July	Justin Evans
Asham Wood	17 September	Tony Smith

On 20 November Dr Paul Davis gave a talk entitled "Insect Evolution." At this meeting the requisite 20 signatures of members were achieved requesting Council to approve the formation of an Invertebrate Section. In the light of this, Tony Smith agreed to act as Secretary, during 1996, of an informal "Invertebrate Group" prior to the formation of a full section.

As for the invertebrates themselves, 1995 was an interesting year dominated by a very hot, dry summer and by a massive influx of immigrant insects across southern England. Most impressive, perhaps, were the numbers of immigrant dragonflies, particularly of the Yellow-winged Darter. Sightings in this district have been summarised by Waring (1995). Other notable migrants included the Camberwell Beauty and Monarch butterflies. The latter were probably due to natural immigration but a number are known to have been accidentally released in the home counties. Migrant moths included the Old World Webworm, an unusual occurrence as only twelve records exist for the British Isles between 1967 and 1990. Humming-bird Hawk-moths were noted and larvae of the Death's-head Hawk-moth and Bedstraw Hawk-moth found. The Great Brocade at Dolberrow was another exciting immigrant record.

The almost annual event of ladybirds swarming was reported from the coast-line, in particular at Weston-super-Mare, Clevedon and Severn Beach. The hot weather also produced an example of the aberration *semi-ichnusoides* of the Small Tortoiseshell butterfly . High temperatures in the pupal stage encourage the deposition of melanin, resulting in a very dark butterfly. The weather was also responsible for a number of sightings of insects out of their normal season – in particular, additional broods of some sxviipecies of moths *e.g.* the Swallow-tailed Moth.

Aside from the moves to form an Invertebrate Section of the Society, other recording schemes affiliated to the Bristol Regional Environmental Records Centre (BRERC) continued to encourage interest. At the annual meeting of the Avon Butterfly Project on 11 February, provisional distribution maps for the butterflies recorded by the project since 1990 were distributed to recorders. These provisional results sadly relate the disappearance of the High Brown Fritillary, Marsh Fritillary and Adonis Blue from Avon and the worrying decline of the Pearl-bordered and Small Pearl-bordered Fritillaries and the Chalkhill and Small Blues. On the positive side the Brown Argus and Essex Skipper are increasing in the area and eggs of the Brown Hairstreak were found in the county, the first time for about a decade. Also during 1995, numbers of the Silver-washed Fritillary were seen in Leigh Woods indicating a re-colonisation as a consequence of the coppicing regime being carried out by English Nature.

The Bristol & District Moth Group held seven field meetings and interest continues to build in this recording area, particularly with more "birders" taking up the hobby. On 18 February Jim Porter, author of the forthcoming photographic guide to larvae, spoke to the Group. Aside from the migrants, 1995 was notable for the discovery of new species of micro-moth for the region *e.g. Blastobasis decolorella* and for the re-finding of the pyralid *Salebriopsis albicilla*. Apart from an unconfirmed record from Leigh Woods in 1968 this moth was thought to occur only in the Wye Valley.

The rarest species of moth in the district, the Silky Wave, was the subject of further study by Ray Barnett and Andy Pym. Taking advantage of Libby Houston's expert knowledge of the Avon Gorge and its botany, the moth was found to be widespread on the Bristol side of the Gorge, from the Suspension Bridge to the Sea Walls. This should allay the fears expressed in Waring (1994) that scrub growth was potentially damaging the site for the species, at least in the short term. Traditionally the site for the moth is quoted as the Gully.

At a meeting on 29 March, twelve entomologists assembled to hear Brigitte Peterek talk about her work on mimicry in hoverflies. This marked the formation of another informal recording group - the Bristol & District Hoverfly Group. As a consequence, provisional distribution maps for 135 species of this family of flies were produced and circulated. They included two Red Data Book and thirteen Nationally Notable species. Many of those records represent work carried out by Bristol Naturalists, particularly R. H. Poulding and Simon Randolph, during the 1980s. Currently a national hoverfly atlas is being prepared, as well as recording schemes for Somerset (Ted and Dave Levy) and Gloucestershire (David Iliff).

The Gordano Valley Invertebrate Study Group met twice on the National Nature Reserve and continued to build up the species lists for that site. Similarly the atlas project for Somerset molluscs continued to gather data.

The most distressing sight of 1995 was the contamination of the Avon Gorge by the fall-out of slag from the grit-blasting of the Suspension Bridge, prior to re-painting. Attention has naturally focussed on the implications for the Gorge's unique flora but the consequences for the invertebrate life are also potentially very damaging and much more difficult to assess.

Red Admiral *Vanessa atalanta* (L.) Wetmoor ST78 6 January (PP).

Camberwell Beauty *Nymphalis antiopa* (L.) Easton in Gordano ST5175 6 August (ABP); Patchway ST6182 22 August (RH); Yatton ST4365 26 August (D&SH).

Pearl-bordered Fritillary *Boloria euphrosyne* (L.) Dolebury Warren ST4559 8 June (JB).

Monarch *Danaus plexippus* (L.) St. Werburghs, Bristol ST6074 13 August (MW); Whitchurch ST6167 14 October (Mr Hiron).

LEPIDOPTERA (macro-moths)

Six-spot Burnet *Zygaena filipendulae* (L.) f. *flava* Robson Ashton Court ST5472 28 June (RE).

Currant Clearwing *Synanthedon tipuliformis* (Cl.) Filton ST67 20 June (AP); Weston-super-Mare ST3362 autumn (KP), empty larval tunnel.

Small Eggar *Eriogaster lanestris* (L.) Sand Bay ST36 no date (AM), larval web.

Mullein Wave *Scopula marginepunctata* (Goeze) Clevedon ST3970 10 August (RA, ME, RH, JM, JP, AP).

The Vestal *Rhodometra sacraria* (L.) Timsbury ST6558 October (MB); Portishead ST4574 21 October (WD).

Oblique Striped *Phibalapteryx virgata* (Hufn.) Berrow ST25 no date (BS).

Gallium Carpet *Epirrhoe galiata* ([D. & S.]) Clevedon ST3970 10 August (RA, ME, RH, JM, JP, AP).

Juniper Carpet *Thera juniperata* (L.) Blagdon ST4958 Oct (NM).

Valerian Pug *Eupithecia valerianata* (Hb.) Gordano Valley NNR ST47 8 June (ED, ME).

Swallow-tailed Moth *Ourapteryx sambucaria* (L.) Congresbury ST46 8 October (GS), late date.

Death's-head Hawk-moth *Acherontia atropos* (L.) Flax Bourton ST5070 10 August (RM), larva.

Humming-bird Hawk-moth *Macroglossum stellatarum* (L.) Goblin Combe ST4765 25 August (CW); Chipping Sodbury ST78 7 August (JBr); Axbridge ST45 29 August (PF); Westbury Park ST5775 1 September (SH).

Bedstraw Hawk-moth *Hyles galii* (Rott.) Weston-super-Mare ST36 8 August (*per* DM det confirmed by KP), full grown larva.

Poplar Kitten *Furcula bifida* (Brahm) Uphill ST35 6 June (ED).

Heart & Dart *Agrotis exclamationis* (L.) Portishead ST47 21 October (WD), late date.

February was similar, mild and with few frosts, mainly south westerly winds, 23 rain days and eleven sunless. It too was the wettest February on record and the winter as a whole was the wettest. There was a spectacular thunder and hail storm on the 22nd.

TABLE 1. Monthly and seasonal trends in climate during 1995

	Monthly differences			*Seasonal differences*	
	Max. T°C	*% Rain*	*% Sun*	*Max. T °C*	*% Rain*
Dec. '94	+1·3	182	80		
Jan. '95	+1·3	183	75		
Feb.	+2·5	205	80	+1·7	188
March	−1·7	83	130		
April	+0·8	47	115		
May	+0·8	127	125	+0·2	82
June	+0·8	24	125		
July	+2·7	20	100		
Aug.	+6·2	4	150	+3·3	15
Sept.	+0·1	192	100		
Oct.	+3·0	66	120		
Nov.	+1·6	117	120	+1·6	117

Spring started with an upset, the March mean temperature being lower than February's, although the predominant winds remained from the south west. Rain days were high at 18, and the eight days on which hail fell was the highest in any month since March 1982. But there were only four days with no sun. The main feature of April was the three nights of damaging air frosts from the 19th to the 21st. Winds were mainly from the north-east and there were six sunless days.

In May winds returned to south-westerlies, sunless days fell to three yet the maximum temperature on the 11th of only 8·5° was the lowest in May since records began. The last spring frosts occurred on the 14th (air) and 21st (ground), both comparatively late dates. The 16th was exceptionally wet over the whole area (28·1 mm at Yatton).

The three summer months were all the driest on record here, and sunless days were, respectively, two, one and zero. The first three days of August saw temperatures soar to over 32° (90° F). The heat triggered off thunderstorms on the 1st, and on the 2nd an exceptionally heavy storm broke out in the late afternoon over Burnham on Sea, giving 81·0 mm of rain. The comparative figures for the *month* were 3·2 mm at Yatton and 2·8mm at Weston-super-Mare!

Autumn consisted of a dry month sandwiched between two wet ones. September was the wettest month of that name since 1984. On the 10th, heavy rain fell over the entire area (74·7 mm at Minehead, 43·7 mm at Yatton, 37·0 mm in Bristol). October's surprise was that its mean temperature was higher than September's. The only ground frost of the month occurred on the 28th, the latest date for the first frost of the season on record here, and the lowest incidence of frost in October since 1989. Both September and October had only four sunless days while November had eleven. A frosty start to November and another cold snap in mid-month were more than balanced out by warm weather brought in by winds mainly from southerly quarters.

December was the coldest month of any name since February 1991 with eleven air frosts and 18 ground frosts, severe at month-end. Both minimum and maximum mean temperatures were 3·6° below average and rainfall was just above average. Sunshine was in short supply - 16 days of no sun and a duration only 60% of normal.

SPECIES OF NOTE IN 1995

ODONATA (dragonflies)

Scarce Chaser *Libellula fulva* Mull. Keynsham ST6669 13 July (AP).

Yellow-winged Darter *Sympetrum flaveolum* (L.) Priddy Mineries ST5451 12 Aug (AP), Middle Hope ST36 8 August (JM), Weston Moor ST4473 11 August (JM) Weston Moor ST4473 13 August (RA), Portbury Wharf ST47 13 August (RA), Avonmouth Sewage Works ST57 24 August (JM).

HEMIPTERA (true bugs)

Juniper Shieldbug *Elasmostethus tristriatus* (Fabr.) Clifton ST5873 May (RE det. RB).

Legnotus limbosus (Geoff.) Brandon Hill ST5772 23 May (RE, SH det. RB).

Sciocoris cursitans (Fabr.) Dolebury Warren ST4558 23 June (ME, AP).

Peritrechus geniculatus (Hahn) Troopers Hill ST6273 26 May (RB).

Ranatra linearis (L.) Yate ST7184 5 May (AP).

LEPIDOPTERA (butterflies)

The Swallowtail *Papilio machaon* L. Clevedon ST3970 15 May (ABP), three seen, presumably released.

Wood White *Leptidea sinapis* (L.) Great Breach Wood ST5032 1 August (AD).

Brown Hairstreak *Thecla betulae* (L.) Walton Common ST47 25 February (KG), ova.

Small Tortoiseshell *Aglais urticae* (L.) ab. *semi-ichnusoides* Pronin Whitchurch ST6067 (DF).

I am, as always, very grateful to those observers who have submitted their sightings to me and to the Bristol Regional Environmental Records Centre and their recorders. In particular, my thanks go to John Weeks for submitting his annual weather synopsis. The species selected for inclusion in the Species List have by necessity been chosen subjectively but I hope they are of interest.

Observers mentioned in the species list:

Avon Butterfly Project (ABP), Rick Andrews (RA), Mike Bailey (MB), Ray Barnett (RB), Jerry Board (JB), Janet Boyd (JaB), John Boyd (JoB), Bristol & District Moth Group (BDMG), J. Brown (JBr), Paul Davis (PD), Andrew Daws (AD), "Dixie" Dean (ED), Bill Dixon (WD), Roger Edmondson (RE), Martin Evans (ME), Derek Foxwell (DF), Keith Giles (KG), Sam Hallett (SH), Rupert Higgins (RH), D. & S. Horsington (D&SH), Carolyn Lamb (CL), John Martin (JM), David Middleton (DM), Nigel Milbourne (NM), Rob Morris (RM), Tony Moulin (AM), James Packer (JP), Phil Parker (PP), Ken Poole (KP), Andy Pym (AP), Brian Slade (BS), Geoff Sorrell (GS), Mark Sutton (MS), Chris Wiltshire (CW), Ms M. Wood (MW), Neil Woodward (NW).

Scientific nomenclature follows the checklists of Agassiz (1987), Bradley *et al* (1972), Bradley & Fletcher (1979), Duff (1993), Fitton (1978), Hopkin (1990), Kerney (1976), Pope (1977), Potts (1964), Roberts (1995) and Smith (1976).

WEATHER SYNOPSIS (by John Weeks)

From January to November, mean monthly temperatures exceeded the long-term average, with the exceptions of March (1·1°C below) and May (0·3° below). Only in March was the mean maximum below average, by 1·7°. Over the eleven-month period,the mean temperature was 12·2° and the year seemed set to become the warmest in recent times. (The Yatton climatological station came into operation from June 1979, so some of the "records" quoted have to be viewed in the absence of figures for 1976.) However the exceptionally cold December (3·6° below normal) brought the year's mean down to 11·4°, so that 1995 finally fell into third place behind 11·7° in 1990 and 11·5° in 1989. That other essential for insect life - sunshine - was in good supply from March to November.

A very wet 1994/5 winter was followed by average spring rainfall, an extremely dry summer and a wet autumn. Overall the year's rainfall turned out to be very close to long-term average, although some heavy local thunderstorms resulted in some areas having totals well above average.

The year was exceptional in many ways. It started very mild, with no lying snow, indeed falling snow was recorded only after the winter was over, on seven days in March. There were some sharp frosts at the beginning of January, but then comparatively mild weather was brought in, with copious rainfall, on winds predominantly from between the south and west. There were 25 rain days and 15 without sun. It was the year's wettest month, and the wettest January since my records began.

Large Yellow Underwing *Noctua pronuba* (L.) Whitchurch ST6067 late May (RA); Filton ST67 2 June (AP); both early dates.

Great Brocade *Eurois occulta* (L.) Berrow ST25 no date (BS).

Striped Wainscot *Mythimna pudorina* ([D. & S.]) Max Bog ST45 2 June (BDMG); Barton Quarry ST3856 27 June (ED); Gordano Valley NNR ST47 no date (ED, ME).

The Sycamore *Acronicta aceris* (L.) Timsbury ST6558 no date (MB).

Twin-spotted Wainscot *Archanara geminipunctata* (Haw.) Walton Down ST4273 28 July (BDMG); Yatton ST4365 31 July (AM).

Webb's Wainscot *Archanara sparganii* (Esp.) Berrow ST2952 18 August (RA, ME, RH, JM, AP, MS).

Silky Wainscot *Chilodes maritimus* (Tausch.) Berrow ST2952 11 August (RA, ME, RH, JM, AP, MS).

The Anomolous *Stilbia anomala* (Haw.) Goblin Combe ST4765 25 August (BDMG).

Cream-bordered Green Pea *Earias clorana* (L.) Slimbridge SO7204 no date (NW); Yatton ST4365 no date (AM).

Dark Spectacle *Abrostola trigemina* (Werneb.) Berrow ST2952 11 August (JP, AP).

LEPIDOPTERA (micro-moths)

Psychoides filicivora (Meyr.) Clifton ST5773 26 June (ME); Bishopston ST5975 12 November (RE).

Tinea pallescentella Stt. Clifton ST5873 19 June (SH det.RB); Redland ST5874 3 September and other dates (JM).

Aristotelia ericinella (Zell.) Siston Common ST67 11 July (JaB, ME).

Recurvaria leucatella (Cl.) Siston Common ST67 9 July (JaB, JoB, ME, CL).

Dichomeris marginella (Fabr.) Whitchurch ST6067 27 July (RA).

Blastobasis decolorella Woll. Whitchurch ST6067 15 June (RA).

Glyphipteryx linneella (Cl.) Redland ST5874 21 August (JM).

Pammene fasciana (L.) Folly Farm ST6060 30 June (BDMG).

Pediasia aridella (Thunb.) Berrow ST2953 8 July (ED, ME); Gordano Valley NNR ST47 12 July (ED, ME).

Old World Webworm *Hellula undalis* (Fabr.) Whitchurch ST6067 13 October (RA).

Sitochroa verticalis (L.) Filton ST6179 5 June (AP), Redland ST5874 23 June (JM).

Salebriopsis albicilla (H.-S.) Leigh Woods ST5573 28 June (ED, ME), 2nd "Somerset" record.

Euzophera cinerosella (Zell.) Portishead ST4574 no date (WD).

COLEOPTERA (beetles)

Necrodes littoralis (L.) Goblin Combe ST4765 25 August (BDMG).

Omaloplia ruricola (Fabr.) Dolebury Warren ST4558 23 June (AP), 1st Somerset record.

Prosternon tessellatum (L.) Troopers Hill ST6273 26 May (RB)

Twenty-four Spot Ladybird *Subcoccinella 24-punctata* (L.) Lamplighter's Marsh ST5277 June (JaB, ME).

Pyrochroa coccinea (L.) Lamplighter's Marsh ST5277 June (JaB, ME).

Melandrya caraboides (L.) Gordano Valley NNR ST4372 28 May (RB).

Arhopalus rusticus (L.) Walton Down ST4273 28 July (BDMG).

Cryptocephalus aureolus Suff. Troopers Hill ST6273 26 May (RB).

HYMENOPTERA (bees, wasps & ants)

Ammophila sabulosa (L.) Avon Gorge ST5674 4 July (RB, AP).

DIPTERA (flies)

Xanthogramma citrofasciatum (DeG.) Max Bog ST45 31 May (RB).

Chrysotoxum festivum (L.) Gordano Valley NNR ST4372 30 July (RB).

ARACHNIDA (spiders)

Oonops domesticus de Dalmas Filton ST6179 18 November (AP).

MOLLUSCA (slugs and snails)
Acicula fusca (Mont.) Corston Brook ST6964 no date (PD).

Pyramidula rupestris (Drap.) Corston Brook ST6964 no date (PD).

Vertigo antivertigo (Drap.) Corston Brook ST6964 no date (PD). IOPODA (woodlice and slaters)

ISOPODA

All the following recorded at an address in Staple Hill, Bristol (ST6575) during 1995 by Mark Brookes.

Androniscus dentiger Verhoeff

Oniscus asellus L.

Philoscia muscorum (Scop.)

Platyarthrus hoffmannseggi Brandt

Armadillidium depressum Brandt

Armadillidium nasatum Butte-Lund

Armadillidium vulgare

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Proceedings of the Bristol Naturalists' Society (1995), **55**:xxix-xxxviii

AVON MAMMAL REPORT, 1995

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INTRODUCTION

This is the seventh recent mammal report for Avon. Its intention is to be a wide-ranging review of the studies and records of mammals in and around Avon in 1995. (The numbers of BNS record cards received for each species are given in brackets after the scientific name.)

REPORTS ON MAMMALS

INSECTIVORA (hedgehogs, moles and shrews)

Hedgehog *Erinaceus europaeus.* (12) A fairly quiet year. Only 12 records were received, of which nine, all from south of the M4, were for road traffic casualties. The Mammal Society's Hedgehog Road Kill Survey came to an end in 1994. During the five years of the survey, the South West (including Avon) was bottom of the league of ten regions in every year except 1994, when we beat the South East into 10th place. The South West count was only 1.0 hedgehogs per 100 miles of road. The top region in 1994 was East Anglia, with 5.9 dead hedgehogs per 100 miles (P. Morris, personal communication). A Norwegian study of 17 radio-tagged hedgehogs found that six were eaten by badgers while three were run over. A questionnaire sent throughout Norway revealed that areas with high densities of badgers tend to have low densities of hedgehogs (*BBC Wildlife Magazine,* June 1995). The high badger density in the South West of England may explain low hedgehog counts. A letter to the *Western Daily Press* (30 Oct), "Havoc on harmless hedgehogs", held badgers responsible for the apparent decline in hedgehog numbers in the Westbury-sub-Mendip area. Records from ST4064, ST4364, ST4373, ST4962, ST5069, ST5575, ST5577, ST6867, ST7158, ST7263, ST7362 and ST7684 (DT, AG, JP).

Mole *Talpa europea.* (2) As usual, a very under-recorded species. Moles should be one of the easiest mammals to record with their characteristic "hills" clearly visible in fields throughout the countryside.

Common Shrew *Sorex araneus.* (2) Common shrews were trapped in Longworth "live capture" small mammal traps in both the spring and autumn National Field Vole Survey trapping sessions in the Gordano Valley National Nature Reserve (see Mammal Society Field Vole Survey, below).

Water Shrew *Neomys fodiens.* (2) One was found dead in a lane at Bury Hill, ST 6579, 20 March (AFJ), and one was killed by a cat at Berrow ST 5268, 21 March (DC).

CHIROPTERA (bats)

Greater Horseshoe Bat *Rhinolophus ferrumequinum.* Maximum of 14 on 5 May at spring 'fattening-up' site. Of eight bats caught there on 7 April, two were aged 20-21 years, and one was 18 years. Maximum of 85 adults at stable block nursery roost on 21 June, when first baby was seen. At least 42 babies born there. Thirteen in hibernacula in north Avon, 28 October (all GJ). Ringed bat seen at Wookey Hole ST5347 on 8 January and 28 October, five seen at Shute Shelve on 12 November and three at Burrington Combe on 3 December, returning after the grilling of the site (all RC).

Lesser Horseshoe Bat *Rhinolophus hipposideros.* Four in NW hibernacula, 28 October (GJ); 38 at Compton Martin on 1 January, 12 at Hutton on 22 October and six at Shute Shelve on 12 November (all RC).

Whiskered Bat *Myotis mystacinus.* Male seen at Axbridge on 5 March. At least two heard on a bat detector at Brent Knoll on 19 July (both RC).

Daubenton's Bat *Myotis daubentonii.* Female and male at Browne's Hole on 8 January. Male at Compton Bishop on 5 March. Male at Shute Shelve on 12 November (all RC).

Serotine *Eptesicus serotinus.* Seen near Freshford on 18 May. Juvenile male grounded at Portishead on 12 October released after feeding (both GJ). One flying at Crook Peak on 3 July (RC).

Leisler's Bat *Nyctalus leisleri.* Two roosts occupied at Clifton, Bristol in the spring. One had 80 bats on 1 June but they left soon afterwards. At a second roost, 261 were counted on the same evening, giving a combined count of 341 individuals, the largest concentration of the species yet recorded on mainland Britain. The main roost had 161 bats on 5 July and 111 on 7 August. Present at Ham Green Lake ST5375 on 5 June (from sonograghic analysis of echolocation calls). (All GJ.)

Noctule *Nyctalus noctula.* (2) Four seen at Stoke Park, Bristol ST6177 on 25 July and 25 seen at Lockleaze ST6176 on 11 April (both MB). Twenty in a tree roost near Freshford on 18 May. One dead at Knowle, Bristol on 29 June. Visual records over Long Ashton. (All GJ.)

Brown Long-Eared Bat *Plecotus auritus.* (1) Two bats in the roof of a house at Clapton Wick ST4472 on 21 July (DT). Two females near Priddy on 8 January and one at Cheddar on 21 January (both RC).

Pipistrelle *Pipistrellus pipistrellus.* (11) Records from the following 1 km squares ST6176, ST6575, ST6576, ST6670, ST7567, ST7666 (all MB).

45 kHz Pipistrelle Injured males from Nempnett Thrubwell on 5 May and Bristol Zoo on 5 October showed characteristics of the 45 kHz phonic type (GJ).

Nathusius' Pipistrelle *Pipistrellus nathusii.* Songflight calls recorded from Chew

Valley Lake in May and September. Mating roost found on 22 September, containing one male and one female. This is the first record of a mating roost for this species in Britain (KB).

Natterer's Bat *Myotis nattereri.* Male seen near Priddy on 8 January (RC).

Other Bat News

The Avon Bat Group's bat boxes at Chew Valley and Blagdon were checked on two occasions in 1995. A single male pipistrelle was found in a box on an ash tree at Blagdon ST5160 on 21 May, and bat droppings were found in four other boxes at Blagdon ST5159. The late summer inspection on10 September was curtailed by heavy rain; it revealed a single pipistrelle in a box on a larch at Chew Valley Lake ST5760, while two boxes on sycamores at Blagdon ST5159 had two and six pipistrelles respectively. Birds continued to make use of the bat boxes - 13 were occupied by blue tits, great tits, treecreepers and a wren!

Studies on bats continue apace at the University of Bristol. Elena de Fanis and Gareth Jones showed that female pipistrelle bats from roosts near Bristol successfully discriminated between the odours of bats from their own colony and those from a different one, choosing odours of females from their own colony in preference to those of females from another (de Fanis & Jones 1995). Another study showed that female brown long-eared bats taken from a roost near Bristol nursed their own young selectively, recognising them by both olfactory and acoustic cues. As the young bats grew, their calls changed, increasing in frequency and decreasing in duration. Mothers recognised the more recent calls of their own babies in preference to older calls. Echo-location sounds were distinguishable between different lactating females, and the behaviour of the babies suggested that a mutual recognition occurs (de Fanis & Jones 1995).

Gareth Jones and others (Jones *et al* 1995) studied habitat use by greater horseshoe bats from three roosts near Bristol Those from a woodland site generally emerged earlier than bats from a more exposed site, except in early spring when leaf cover was minimal. It was thought that foliage around the roost may benefit bats by extending foraging time and reducing predation. Bats over one year old foraged between 2 and 4 km from their day roosts. During the spring foraging bats made intensive use of ancient semi-natural deciduous woodland, while during the late summer they fed mainly over pasture. Woodland was generally found to be warmer than pasture, so it may be more profitable for bats to forage in woodland early in the spring. During the summer the shift to feeding over pasture was associated with the dominance of *Aphodius* sp. dung beetles in the bats' diet. Juvenile bats first began to fly in the nursery roost at about 15 days old, first flying from the roost at about 28-30 days and beginning to catch insect prey, generally staying within 1 km of the roost, before finally being weaned at about 45 days. By 60 days, the juveniles were foraging up to 3 km from the roost, a similar range to that of the adults.

The authors conclude that the provision of favourable feeding habitats (cattle-grazed permanent pasture alongside deciduous woodland) within 4 km radius of maternity roosts should greatly enhance survival rates in juvenile bats and hence significantly increase population levels.

The diet of a colony of noctule bats living in the Willsbridge Valley ST6670 was the subject of a further paper by Dr Jones (Jones 1995). During May 1988, the bats fed mainly on cockchafer beetles *M. melolontha* and craneflies (tipulidae). By late May/early June, moths and beetles (species unidentified) were the main dietary component. During mid summer, small dipterans (less than 5mm long) and many species of beetle predominated. By late July/August the dung beetle *Aphodius sp.* was an important component of the diet. (The hollow Scots pine in which the bats roosted was blown down by a storm in the winter of 1989/90. Fortunately the bats were not in residence at the time – DT).

1995 saw the publication of *Auritus. A Natural History of the Brown Long-eared Bat* by BNS member R. W. Howard. It is the first comprehensive monograph of any single species of bat and tells the story of 15 years of observations of a colony of brown long-eared bats in the roof of his house at Chewton Keynsham ST6465 (Howard, 1995).

LAGOMORPHA (rabbits and hares)

Brown Hare *Lepus europaeus.* (14) A very under-recorded species in Avon. Paul Chadwick recorded hares in "his" 10 km bird square (ST77, centred on Dyrham Park) finding them in the following 1 km squares between March and July: ST7276, ST7374, ST7375, ST7378, ST7474, ST7676, ST7775, ST7971, ST7975, ST7976. At least twenty individuals were seen in squares ST7374 and ST7375. Mixed (pasture and tilled land) farming is the predominant land use in the area. Elsewhere, a single record of a hare from Farmborough Common ST6860 on 2 May (DT).

Rabbit *Orytolagus cuniculus.* (9) Widespread throughout the county except in built-up areas - records from ST4373, ST5382, ST7372, ST7473, ST7484, ST7658, ST7659 and ST7863. There was a single record of a wild rabbit with Viral Haemorrhagic Disease (VHD) from Wedmore ST4351.

RODENTIA (rats, mice,squirrels and voles)

Brown Rat *Rattus norvegicus.* (4) and **House Mouse** *Mus domesticus*

Rat records from: ST6375, ST6575, ST6576 and ST6670 (MB and DT)

In June 1995, MAFF announced the publication of the *National Rodent Survey 1993.* Local authorities, under the provisions of the Prevention of Damage by Pests Act 1949, are responsible, as far as is practicable for keeping their district free of rodents. They also have powers to require occupiers of land to keep it free of rodents. The survey showed that there had been little change in the overall level of rodent infestations since the late 1970s. Levels of infestation of both brown rats and house mice have decreased in properties used for business purposes and in premises used for both domestic and business purposes, and increased in some domestic properties. House mouse infestation in domestic properties in villages had increased significantly. Brown rat infestation of domestic properties in large towns and villages had also shown a significant increase. Infestation of farms was significantly higher than for most other classes of property. Mouse infestation levels were low on livestock farms and high on mixed farms. Rats showed no particular preference for particular farm types. Within the Chartered Institute of Environmental Health Officers, South West Region, 7.1% of all non-agricultural properties were infested by rats and 3.1% by mice. For all regions (England and Wales) the figures were 4.8% by rats and 3.9% by mice (*MAFF News Release* 208/95, 6 June 1995).

Grey Squirrel *Sciurus carolinensis.* (11) Records from: ST4372, ST5572, ST5573, ST5675, ST5677, ST5761, ST5772 ST5773, ST5777, ST7863 (IFG, S and JP, DT and ER). One unfortunate squirrel was found run over opposite the Post Office in Queen's Road, Clifton, Bristol.

Dormouse *Muscardinus avellanarius.* The regular surveys of the dormouse boxes at Kings Wood (DC), Leigh Woods (AR) and Dawlings Wood (Avon Wildlife Trust) continued throughout 1995.

Studies by Claire Ozanne, an entomologist at the Roehampton Institute, London and Paul Bright of the University of London (formerly of the University of Bristol) have shown that insects may account for 80% of dormouse diet in June, with pollen accounting for the remaining 20%. Results showed that their favourite trees were oak and hazel but that they also spent a quarter of their time in sycamores. Sycamores harbour some 600 aphids per 'square metre column', far more than any native tree - this may have interesting implications for dormouse conservation! (*BBC Wildlife Magazine* December1995).

Water Vole *Arvicola terrestris.* In 1995 the Somerset Environmental Records Centre and Somerset Wildlife Trust began a survey of the distribution of water voles in Somerset and provided management advice on sites where they still occur. All records of water voles, past and present, throughout the region will help build up a picture of the rapid decline of "Ratty" made famous by Kenneth Grahame in 'Wind in the Willows'.

Guinea-pig *Cavia* sp. Free-living guinea-pigs in the Langport area of Somerset, numbering some 25 individuals, were being captured by staff from the RSPCA centre at West Hatch. The guinea-pigs were said to be "breeding like rabbits" (*Western Daily Press* ,1 December 1995).

SMALL MAMMALS

The Mammal Society National Field Vole Survey continued in 1995. The Gordano Valley National Nature Reserve site, ST 4373, was "trapped" using Longworth live-capture mammal traps on two occasions in 1995. The April week produced the grand total of one male field vole *Microtus agrestis* (captured in the same trap on four occasions!) and one common shrew *Sorex araneus.* The November week resulted in a total of 40 woodmice *Apodemus sylvaticus* (16 male and 24 female), four bank voles *Clethrionomys glareolus* (two male and two female), 10 field voles (three male and seven female) and three common shrews. Nationally, eight other sites were trapped, Monks Wood, Huntingdon coming top with 18 field voles. In the autumn, seven further sites were trapped, of which Moat Meadow, Cambridge, came top with an impressive 52 field voles trapped, double the 1994 total. (M. Woods, personal communication).

The winter "A Year in the Avon Gorge" walk on 22 January featured a Longworth trapping exercise in recently coppiced woodland, ST5573. Ten traps set in two-year-old coppice yielded six woodmice and one bank vole. Ten set in three-year-old coppice produced three woodmice and one bank vole (AR and DT).

PINNIPEDIA (seals) and CETACEA (whales, dolphins and porpoises)

A small group of harbour porpoises *Phoecoena phocoena* observed in the spring off the southern end of Lundy ceased feeding and immediately left the area when a bull Grey Seal *Halichoerus grypus* appeared. (*British Wildlife* **6** (5), June 1995).

CARNIVORA (carnivores)

Polecat M*ustela putorius.* The polecat continues to re-colonise the English countryside from its Welsh stronghold at the rate of at least one mile per year. Records of polecats, especially from Southern Gloucestershire/North Avon will be particularly useful in monitoring its spread. (H. J. Birks, personal communication).

Mink *Mustela vison.* (3) Records from Walton Moor ST4372, 29 August (LR), Congresbury ST4264, 26 March and Puxton ST4164, 1 August (both DT). "Mink invasion poses threat to countryside" (*The Times* 22 April) and "The killer that lurks along our riverside" (*Western Daily Press* 26 September). Nationally, mink are thought to outnumber otters *Lutra lutra* by 15 to one and are held to be partly responsible for the decline in numbers of water voles as well as of moorhens, wagtails, dippers and kingfishers.

Weasel *Mustela nivalis.* (4) Records from West Littleton ST7575, 18 April (S & JP), Walton Moor ST4372, 24 April (LR), Cadwell Hill ST7774, 24 April and Doynton ST7274, 4 July (both PJC).

Stoat *Mustela ermina.* (5) Records from Walton Moor ST4372, 2 March (LR), Norton Wood ST4372, 12 March (PT), Keynsham ST6469, 16 April (PJC), Little Sodbury ST7583, 2 May (DCG & MJM) and West Harptree ST5557, November (BW).

Robbie McDonald of the University of Bristol is currently undertaking a PhD study on the ecology of stoats and weasels in the Castle Combe area.

Badger *Meles meles.* (19) As usual, badgers hit the local headlines at regular intervals, with their setts being in the way of development and being illegally interfered with, populations increasing "out of control" and causing "untold" crop and garden damage and being involved in the TB debate. "Badger to Blame for Path Damage" (*Bristol Evening Post,* 11 April), "MP's Concern for Badgers Fails to Sway Planners" (*Bristol Observer* 28 April), "Act Now on Badgers, Urges Farmer" (*Western Daily Press,* 11 May), "It's a Badgering Nightmare - Crops are Rolled and Hedges are Damaged" (*Farming Review, Western Daily Press,* 30 May), "Everyone's a Loser in the Badger Battle" (*Western Daily Press,* 25 October), "Sett to on the

Culling Fields" (*Western Daily Press*, 26 October), "Badgers Sett to Move" (*Western Daily Press*, 31 October), "Badger Trappers Deny Sales for Experiments" (*Western Daily Press*, 6 November), "Badger Count is just Guess-Work" (*Western Daily Press*, 10 November), "Badger Sett Meddling Costs Woman £600" (*Western Daily Press*, 6 December).

Badgers and Bovine Tuberculosis In 1995 MAFF destroyed 1,448 badgers following TB breakdowns in cattle. This compares with 1,682 in 1994 and 1,094 in 1993. (*Hansard* Written Answer p690, 13 December). An article in *BBC Wildlife Magazine*, August 1995, in the "Taking Issue" series, debated the Bovine TB and Badgers issue. On the "pro-continued control" side was K.C. Meldum (Chief Government Veterinary Officer), and on the "against control" side Mary Jarvie of the National Association of Badger Groups.

The main points for continued control were:

- The scientific consensus is that badgers can infect cattle with TB.
- The Government's control programme is based on the recommendation of two independent enquiries.
- New research and a new blood-testing technique will allow for more selective culling.
- A vaccine for badgers could be 15 years away.

The main points against continued control were:

- There is no evidence that badgers pass TB to cows.
- The money wasted on culling could be spent looking for a real solution.
- In Northern Ireland, where there is no culling, the TB fluctuations match Britain's.
- The 'live test' will result in the deaths of four times as many badgers.

No doubt the debate will continue!

Records of badgers (almost all road traffic casualties) came from the following 1km squares:- ST3857, ST3862, ST5369, ST5781, ST6457, ST6469, ST7271, ST7473, ST7476, ST7573, ST7660, ST7757, ST7759, ST7760, ST7787, ST7858, ST7988.

(DT, PJC, JP, RH).

Fox *Vulpes vulpes.* (32) Bristol's world-famous foxes were hit by an epidemic of sarcoptic mange. (Mange is caused by a parasitic mite that burrows into the skin and, without treatment can lead eventually to the animal's death) At least half the University of Bristol's tagged and radio-collared foxes were reported to be infected. Exactly how the disease reached Bristol is unclear but it is likely to have come from rural foxes to the south-west of the city, where it has been reported for the last couple of years (*BBC Wildlife Magazine*, February 1995).

Fox records for 1995 from the following 1km squares:- ST4064, ST4372, ST5259, ST5575, ST5576, ST5773, ST5777, ST5779, ST5876, ST5877, ST6079, ST6469, ST6475, ST6568, ST6569, ST6575, ST7172, ST7290, ST7374, ST7474, ST7481, ST7575, ST7858, ST7862, ST7865 (DT, LR, MB, JP, PJC, S & JP, SK, AFJ, IFG).

ARTIODACTYLA (deer)

Red Deer *Cervus elaphus.* (2) A red deer stag and four hinds were seen in the Failand area on 22 June grazing in corn and oil-seed rape fields. The stag was shot in September and the hinds were seen again on 23 October with another stag. The deer are thought to have been released/escaped from a deer farm near Portbury. They were causing extensive crop damage and were all eventually shot (JH).

Roe Deer *Capreolus capreolus.* (16) Records from ST6464, ST6564, ST6878, ST7171, ST7370, ST7374, ST7377, ST7477, ST7569, ST7574, ST7575, ST7577, ST7672, ST7676, ST7863 (S & JP, DT, DC, PJC).

Roe deer became extinct throughout much of Great Britain, and at the beginning of the 18th century were thought to survive only in parts of central and mid Scotland. They were reintroduced at Milton Abbey, Dorset in 1800 and all those in Southern England are considered to be derived from introduced stock. Roe have so far spread northwards as far as Gloucestershire/Oxfordshire. Other introductions were in East Anglia and the Lake District. (Corbet & Harris, 1991).

Reeves' Muntjac *Muntiacus reevesi* (2) Records from Frenchay ST6477, February of one being chased by a dog (AFJ), and Barrow Gurney, 19 October, of four seen grazing in a grass field (JH)..

THE 1995 DROUGHT

The summer of 1995 was the third hottest, second driest and fifth sunniest on record. Moles, hedgehogs and badgers suffered when their main food sources such as earthworms became hard to find. The hot weather seems to have suited Britain's bats, and species such as the rare greater horseshoe bred earlier than ever previously recorded. Brown long-eared bats and pipistelles were reported to have bred well. Dormice may have come under pressure before hibernation, as hazelnuts matured early - dormice find them very difficult to open when they are fully ripe. (*BBC Wildlife Magazine* December 1995)

EXTINCT MAMMALS

An interesting paper by Aybes &Yalden (1995) compared the place-name evidence for the former presence of wolves, beaver and wild boar throughout Great Britain with archaeological evidence. Wolf place names in Gloucestershire include Wolfridge Hill ST6087 (ridge haunted by a wolf) and in Wiltshire, Woolley ST8261 (wolves' clearing /wood). Beaver place names in Gloucestershire include the 'lost' names Befer Pyttas ST6979 (beaver pit) and Beverwelle ST7773 (beaver stream). Wild boar place names include Evercreech ST6637 in Somerset and Everley ST6788 in Gloucestershire.

Archaeological sites for wolves include Bleadon ST3456, Durdham Down ST5674, Walton near Clevedon ST4274 and Wookey Hole ST5347. Beaver remains have been recorded from the bed of the River Avon near Chippenham ST9173 and near Melksham ST9064, and also near Westbury sub-Mendip ST8650. Wolves were last recorded in England in 1304-05 and they may have survived in Scotland until 1743. Beavers were probably already extinct in Britain in 1188, again hanging on in

Scotland until the end of the 15th Century, although one is known to have lived recently for some years in a river in Somerset in the Cricket St Thomas area.

"BEASTS"

"Beast of Bodmin is just a Pussycat" (*Sunday Times* 26 February). Following a MAFF- funded investigation into the presence of the "Beast of Bodmin" (first sighted in 1983), Charlie Wilson and Simon Baker of ADAS concluded there was no evidence to prove that any of the photographs or films of the "beast" depicted anything other than a feral or domestic cat. Plaster casts of two footprints proved to belong to a cat and a dog and there was no evidence that any of the sheep killings were caused by a large cat (Baker & Wilson, 1995).

MAMMAL POPULATIONS

The Joint Nature Conservation Committee (JNCC) commissioned a report on the populations of all British mammals, an evaluation of their current population trends and any threats to their survival. After what the report authors called a Herculean task, they came up with a (very) educated 'guesstimate' of the population sizes for every species of wild British mammal before the onset of the breeding season. The most numerous mammal is the field vole with an estimated population of 75 million, followed by common shrew with 41.7 million, woodmouse 38 million and rabbit, 37.5 million. The least common mammals are the introduced red-necked wallaby *Macropus rufogriseus* (29 individuals), park cattle *Bos taurus* (45), reindeer *Rangifer tarandus* (80), Chinese water deer *Hydropotes inermis* (650) and the native grey long-eared bat *Plecotus austriacus* (1,000). (Harris *et al.,* 1995).

WILD MAMMALS (PROTECTION) BILL

Despite wide cross-party support, the Wild Mammals (Protection) Bill, making it an offence to 'cruelly kick, beat, impale, crush, burn or drown any wild mammal', ran out of time in the last parliamentary session of 1995. Its supporters promised to continue the fight to get it onto the statute books (*Veterinary Record* 18 November 1995).

ACKNOWLEDGEMENTS

The author is grateful to all those who have provided records and information for the 1995 report:

Kate Barlow (KB), Mark Brookes (MB), Paul Chadwick (PJC), David Clarke (DC), Bob Cropper (RC), R Elwood (RE), Alison Gowers (AG), D. C. Grenfell (DCG), Florence Gravestock (IFG), John Haines (JH), Royston Hoddinott (RH), Jim Jayne (AFJ), Gareth Jones (GJ), Sylvia Kelly (SK), Mary Marsh (MM), MJ Morgan (MJM), James Packer (JP) (Mammalaction Survey), Susan and John Prince (S & JP), Lyndon Roberts (LR), Liz Roberts (ER), Tony Robinson (AR), Phil

Tollerton (PT), Roger Symes (RS), David Trump (DT) and Barbara Winn (BW).

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Proceedings of the Bristol Naturalists' Society, **55**:xxxix-xlviii

BRISTOL BOTANY IN 1995

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The year 1995 was the warmest in the record of the Earth's temperature series, just beating 1990, and being about 0.4°C warmer than the 1961-1990 reference period. At Long Ashton temperatures were about 1.0°C higher than the norm in the annual mean maximum value (14.7°C) and the annual mean minimum (7.2°C), but even so there were 66 ground frosts. Except for March, September and December (a very cold month), all months were above average temperatures, with February, July and especially August and October being notably warm. Rainfall at Long Ashton was slightly above average (878 mm), but 1995 was the driest year since 1990. January, February and September were very wet months, but the spring and particularly the summer were exceptionally dry, all months from March to August inclusive being drier than usual.

The season was a quite early one with vernal species flowering well. In January *Daphne laureola* was flowering in Cheddar Wood and Snowdrops at Uphill; in early February there were flowers of *Helleborus viridis* at Nettlebridge and of *Chrysosplenium alternifolium* in Stoke Lane Valley. A notable feature was the display of *Gagea lutea* at Stoke St. Michael, a plant which is a notoriously shy flowerer. From May onwards the hot dry weather adversely affected the flowering of some species; no inflorescences were produced by *Himantoglossum hircinum* at Berrow, *Ophrys insectifera* flowered poorly at Cleaves Wood on a hot south-facing slope in open grassland (but flowered well in the shaded Leigh Woods) and *Aster linosyris* did not flower at Uphill or Brean Down (all records RSC). Exceptionally a little *Prunus spinosa* was flowering on Clifton Down at the end of the warmest October on record in Bristol (PJMN).

A substantial number of new localities for both native and alien species was reported in 1995. The persistence of *Carex* □ *evoluta* (which was feared lost) on the peat moors is welcome news, but regrettably *Thalictrum flavum* seems to be lost from near Leigh Woods and *Tragopogon porrifolius* from Sneyd Park. New vice-county records include hybrids of *Rumex* (*lousleyi* and *knafii*), the intergeneric hybrid *Festulolium braunii*, and the aliens *Colutea* × *media*, *Epilobium brunnescens* and *Campanula pyramidalis*. Of particular interest is the report of *Crataegus pentagyna* on Durdham Down, the only record for Britain. Also of very considerable note is the good performance of *Limosella aquatica* on the shores of Chew Valley Lake, last recorded in v.c. 6 (North Somerset) by Sole in 1791.

Considerable concern arose when it was discovered in the summer that the Suspension Bridge was blasted, to remove paint, with 100 tonnes of slag, being waste from a Swedish copper smelting works. Approval for the use of this slag was given because it was reported to be 'inert'. However, subsequent analyses of the slag (and paint debris) which had fallen into the Avon Gorge, giving deposits some 2 cm thick, with deeper amounts on some ledges, showed that it contained 200-300 times the normal levels of copper and zinc in soils as well as smaller quantities of other undesirable elements. The possible extent of damage to the flora is indicated in the article 'Rare plants in the Avon Gorge, Bristol, contaminated with heavy metals' by T. Rich, L. Houston and M. H. Martin in *BSBI News*, 1996, Vol. **72**, pp. 36-37. Efforts have been made to remove the toxic deposit, a difficult operation especially on the steep and dangerous slopes. Likely to be most affected are two of the statutorily protected rarities of the Gorge, *Allium sphaerocephalon* and *Veronica spicata*, but many other species will probably suffer, as the contamination extended some distance from the bridge. Hopefully the efforts being made to save the plants will be successful.

Names of contributors associated with several records, or with the determination of specimens, are abbreviated thus:

PJC	P.J. Chadwick	CG	C. Greenway
EJC	E.J. Clement	CK	Mrs C. Kitchen
RSC	R.S. Cropper	MARK	M.A.R. Kitchen
JF	Mrs J. Fryer	RVL	R.V. Lansdown
FG	Miss I.F. Gravestock	JM	J. Martin
IPG	I.P. Green	PJMN	P.J.M. Nethercott
PRG	P.R. Green	MJT	M.J. Trotman

The area covered by this report is essentially that defined by J.W. White for his *Flora of Bristol* (1912). The eastern boundary is taken as the old boundary of Wiltshire where it meets the old boundaries of both Gloucestershire and Somerset. The southern limit is taken as approximately the course of the River Brue along some of its length. The area comprises the northern part of the Watsonian vice-county of North Somerset (v.c. 6) and the southern part of West Gloucestershire (v.c. 34). In the following records these parts are designated S and G respectively

.Plant names are in accordance with C. Stace, *New Flora of the British Isles*, 1991.

Helleborus viridis L. Well distributed in Stickstey Wood and nearby wood and field, Upper Kilcott, G, RSC. Two patches on stream banks, on south edge of Flat Wood, West Compton, S, IPG.

Ranunculus baudotii Godron Blake's Pools, north of Wick St. Lawrence, S, JM. Also *Petroselinum segetum* (L.) Koch and *Trifolium squamosum* L.

Aquilegia vulgaris L. Lane, Stoke Bishop, Bristol, G, IFG. Also *Saponaria officinalis* L

Thalictrum flavum L. A small colony known for many years in a saltmarsh below

Leigh Woods, Bristol, S, was last seen by PJMN in 1975. Its loss may result from vegetation changes in this unstable area.
Nymphaea alba L. ssp. *alba* Gall Pond, Tortworth, G, RVL.

Ceratophyllum submersum L. In rhyne near Blackford Moor Lane, Mark, S, Mrs A. Bodley.

Raphanus raphanistrum L. ssp. *maritimus* (Smith) Thell. Roadside by upper saltmarsh, Old Passage, G, MARK & CK.

This is an extension of its range, being previously noted as having reached south of New Passage (*Bristol Botany in 1976*, p. 18). Listed by J.W. White *Flora of Bristol* (1912, p. 167) as very rare, it is now not infrequent along the Severn below New Passage.

Viola canina L. Plentiful between the Round Clump and Pen Hill Wood, Rookham, S, PRG.

Malva neglecta Wallr. One plant in rough meadow, Walton Moor, Gordano, S, RSC.

Trifolium striatum L. A few plants, with *Cerastium diffusum* Pers. and *C. pumilum* Curtis, in short grassland, King's Castle Wood, Dinder, S, IPG.

Hippocrepis comosa L. Dulcote Hill, S, RSC. Also *Aira caryophyllea* L., *Carex divulsa* Stokes and *Myosotis ramosissima* Rochel

.
Lathyrus sylvestris L. Several large patches, old railway line, Shapwick Heath, S, RSC

.
Agrimonia procera Wallr. Flowering and fruiting in good quantity in rough vegetation, Leighton Hanging, S, RSC.

Rosa tomentosa Smith Large bush on road verge, Westhay, S, RSC.

R. rubiginosa L. Two bushes on bank of the River Chew, Compton Dando, S, RSC.

R. micrantha Borrer ex Smith Several bushes, and probable hybrids, Draycott Sleights, S, RSC.

R. agrestis Savi On southern slopes of Cadbury Camp, Tickenham, S, CG, conf. Rev. A.L. Primavesi. It has long been known here - see J.W. White *Flora of Bristol* (1912, p. 294) and *Bristol Botany in 1985*, p. 56.

Chrysosplenium alternifolium L. In good quantity in boggy copse and along stream bank, North Nibley, G, and abundant along stream in woodland, Ozleworth Bottom, G, RSC.

Oenanthe pimpinelloides L. Large colony in damp field, foot of limestone slope, Twinhills, near Wells, S, RSC.

O. lachenalii C. Gmelin Plentiful in damp flush below Folly Wood, North Wootton, S, PRG.

Rumex □ *lousleyi* Kent (*R. cristatus* DC. □ *R. obtusifolius* L.) Several specimens, with both parents, dunes, Sand Bay, S, IPG. This is a first record for v.c. 6.

R. □ *pratensis* Mert. & Koch (*R. crispus* L. □ *R. obtusifolius* L.) Several plants, Brean Down, S, IPG.

R. pulcher L. Flowering well, persistent and spreading on Durdham Down, Bristol, G, IFG.

R. □ *knafii* Celak. (*R. conglomeratus* Murray □ *R. maritimus* L.) One plant in disused peat cutting, Meare Heath, S, PRG, conf. Dr J.R. Akeroyd. This is a first record for Somerset.

Salix triandra L. Pond opposite church, Tortworth, G, RVL.

Symphytum tuberosum L. Large patch by track, Leigh Woods, Bristol, S, JM.

Lithospermum purpurocaeruleum L. Where well-known, a substantial colony persists on a bank in Weston Big Wood, Weston-in-Gordano, S, E.G.M. Niblett. It was noted here by J.W. White, *Flora of Bristol* (1912, p. 436).

Hyoscyamus niger L. Middle Hope, S, JM.

Limosella aquatica L. Plentiful around the shores of Chew Valley Lake, S, T.W.J.D. Dupree. Also reported in different places on the shores by JM and by PRG. It flowered and fruited well. Associates included *Artemisia biennis, Gnaphalium uliginosum* and *Veronica catenata.*

The Mudwort was feared extinct in v.c. 6, the former record (cart ruts near Highbridge) being made by Sole in 1791. J.W. White (*Flora of Bristol*. 1912, p. 456) considered it likely that it might prove to be a Bristol plant.

Lamium amplexicaule L. Several plants in garden border, Berrow, S, RSC.

Ajuga reptans L. A single white-flowered plant with normal ones, grassy bank, Cheddar, S, RSC.

Campanula rotundifolia L. One white-flowered plant with a few normal ones, Compton Martin, S, RSC.

Sambucus ebulus L. Large patch, Avonmouth Sewage Works, G, JM.

Dipsacus pilosus L. American Museum, Claverton, S, and also Stephens Vale, east of Temple Cloud, S, JM.

Crepis biennis L. Goose Green, near Yate, G, JM. Also *Genista tinctoria* L. ssp. *tinctoria.*
Butomus umbellatus L. Backwell Lake, S, JM

.
Zannichellia palustris L. Flowering and fruiting well in water tank, Brinsea, south of Congresbury, S, RSC.

Polygonatum multiflorum (L.) All. Lane, Stoke Bishop, G, A.G. Smith.

Gagea lutea (L.) Ker Gawler Flowering in Littlewood Wood, G; many plants flowering in small patch of rocky wood, Stoke St. Michael, S, RSC.

Colchicum autumnale L. Flowering in good numbers, rough field, Shipham, S, RSC.

Juncus compressus Jacq. Several plants, damp rushy pasture, Latcham, near Wedmore, S, Mrs E.J. McDonnell.

J. acutus L. Increasing well from seed around the original colonist (see *Bristol Botany in 1988*, p. xxviii), and also one plant some 100 yards distant, northern part of saltmarsh, Berrow, S, RSC and A.J. Willis.

Epipactis purpurata Smith Frequent, where well-known, Littley Wood, Lower Woods, G, MJT.

Spiranthes spiralis (L.) Chevall. Abundant on playing field, Burnham-on-Sea, S, RSC.

Coeloglossum viride (L.) Hartman Flowering well on Shapwick Heath and adjoining meadow, S, RSC.

Ophrys apifera Hudson A small population on roadside bank, Cold Ashton, G, and on grassy bank, Tormarton Interchange, G; also a few plants on grass verge, Pennsylvania, G, all PJC. One plant in grass by ride, Stock Hill Plantation, Priddy, S, RSC. Old grassland on north-facing slope, Croscombe, S, P. White.

Orchis morio L. More than a thousand spikes in field, Knowle Hill, West Compton, S, RSC.

Anacamptis pyramidalis (L.) Rich. Plentiful on grassy bank, Tormarton Interchange, G, and on road verge, Tolldown Farm, southwest of Tormarton, G, PJC. Also in paddock by monument, Battlefields, Lansdown, G, PJC.

Carex distans L. A few specimens, with *C. hostiana* DC. and *Ophioglossum vulgatum* L., in field near Pilton Wood, West Compton, S, IPG. In damp flush below Folly Wood, North Wootton, S, PRG.

C. binervis Smith Two plants on heathland between the Round Clump and

Rookham Wood, Rookham, S, PRG.

C. extensa Gooden. Several clumps in upper parts of saltmarsh, Kewstoke, S, IPG.
C. rostrata Stokes Blake's Pools, north of Wick St. Lawrence, S, JM.

C. □ *evoluta* Hartman (*C. lasiocarpa* Ehrh. □ *C. riparia* Curtis) Large patch in peat hollow, Street Heath NatureReserve, S, Mrs M. Collins, conf. A.O. Chater.

First reported from Sharpham Moor in 1915, it was rediscovered there in 1955 (*Bristol Botany in 1955*, p. 106) but subsequently feared lost. Originally this was its only station in Britain but it is now known from Cambridgeshire.

□ *Festulolium braunii* (K. Richter) A. Camus (*Festuca pratensis* Hudson □ *Lolium multiflorum* Lam.) Market garden, Bromley Heath, G, MJT, det. R.M. Payne. This is the first record for v.c. 34.

Parapholis strigosa (Dumort.) C.E. Hubb. Persisting but in much reduced amount at Sea Mills, Bristol, G, PJMN, where previously recorded (*Bristol Botany in 1966*, p. 243).

ALIENS

Adiantum capillus-veneris L. Naturalised on walls near American Museum, Claverton, S, JM.

Berberis □ *stenophylla* Lindley (*B. darwinii* Hook. □ *B. empetrifolia* Lam.) Uphill, S, JM.

Chelidonium majus L. flore pleno Several clumps under wall on Downs, Rockleaze, Bristol, G, IFG.

Corydalis cava (L.) Schweigger & Koerte Persisting, in abundance, in both pink and white forms, over much of Terrace Wood, Ston Easton, S, JM. This plant was earlier recorded here as *C. bulbosa* by Mrs K. Targett (*Bristol Botany in 1986*, p. 69); it was found (both colours) in this site in great abundance in 1992 by S. Preddy.

Rapistrum rugosum (L.) Bergeret Several plants, waste ground near the River Avon, Shirehampton, G, PJMN. Also Herriotts Bridge, Chew Valley Lake, S, JM.

Barbarea verna (Miller) Asch. Garden weed, Rowberrow, S, IPG.

Sisymbrium orientale L. Lamplighters Marsh, Shirehampton, G, JM.

Hypericum □ *inodorum* Miller (*H. androsaemum* L. □ *H. hircinum* L.) Well naturalised on walls near American Museum, Claverton, S, JM.

Amaranthus retroflexus L. One plant, market garden, Bromley Heath, Bristol, G, MJT.

Oxalis exilis Cunn. In roadside turf. Stoke Bishop, G, IFG. Also *Colchicum autumnale* L.

Genista hispanica L. ssp. *occidentalis* Rouy Uphill, S, JM. Also on dry bank of quarry on roadside, probably planted, north of Westbury-sub-Mendip, S, J. Poingdestre, det. IPG.

Colutea □ *media* Willd. One tree of about 2 m, in stonework of bridge (parent tree in garden in village), Croscombe, S, PRG. This is a new county record.

Rubus tricolor Focke Hedgerow, waste ground, Westbury-on-Trym, Bristol, G, IFG, det. A.C. Titchen.

Fragaria □ *ananassa* (Weston) Lois., Vilm., Nois. & J. Deville Royate Hill, Bristol, G, JM.

Alchemilla mollis (Buser) Rothm. Lamplighters Marsh, Shirehampton, G, JM.

Prunus cerasifera Ehrh. Avon Gorge, G, JM

Cotoneaster dielsianus E. Pritzel ex Diels Royate Hill, Bristol, G, JM, det. JF. Also *C. simonsii* Baker, JM, det. JF.

C. sternianus (Turrill) Boom Royate Hill, Bristol, G, JM, det. JF.

C. vilmorinianus Klotz Royate Hill, Bristol, G, JM, det. JF. This is the second record for v.c. 34.

Crataegus pentagyna Waldst. & Kit. ex Willd. A single small tree, fruiting abundantly, Durdham Down, above the Gully, Bristol, G, MARK, CK, C.J. & C.V. Galbraith, L. Houston & N. Wray, det. MARK, conf. EJC. This is the only British record; Herb. MARK & CK and Herb. EJC.

This tree was incorrectly named as *C. nigra* in 'A review of the alien and introduced plants of the Avon Gorge' by A.L. Grenfell in these *Proceedings* Vol. **47**, pp. 33-44. (1987)

Pyrus communis L. A single tree of medium height, close to the bank of the River Boyd, Wick Rocks, G, PJMN.

Sedum stellatum L. Two large stands on slope of grassland, Croscombe, S, IPG, conf. Dr H.J.M. Bowen & R. Stevenson.

Ribes alpinum L. Small stand by track on site of ruin, Rowberrow, S, PRG.

Epilobium brunnescens (Cockayne) Raven & Engelhorn About a hundred plants along forest ride, Rowberrow Warren, S, IPG. This is a new record for v.c. 6.

Gunnera tinctoria (Molina) Mirbel One plant by pond adjoining stream, Ston Easton, S, IPG.

Ammi majus L. Herriotts Bridge, Chew Valley Lake, S, JM.

Cucumis melo L. Sewage Works, Avonmouth, G, JM. Also *Cucurbita pepo* L. and a single plant of *Physalis peruviana* L.

Polygonum wallichii Greuter & Burdet Large stand in old quarry, Shepton Mallet, S, PRG.

Rumex cristatus DC. Several plants, with *R. obtusifolius* L. on sand hills near Sand Point, Sand Bay, S, Mrs D. Maxwell, conf. IPG.

Phillyrea latifolia L. In dunes, Uphill Sands, S, CG. Probably bird-sown.

Symphytum grandiflorum DC. Hedgebank, Stowey, S, JM.

Nicandra physalodes (L.) Gaertner Coastal path, Clevedon, S, CG.

Veronica filiformis Smith Lay-by, Lawrence Weston, G; in turf, Weston-super-Mare, S; playing field, Hutton, S, IFG.

Nepeta □ *faassenii* Bergmans ex Stearn Sandbank, Kewstoke, S, IPG.

Campanula pyramidalis L. On 200-year-old wall, Bromley Heath, Bristol, G, MJT, conf. EJC. This plant, not grown by the owners in the garden, was observed by them for the last five years. This is the first record for v.c. 34.

Inula helenium L. Plentiful in field, Panborough, S, P. White.

Aster □ *salignus* Willd. (*A. novi-belgii* L. □ *A. lanceolatus* Willd.) Sewage Works, Avonmouth, G, JM.

Tragopogon porrifolius L. In 1994, several robust plants, persisting in 1995, but not seen in adjoining gardens, lane, near Sea Mills, G, IFG.

A single specimen was last seen in 1965 in Sneyd Park, Bristol, G, by PJMN. Its loss here is apparently because of the laying-out of a sports field and change in land use by the railway. The plant was first recorded in this site by Banks and Lightfoot in 1773 (J.W. White *Flora of Bristol*, 1912, p. 398).

Cicerbita macrophylla (Willd.) Wallr. Lane, Westbury-on-Trym, G; also Stoke Bishop, G, IFG.

Stratiotes aloides L. Gall Pond, Tortworth, G, RVL.

Hemerocallis fulva (L.) L. Several plants, Stoke Bishop, G, IFG.

Allium roseum L. Plentiful, Draycott, S, PRG

Hermodactylus tuberosus (L.) Miller Planted on roadside bank, where becoming well naturalised (two large clumps) and known for several years, Alveston Down, G, Mrs S.M. Wilton.

Yucca recurvifolia Salisb. One small plant on sandbank, Kewstoke, S, IPG.

Acorus calamus L. Backwell Lake, S, JM.

Arum italicum Miller ssp. *italicum* Well naturalised on roadside bank, Alveston Down, G, MARK, CK & Mrs S.M. Wilton. Several clumps, with *Adoxa moschatellina*, North Wootton, S, IPG.

Cyperus longus L. Gall Pond, Tortworth, G, RVL. Blake's Pools, north of Wick St. Lawrence, S; also Backwell Lane, S, JM.

Polypogon viridis (Gouan) Breistr. Several plants as weeds in nursery, Woodford, near Wells, S, IPG.

Echinochloa crusgalli (L.) P. Beauv. Sewage Works, Avonmouth, G, JM. Also *Panicum miliaceum* L.

LIVERWORT

Reboulia hemisphaerica (L.) Raddi Plentiful in a small damp area, with loose stone and shallow earth, The Gully, Durdham Down, Bristol, G, PJMN.

This liverwort is mentioned for St. Vincent's Rocks and Durdham Down by H.H. Knight in 'The Hepatics of Gloucestershire' (*Proceedings of the Cotteswold Naturalists' Field Club*, Vol. **xx**, Pt. 3, 1920).

ACKNOWLEDGEMENTS

I thank everyone who has supplied records and helped with these, especially Mr I.P. Green, Mr M.A.R. Kitchen and Mr P.J.M. Nethercott. I am indebted to Mr D.J. Lovell at Long Ashton Research Station for meteorological records.

Facing: The Waldegrave Pool, Priddy Mineries, January, 1994
(C) Robin Williams/Vanellus

Overleaf: V. D. Dennison.
Photograph courtesy of Edward Dennison.

THE MENDIP HILLS

Edited by ANNE F. HOLLOWELL

ASSISTED BY A COMMITTEE

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Cover: Cheddar Pink, *Dianthus gratianopolitanus*, above Cheddar Gorge. K. C. Allen.
Frontispiece: Waldegrave Pool, Priddy Mineries, Jan. 1994.© RobinWlliams/Vanellus
Opposite: V. D. Dennison. Photo courtesy of Edward Dennison.

Proceedings of the Bristol Naturalists' Society (1995), **55**:1-2

THE MENDIPS - INTRODUCTION

Anne F. Hollowell, Hon. Editor

81 Cranbrook Rd, Redland, Bristol BS6 7BZ

This volume came about through the initiative of V. D. Dennison. He recognised that earlier accounts of his beloved hills were becoming out of date in some respects, and that much new information had become available. This led him to suggest the Mendips as a fitting subject for one of the Special Issues of our *Proceedings*, and to propose that it should be produced as a joint project with the Mendip Society. Vic, as his many friends knew him, studied geography and geology at the London School of Economics and later at Cambridge University, and taught these subjects at schools and colleges in Lincolnshire and then in Bristol. His great interest was in geomorphology, the study of land forms, which combined his two disciplines, and it is fitting that the geomorphic evolution of Mendip is the subject of our final chapter.

Vic Dennison was ideally placed to act as a link between the two Societies, as he had actively served both in various capacities for many years, and had held their highest offices – he was President of the Bristol Naturalists' Society in 1983 and 1984, and was Chairman of the Mendip Society for six years, up to a month before his death. He paved the way for the co-operation, and represented both Societies during the planning of the contents and the choosing of contributors, who are drawn from both bodies. We are proud to dedicate this volume to his memory. It is sad that he did not live to see its publication.

Many books have been written about the Mendip Hills, from various points of view. Some have dealt at length with aspects of their natural history and the effects of human activites, while others have only touched on these matters. In this, the fourth in an occasional series of special Theme Issues of our annual *Proceedings.,* we do not seek to replace these earlier accounts, nor to give a comprehensive coverage of the area's natural history. Rather, our contributors have used the results of observations and studies made in recent years to deal with a variety of topics. For some subjects, the story is brought up to date or re-told in the light of the latest researches, and for others it is told for what seems to be the first time.

We did not constrain authors to a particular level of treatment. Most articles are suitable for the general reader; the few which are necessarily more technical than the others still contain much to interest the non-specialist. Some tackle broad aspects. Thus 'Botanical Walks...' describes the wild flowers and the habitats whch ramblers may see in a variety of Mendip areas. 'Agriculture on the Mendips' shows how the special characteristics of the hills – the soils, underlying rocks, restricted water supply, aspect and slope of the land and the local climatic conditions have constrained farming activities from the earliest times, with the added burden today of

Very different is the account of the biological implications of heavy metals, which deals with the effect of mining for minerals from Roman times or earlier, leading through soil contamination to the evolution of specialised plant communities of great scientific interest. Incidentally, this contribution is one of several that contain data not previously published.
The article on 'Ancient ponds' solves an old puzzle about farm water supplies, and other authors deal with specific topics or groups of animals – plant galls, invertebrates under logs and stones, dragonflies, reptiles and amphibians, birds and mammals. We then go back some hundreds of years with an account of the geologically recent development of the vegetation on the northern slope of Black Down.

Finally we have two fascinating accounts of how the Mendip Hills came to be as they now are. From a common starting point, the authors deal with different aspects – the geology and the geomorphology resepctively, reflecting the forces which shaped the Hills and gave rise to the rock formations and drainage patterns which, to this day, place constraints on all life on Mendip, both the wildlife and the human inhabitants.

ACKNOWLEDGEMENTS

The colour photograph of the Cheddar Pink, *Dianthus gratianopolitanus*, above Cheddar Gorge which forms our cover was taken by Dr Keith Allen, one of our authors, as were the colour photographs (facing page 62) which illustrate his account of Mendip flowers and habitats. Mrs Janet Boyd provided her own colour photographs (facing page 63) to accompany her contribution on plant galls and Robin Williams produced, specially for this issue, the pen and ink drawings of two of the 'creatures under logs and stones' about which he writes. Biographical details of V. D. Dennison were derived from an 'Appreciation' by his son Edward, which appeared in the Mendip Society's Newsletter.

The contents of this issue were agreed between the Bristol Naturalists' Society's Publications Committee and representatives of the Mendip Society. Generous financial support for the project from the Mendip Society is gratefully acknowledged. The former Honorary Editor of this series, Dr Peter Crowther, undertook the initial correspondence with potential authors before he left Bristol for a new post at the National Museum of Ulster. Thanks are also due to Mr S. M. Taylor for his skill in preparing the camera-ready copy for the printer, which has maintained a high quality of presentation in a publication which is still an economic proposition for the Society. He has been a very long-standing member of the Society's Publications Committee, and our debt to him over the years has been considerable. The present Honorary Editor is most grateful to the Chairman and members of this Committee for their support during the preparation of this volume, as well as to the members of the Mendip Society who have been involved. The considerable delay between inception and publication is partly a consequence of the multiple authorship but is largely, I'm afraid, to be laid at the door of the present Honorary Editor, who offers her apologies to all concerned.

Proceedings of the Bristol Naturalists' Society, **55**:3–18

BOTANICAL WALKS AND WANDERINGS IN THE MENDIP HILLS

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ABSTRACT

The Mendip Hills are renowned for plant species which are rare or restricted in other parts of the British Isles. Much has been written about these rareties but little on the overall flora. To help to appreciate this flora, the major habitats are briefly described and then twelve walks and wanderings of varying distances are suggested, which will incorporate the wide variety of species and habitats found on Mendip. The number of walks is necessarily restricted here and many others can be found. The walks are at

Brean Down	Draycott Sleights
Wavering Down to Crook Peak	Blackmoor and Ubley Warren
Cheddar Wood	Chancellor's Farm
Dolebury Warren to Blackdown	Ebbor Gorge
Above Cheddar Gorge - Southern side	Priddy Mineries
Black Rock, Black Rock Drove and Long Wood	Asham Wood

INTRODUCTION

With the selection of walks, the author has tried to include the best and most varied botanical areas. Many of these are owned or managed by the Somerset Wildlife Trust (SWT) or owned by the National Trust. The walks are not intended as a series of direct walks from A to B but, by wandering along these routes, the important habitats listed below will be seen. A six-figure map reference is given as a recommended start to each area on the Ordnance Survey. Landranger maps Nos. 182 and 183, on a scale of 1:50,000 or 2cm to 1km.

In this chapter, English names are used for each plant mentioned. An appendix lists these in alphabetical order, with their scientific names. These follow Stace (1991), but where more familiar alternatives have been used in earlier publications, these are added in brackets.

HABITATS

LIMESTONE GRASSLAND

The best examples of limestone grassland are on the southern slopes of Mendip, where the calcareous soils are thin. Good examples are the southerly slopes of Wavering Down, Crook Peak, Dolebury Warren, Black Rock and the southern side above Cheddar Gorge.

Certain plant species are characteristic of these rather treeless slopes. Common shrubs include Hawthorn, which is often the dominant shrub, Privet, Wayfaring Tree and Ash saplings. Characteristic herbaceous plants include many calcicole (calcium-loving) species such as Fairy Flax, Common Rockrose, Stemless Thistle, Carline Thistle, Dropwort, Horseshoe Vetch, Kidney Vetch, Wild Thyme, Burnet Saxifrage, Mouse-ear Hawkweed, Salad Burnet, Yellow-wort, Glaucous Sedge, and Quaking Grass. Others like Bird's-foot Trefoil, Lady's Bedstraw, Yellow Rattle, Common Eyebright and Common Centuary occur on calcareous or more neutral soils.

LIMESTONE ROCKS

Limestone rocks include scree, cliffs and rocky hillsides. Many of the Mendip rarities which are uncommon or absent from other parts of the British Isles occur here and are listed within the individual walks (see also Willis, 1962, Hope-Simpson, 1975 and Hope-Simpson and Willis, 1955 for Mendip rarities).

Good areas are the Cheddar Gorge, the rocky south-facing slope of Brean Down and Burrington Combe. The latter is not dealt with here but many of the common limestone rock plants of the Cheddar Gorge occur there, though none of the rarities.

Shrubs typical of the limestone rocks include Hawthorn, Dogwood, Privet, Wayfaring Tree and the smaller trees, Yew, Whitebeam, sapling Ash and the scramblers Honeysuckle and Madder. The herbaceous plants typical of the rocks include Marjoram, Wild Thyme , Salad Burnet, Greater Knapweed, Small Scabious, Biting Stonecrop, the introduced Red Valerian and a number of small fern species. As with the rarities, a selection of less widespread plants are recorded under the individual areas of Brean Down and Cheddar Gorge.

LIMESTONE HEATHLAND

The more acid soils on limestone rock are the result of either leaching of the original calcareous soils or a covering of wind-blown loess from interglacial times. In either case, the soil is more acid than in the limestone grassland and the flora includes a number of calcifuge (limestone-hating) or more catholic species. Limestone heath is usually found on the plateau above the limestone or on the north-facing slopes. Where the leaching is irregular, calcicoles may be found intermixed with more acid-loving species. The loess is often found in quite small patches within the limestone grassland, as at Wavering Down and Dolebury Warren. Good areas in which to see limestone heath are towards the top of Dolebury Warren, the north side of Brean Down, at Ubley Warren and at Chancellor's Farm.

Characteristic plants of these more acid soils are Bell Heather, Heather or Ling, Bilberry, Tormentil, Heath Bedstraw, Slender St. John's-wort, Heath Speedwell, and the invasive Bracken. Most of the species that occur here also occur in the acid heathland. On part of Chancellor's Farm, as recorded later, neutral grassland has developed on the loess which here covers much of the Black Rock Limestone.

ACID HEATHLAND

Unlike the limestone heathland, these are acid soils which overlie the Devonian sandstone on the Mendip plateau. The soil tends to have a lower pH value than that of the limestone heath. The best areas are the Priddy Mineries and at Blackdown. Dominant plants are Heather or Ling, Bell Heather, Bilberry, Gorse and Western Gorse. Other species include Tormentil, Heath Bedstraw, Heath Milkwort,. Heath Spotted Orchid, Pignut, Lousewort, Heath Rush, Purple Moor Grass, Matgrass and Wavy-hair Grass. In the damper areas are the Cross-leaved Heath and Common Cottongrass.

WETLANDS

Wetland is an uncommon habitat on Mendip, being more or less restricted to a few sites on the plateau. It includes both ponds and surrounding, wetter, areas. The best area is at Priddy Mineries and details from here are given later.

Dominant plants include Common Reed, Reedmace or False Bulrush, Marsh Marigold and Water Horsetail.

LEAD SPOIL

Lead spoil and other lead workings produce a soil rich in lead, zinc and cadmium. Important lead-influenced areas are at Ubley Warren, Blackmoor, Priddy Mineries and Velvet Bottom. These have their own characteristic flora and two plants of special interest on the lead spoil are the Spring Sandwort and the Alpine Penny-cress, two species mostly found in northern Britain. (See also Martin & Fawcett, 1997, in this volume.) Also of interest is the inland occurrence of Sea Campion. Other plants of these soils include Biting Stonecrop, Wild Thyme, Hairy Rock-cress and Bird's-foot Trefoil, all of which are common on the calcareous soils of the limestone grassland.

LIMESTONE WOODLAND

Hope-Simpson & Willis (1955, pp.98, 99) examined eight Mendip limestone woodlands and in their fig. 161, p. 99, detailed the tree composition of four of them. They indicated that the four major trees of the woodland are Ash, Small-leaved Lime, Pedunculate Oak, and in the two more easterly woods, Wych Elm.

Good woodlands to visit are Cheddar Wood, Rose Wood, Rodney Stoke Wood and Asham Wood. In this short account, only Cheddar and Asham Woods will be mentioned in any detail as representing western and easterm Mendip respectively.

The shrub layer and smaller trees of the limestone woodlands include Dogwood, Hawthorn, Hazel, Privet and Buckthorn. The herb layer is dominated by Bluebell, Dog's Mercury and Ramsons. Other interesting herbaceous species are listed in the walks section below and in Hope-Simpson & Willis (1955).

SELECTED AREAS

These are listed from west to east across the Mendip Hills.

BREAN DOWN

Permission: Not required

Ownership: National Trust

Habitats: Limestone grassland on the top, limestone rocks to the south side and limestone heathland on the north side, all with maritime influence

Best time: end of May to end of June to see this fine flora at its best, especially the White Rock-rose.

The Area: Start from the car park at ST296587 and head up the steps to the ridge. To the left and right of the steps, the limestone rocks are yellow with Biting Stonecrop, and towards the top is the glaucous-leaved White Rock-rose , which here reaches its most northerly locality in Europe (see Hope-Simpson, 1975). There are two localities in western Mendip, and on Brean Down it is plentiful on the limestone rocks west of the steps. In June, the mass of colour is impressive,with the White Rockrose, the yellow of Bird's-foot Trefoil and the pink of Sea Thrift. The limestone towards the top, though heavily grazed by rabbits, has a typical flora (see under Limestone grassland habitat). Noticeable here is the abundance of Yellow-wort.

Also occurring here are two further rareties, the Dwarf Sedge and the Somerset Hair-grass. On the limestone rocks towards the western end with the Sea Thrift is the Sea Campion in its more usual habitat (see Lead spoil above). Other plants which are often associated with a maritime influence are Stinking Iris, Alexanders, Wild Carrot and Sea Carrot.

The shrubs on the south side are mostly Hawthorn and Privet. A walk back from the fort along the military road is on more acid loess and provides a sharp contrast, with much Bramble and Bracken. Following the military road back to the car park, look out for the Milk Thistle, an uncommon casual, and Bugloss, which is rarer inland.

WAVERING DOWN TO CROOK PEAK

Permission: Not required

Ownership: National Trust

Habitats: The best habitat is superb limestone grassland. Other smaller habitats include limestone rocks and small areas of limestone heath.

Best times: Middle of May to end of June for most spring and summer flowers, August and early September for the Autumn Lady's Tresses and fine displays of the Stemless Thistle and the Carline thistle.

The Area: Start up the public footpath east of the White Hart in Cross village at ST 418548. On the wall up the path is the Navelwort, which is common on limestone walls throughout Mendip. Through the gate and near the base of the hill is the White Horehound, which is uncommon on Mendip. The climb up Cross Plain towards Wavering Down provides one of the best examples of limestone grassland in the area. Typical calcicoles occur here on the south-facing slopes above Cross, with the Common Rock-rose being abundant. Other common plants occurring here include all those previously mentioned under limestone grassland, together with Common Storksbill, Bulbous Buttercup and Common Milkwort. In late summer, there is a good display of Stemless Thistle. Limestone grassland plants occur over much of Wavering Down but, in a few sites, the very local Spring Cinquefoil is found. Towards the trigonometric point on Wavering Down, small areas of wind-blown loess give a more acid soil, with Bracken, Tormentil, Slender St. John's-wort, Bell Heather and Heath Bedstraw. Small cliffs south of the trigonometric point have little of interest except the Wall Lettuce and, above the cliffs, Horseshoe Vetch.

Walk on to Crook Peak and then take a route down towards the road west of Compton Bishop. Of special interest here are two Mendip rarities, the Dwarf Mouse-ear on the rocks south of the summit and, slightly lower down in the grassland, the Honewort. Other species occurring here are typical of the limestone grassland. The Musk Thistle can be seen in this area. Towards the road, in late summer, are quite small specimens of Autumn Lady's Tresses.

CHEDDAR WOOD

Permission: Permit required. Contact SWT at Fyne Court, Broomfield, Bridgwater.

Ownership:CAMAS (a subsidiary of English China Clays, plc.) but leased by SWT who also own a small part.

Habitat: Limestone woodland

Best time: Late May for Purple Gromwell and September for the Autumn Crocus.

The Area: Park alongside the A371 at ST 444546 and go up the path to the wood. Along the path is the Starved Wood Sedge, in what is probably its only surviving locality in Britain.

Rackham (1988, p. 30) regards Cheddar Wood as "probably the grandest ancient wood in Somerset". Among the trees, Small-leaved Lime, Ash and Pedunculate Oak are dominant. The shrub layer includes Ash saplings, Hazel, and much Privet. In the herb layer, there are many interesting woodland species typical of limestone, for example Hairy St John's-wort, Spurge Laurel, Wood Spurge, Woodruff, the rare Purple Gromwell, particularly on the margins of the wood, and the Wood Sedge. In September, the Autumn Crocus is to be seen.

DOLEBURY WARREN TO BLACKDOWN

Permission: Not required

Ownership: National Trust and others

Habitats: Limestone grassland, limestone heath and acid heathland. There is also some planted woodland and a small area of wetland.

Best times: Much of interest from April to September. Spring and early summer for many of the limestone species, late summer or early autumn for Autumn Lady's Tresses, Autumn Gentian, Woolly Thistle and Heather.

The Area: Park in the parking area at the end of the small side road at ST 446588. Take the steps up the south side of the Iron Age earthworks. Good limestone grassland on this south-facing slope, with most of the species listed earlier for this habitat.

Beyond the earthworks, the slope towards the crest is an area of wind-blown loess giving limestone heathland, with Bell Heather, Tormentil and Bracken.

Near the summit of Dolebury Warren, at the eastern top of the earthworks, is rather bare limestone with more Kidney Vetch than the author has seen elsewhere, and in late summer the autumn Gentian occurs here.

From the Iron Age fort, walk east along Dolebury Warren to the bridleway at ST 466586 and follow this to Blackdown. On the way, dense hawthorn scrub can be seen on the south side of the ridge, which indicates how this scrub would dominate this grassland if it wasn't managed. Along the bridleway hedge towards Blackdown there are typical limestone shrubs, with good examples of the Guelder Rose. Along the path, the Carboniferous limestone is replaced by Devonian sandstone, the soil of which produces the acid heathland of Blackdown. The lower part of Blackdown, alongside Rowberrow Wood, supports a typical acid heathland flora, with Bitter Vetch, Pignut, Lousewort, Heath Bedstraw and Purple Moorgrass. On Blackdown itself, the lower slopes are dominated by Bracken, with both Gorse and Western Gorse present. Towards the top, Heather, Bilberry and Bell Heather are abundant. In wetter areas the Cross-leaved Heath occurs. Follow the bridleway west, between Dolebury Warren and Rowberrow Warren to the car parking area. In the woods are many typical woodland ferns, including Hard Fern. A wet region on the left has some typical wetland plants with Ragged Robin, Water Mint, Cuckoo Flower, Soft Rush and the fine Pendulous Sedge.

On a sunny August evening take a short walk from Tyning's Farm ST 470566 towards the top of Blackdown; the flowering heather makes a fine sight in the low sunlight

ABOVE CHEDDAR GORGE - SOUTHERN SIDE

Permission: Not required

Ownership: Longleat Estate and a small area owned by SWT.

Habitats: Limestone woodland, limestone grassland and limestone rocks

Best time: Middle of May to end of June to see, in particular, the limestone rarities.

The Area: Park on the side of the road near the Blackrock notice board at ST 482545. Take the steep path over the stile on the southern side of the road from the parking area. This leads up through the woods to the top. The limestone woods are dominated by Ash with some Beech, Yew and Whitebeam. The shrub layer has abundant Hawthorn and Hazel. The woodland herb layer along the path includes Wood Anemone, Wood Sanicle, Yellow Pimpernel, Wood Melick and several ferns, including Adder's Tongue. In the more open areas are the Common Spotted and Early Purple Orchids. At the top, turn right at the signpost and head west through the scrub. From here, much of the area is limestone grassland with limestone rocks near the edge of the gorge. The limestone grassland species are similar to those listed earlier for this habitat, except for the presence near the path of the Cut-leaved Self-heal, a plant which is quite local in Britain but commoner in southern Europe.

The limestone rocks above the gorge, near the top of the cliffs, support a number of very interesting species, including Cheddar Pink, which occurs on Mendip and nowhere else in Britain (see Hope-Simpson, 1975). Restricted British species also occurring here are Lesser Meadow Rue and Rock Stonecrop. Other species of the limestone rocks include several which also occur in limestone grassland, together with Marjoram and Navelwort, and the introduced but long-established Red Valerian. Surprisingly, also occurring here are the Burnet Rose, which may be an escape, and the Common Scurvy-Grass, which is more at home on the coastal limestone rocks. For a complete list of Cheddar Gorge plants see Gravestock (1970).

Readers may retrace their steps from the top of Jacob's Ladder or descend, turn right for 100m up the road and then turn left along a public footpath and ascend by a marked path along the northern side of the gorge to the Black Rock gate

BLACK ROCK, BLACK ROCK DROVE AND LONG WOOD

Permission: Not required

Ownership: Black Rock and Black Rock Drove - National Trust, managed by SWT. Long Wood: Bristol Waterworks Company, leased by SWT.

Habitats: Limestone grassland and limestone woodland

Best times: March for the Toothwort, April to June for the rest.

The Area: Park at Black Rock gate, ST 482545. There are two nature trails, the Black Rock Nature Trail and Long Wood Nature Trail, and details of these are given in leaflets published by SWT and usually available on the site. Only a few botanical details will be repeated here. The walk along the drove from Black Rock gate towards Long Wood passes initially alongside calcareous scrub to the left and plantations to the right. Further along on the left is calcareous grassland on the south-facing slopes of Black Rock Drove Reserve. Many of the limestone grassland species listed previously under this habitat occur and will not be repeated here. The wall to the right of the drove supports many ferns, including the rare Limestone Fern and the Brittle Bladder-fern, a species more common in northern Britain. Other ferns common throughout Mendip on limestone walls are Maidenhair Fern, Wall-rue, and the Intermediate Polypody. Further along on the left, before entering Long Wood, there is an area of orchid-rich limestone grassland, with Early Purple Orchid, Common Spotted Orchid and Common Twayblade. Cowslips, are also present here, and by the side of the West Mendip Way path is Herb Paris.

Long Wood is an area of mainly broad-leaved calcareous ancient woodland and is now being restored to mixed woodland. Trees include dominant Ash, Beech, Pedunculate Oak and some Sycamore. The shrub layer is dominated by Hazel, but other typically calcareous woodland shrubs also occur. In the herb layer, there is much Dog's Mercury, Bluebell and Ramsons. Other species common to limestone woodland also occur but in March, along the path, the Toothwort is frequent. It is mostly parasitic on Hazel.

This walk may be extended to include Velvet Bottom Nature Reserve. The walk to Charterhouse is less interesting botanically, though it does have less common species, including Golden Rod, and Ploughman's Spikenard.

DRAYCOTT SLEIGHTS

Permission: Not required.

Ownership: SWT.

Habitat: Limestone grassland with limestone rocks outcropping above; there is also some coppiced scrub and secondary woodland.

Best times: April for the cowslips and May to late June for the other flowers.

The Area: Start at ST 485514 on the north side of the road near the SWT notice board. The Greater Butterfly Orchid occurs on the edge of the woodland. Along the path to the right on the southern slopes is good limestone grassland. In spring, Cowslip is more abundant than the author has seen elsewhere on Mendip and makes a fine display. The flora is typical of the limestone grassland and most of the species recorded elsewhere also occur here. Species more abundant here than in other areas are Horseshoe Vetch, Yellow Rattle, Lady's Bedstraw and, on the rocks, Hairy Rock-cress.

BLACKMOOR AND UBLEY WARREN, CHARTERHOUSE

Permission: Not required

Ownership: Blackmoor Reserve mostly by Somerset County Council, Ubley Warren Reserve by SWT.

Habitat: Most habitats are represented here except acid heathland.

Best time: May–July, although Whitlow-grass will be seen earlier and Harebell later.

The Area: A leaflet (with map) is available for the Blackmoor Reserve from the Charterhouse Centre. Park at the end of the side road, by the Blackmoor Reserve notice board at ST 505557. This area is much affected by earlier lead mining and good evidence still exists, including the limestone rakes, circular buddles where ore was refined, condenser flues associated with smelting, slag heaps and settling ponds.

From the parking, walk north east along the path. On the right is a mixture of limestone grassland and limestone heathland with plants typical of those two habitats. Further along is a large settling pond, dominated by Reedmace or False Bulrush. Alongside the pond to the south-east is an area of slag from the old lead smelting. The soil on this slag contains high levels of lead, zinc and cadmium, which results in an interesting but resticted flora. The best slag area for plants is to the north of the condenser flues. Here the flora includes Wild Thyme, Biting Stonecrop and the rareties Alpine Penny-cress and Spring Sandwort. Also abundant on the lead spoil is Sea Campion. Compare this with the White Campion which occurs nearby.

The path continues through Nether Wood. The lower, wetter area is dominated by Ash, with Beech at the margins. In the wood, the large ferns are excellent and include Broad Buckler Fern, Male Fern, Scaly Male Fern and in slightly damper areas, Lady Fern. Other woodland plants are those recorded elsewhere. In one wet area alongside the path is the large-leaved Indian Rhubarb, a garden escape naturalised in this area.

Ubley Warren Reserve is reached from the south-east corner of Blackmoor Reserve. A dramatic area which includes limestone grassland with the lead-worked rakes and limestone heathland. The limestone grassland has many of the species recorded earlier, together with the Early Purple Orchid, Common Spotted Orchid, Bee Orchid, Dyer's Greenweed and the very local Soft-leaved Sedge. Also occuring here is the rare Hutchinsia.

The nearby limestone heathland includes Sheep's Sorrel, Western Gorse, Bilberry and the Heath Spotted Orchid.

CHANCELLOR'S FARM

Permission: A military buffer zone, so visits **must be arranged with**, and be accompanied by, SWT. Usually one general visit is organised in June to see, in particular, the fine display of orchids. Groups can be taken round at other times by arrangement with SWT, Fyne Court, Bloomfield, Bridgwater.

Ownership:The Territorial Army. Leased and managed by SWT.

Habitats: Neutral grassland and limestone heathland

Best time: May to June. The grassland is cut in the middle of July.

The Area: Park by the side of the road at ST 527526 or, if the gate is open for a visit, park by the farm buildings. This grassland site is at 290m in height and, as far as is known, has never been sprayed with pesticides or herbicides. As with other sites where loess occurs as a variable blanket over the limestone, the pH value can range from neutral to fairly acid. This would appear to be the case at Chancellor's Farm, where the term neutral grassland can be used for the meadows to the north and south of the track to the farm and the term limestone heathland for the more acid soil to the west of the farm.The neutral grassland is species-rich, with the orchids in particular being in greater abundance than the author has seen elsewhere on Mendip. The commonest are Heath Spotted Orchid and Common Spotted. Less common are Twayblade, Green-winged Orchid (mostly flowering earlier) and Fragrant Orchid (mostly flowering later). Many other plant species preferring either acid or neutral soils occur in these meadows, including Common Cat's-ear and Pignut, whilst others like Yellow Rattle and Bird's- foot Trefoil occur on neutral or calcareous soils. The more acid limestone heathland soil west of the farm includes more typical calcifuges such as Lousewort and Mat-grass.

In all, 261 species of vascular plants have been recorded on this thirty-three hectare (eighty acre) site.

EBBOR GORGE

Permission: Not required. Information leaflet available at the display centre

Ownership: English Nature

Habitats: Mostly limestone woodland but some limestone cliffs

Best time: Almost any time before the leaves fall. In spring for the woodland flowers.

The Area: Car park at ST 524483. Two walks are sign-posted; the longer red walk is botanically the most interesting and goes through the gorge. In the tree layer, Ash is predominant and there are some magnificent specimens. Wych Elm, Pedunculate Oak , Beech and Hornbeam are well represented. The scrub layer includes species previously listed for the limestone woodland habitat. Likewise, most of the herbaceous plants have already been listed but those more common here include Wood Avens, Yellow Archangel and Foxglove , which is uncommon on the limestone of Mendip. In the wetter areas, the Opposite-leaved Golden Saxifrage, the thin-spiked Wood Sedge and the Wood Sedge occur.

PRIDDY MINERIES

Permission: Not required

Ownership: The Waldegrave Estate; managed by the SWT.

Habitats: Acid heathland, wetland and lead spoil

Best times: May to June for early flowers, July especially for Bog Asphodel . There is some botanical interest throughout the year.

The Area: Park by the road, near Waldegrave (Priddy) Poool at ST 546515. Maps of the area are on the Reserve notices. This is probably the best area for acid heathland and wetland on Mendip. As at Charterhouse, there is also much evidence of former lead workings.

The area north of Waldegrave Pool is a good example of acid heathland and is dominated by hummocky Purple Moor-grass, which is deciduous and gives the Priddy area an overall light brown colour in winter. Other plants typical of this acid heathland occur here, including most of those listed previously under the section on habitats.

Waldegrave Pool is well worth walking round as an example of interesting wetland. The water's edge is dominated by Water Horsetail which, in summer, covers much of the pool. Other wetland plants around the pool are Common Cotton-grass, Hare's-tail Cottongrass, Cross-leaved Heath and Deergrass, which is uncommon on Mendip. Though, in this paper, the author has resticted the botany to vascular plants, two moss genera are worth mentioning here: the handsome *Polytrichum commune* and *Sphagnum* moss.

From the road end of the pool, take a path south through the remains of lead-workings and wetland towards the southern end of the reserve. The lead-rich soil here has more Spring Sandwort than is recorded elsewhere. The rest of the flora is typical of the lead spoil mentioned earlier under habitats, though I haven't seen the Alpine Penny-cress here. Several specimens of the Moonwort occur in the area.

The wet region to the east of the path is dominated by Common Reed, with Reedmace or False Bulrush. In the ditches, Common Valerian and the finest of sedges, the Great Tussock Sedge can be seen. In the wetter parts, Ragged Robin, Southern Marsh Orchid, Marsh Thistle, Water Chickweed and, in July, the Marsh Willowherb and Bog Asphodel. Botanically, the Mineries Pond is not as interesting as the Waldegrave (Priddy) Pond.

Return along the higher path through the acid heathland; there are some very fine specimens of Heath Spotted Orchid.

ASHAM WOOD

Permission: Not required for the area managed by the SWT. For the rest, there are public footpaths around the perimeter of the wood.

Ownership: Amey Roadstone Corporation. SWT leases, from the Corporation, a small area in the north west part of the wood.

Habitat: Limestone woodland.

Best times: April to June for the spring flowers, September for Autumn Crocus .

The Area: Park on the old Wells-Frome road at ST 702467 and go SSE down a track, or park in Downhead at ST 693459 and go along the field track to ST 701458. The tree layer in Asham Wood includes much Ash, Pedunculate Oak, Small-leaved Lime, and, unlike Cheddar Wood, the Wych Elm. The shrub layer is very similar to that described in the habitat section for limestone woodland. The herb layer also includes the typical woodland species listed earlier, together with Herb Paris, Lily of the Valley, Solomon's Seal and Autumn Crocus, which is more abundant here than in the more western woodlands. It is interesting to note that Purple Gromwell doesn't occur in the limestone woodlands east of Westbury-sub-Mendip.

SUMMARY

Twelve botanical walks and wanderings of varying lengths are briefly detailed, together with the mention of four others. These will enable the reader to see all the important habitats on Mendip and most of the interesting plant species. An appendix lists plants by their English names together with their scientific names. Many of the plants are listed in the habitat section, and they are repeated in the main text only when they emphasise particular abundance or where they help to bring a locality to life. For a complete flora of Mendip, the reader is referred to Roe (1981).

ACKNOWLEDGEMENTS

I would like to thank all those at the Somerset Wildlife Trust and English Nature who have given me valuable information and my thanks go to Janet Boyd for species lists and guidance around Chancellor's Farm, and to Evelyn Franklin for her fund of knowledge of the Mendip woodlands.

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APPENDIX

Scientific names, as given by Stace (1991), of plants mentioned, in alphabetical order of common names. A few earlier names, long used, have been added in brackets .

Adder's Tongue	*Ophioglossum vulgatum*
Alexanders	*Smyrnium olusatrum*
Alpine Penny-cress	*Thlaspi caerulescens (T. alpestre)*
Ash	*Fraxinus excelsior*
Autumn Crocus	*Colchicum autumnale*
Autumn Gentian	*Gentianella amarella*
Autumn Lady's Tresses	*Spiranthes spiralis*
Beech	*Fagus sylvatica*
Bell Heather	*Erica cinerea*
Bilberry	*Vaccinium myrtillus*
Bird'sfoot Trefoil	*Lotus corniculatus*
Biting Stonecrop	*Sedum acre*
Bitter Vetch	*Lathyrus linifolius*
Bluebell	*Hyacinthoides non-scripta*
Bog Asphodel	*Narthecium ossifragum*
Bracken	*Pteridium aquilinum*
Brittle Bladder-fern	*Cystopteris fragilis*
Buckthorn	*Rhamnus catharticus*
Bugloss	*Anchusa arvensis*
Bulbous Buttercup	*Ranunculus bulbosus*
Burnet Rose	*Rosa pimpinellifolia*
Burnet Saxifrage	*Pimpinella saxifraga*
Carline Thistle	*Carlina vulgaris*
Cheddar Pink	*Dianthus gratianopolitanus*
Common Centaury	*Centaurium erythraea*
Common Cotton-grass	*Eriophorum angustifolium*
Common Eyebright	*Euphrasia rostkoviana*
Common Milkwort	*Polygala vulgaris*
Common Reed	*Phragmites australis*
Common Rockrose	*Helianthemum nummularium*
Common Scurvy-grass	*Cochlearia officinalis*
Common Spotted Orchid	*Dactylorhiza fuchsii*
Common Stork'sbill	*Erodium cicutarium*
Common Twayblade	*Listera ovata*
Common Valerian	*Valeriana officinalis*
Cowslip	*Primula veris*

Cross-leaved Heath	*Erica tetralix*
Cuckoo Flower	*Cardmine pratensis*
Cut-leaved Selfheal	*Prunella laciniata*
Deergrass	*Trichophorum cespitosum (Scirpus cespitosus)*
Dog's Mercury	*Mercurialis perennis*
Dogwood	*Cornus sanguinea*
Dropwort	*Filipendula vulgaris*
Dwarf Mouse-ear	*Cerastium pumilum*
Dwarf Sedge	*Carex humilis*
Early Purple Orchid	*Orchis mascula*
Fairy Flax	*Linum catharticum*
False Bulrush	*Typha latifolia*
Foxglove	*Digitalis purpurea*
Glaucous Sedge	*Carex flacca*
Golden Rod	*Solidago virgaurea*
Gorse	*Ulex europaeus*
Greater Butterfly Orchid	*Plantanthera chlorantha*
Great Tussock Sedge	*Carex paniculata*
Greater Knapweed	*Centaurea scabiosa*
Guelder Rose	*Viburnum opulus*
Hairy Rock-cress	*Arabis hirsuta*
Hairy St John's-wort	*Hypericum hirsutum*
Hard Fern	*Blechnum spicant*
Harebell	*Campanula rotundifolia*
Hare's tail Cottongrass	*Eriophorum vaginatum*
Hawthorn	*Crataegus monogyna*
Hazel	*Corylus avellana*
Heath Bedstraw	*Galium saxatile*
Heath Milkwort	*Polygala serpyllifolia*
Heath Rush	*Juncus squarrosus*
Heath Spotted Orchid	*Dactylorhiza maculata*
Heather	*Calluna vulgaris*
Herb Paris	*Paris quadrifolia*
Honewort	*Trinia glauca*
Honeysuckle	*Lonicera periclymenum*
Hornbeam	*Carpinus betulus*
Horseshoe Vetch	*Hippocrepis comosa*
Intermediate Polypody	*Polypodium interjectum*
Kidney Vetch	*Anthyllis vulneraria*
Lady's Bedstraw	*Galium verum*
Lesser Meadow Rue	*Thalictrum minus*
Lily of the Valley	*Convallaria majalis*
Limestone Fern	*Gymnocarpium robertianum*
Ling	*Calluna vulgaris*
Lousewort	*Pedicularis sylvatica*
Madder	*Rubia peregrina*
Maidenhair Fern	*Asplenium trichomanes*

Marjoram	*Origanum vulgare*
Marsh Marigold	*Caltha palustris*
Marsh Thistle	*Cirsium palustre*
Marsh Willowherb	*Epilobium palustre*
Matgrass	*Nardus stricta*
Milk Thistle	*Silybum maritianum*
Moonwort	*Botrychium linaria*
Mouse-ear Hawkweed	*Pilosella officinarum (Hieracium pilosella)*
Musk Thistle	*Carduus nutans*
Navelwort	*Umbilicus rupestris*
Opposite-leaved Golden Saxifrage	*Chrysosplenium oppositifolium*
Pedunculate Oak	*Quercus robur*
Pignut	*Conopodium majus*
Ploughman's Spikenard	*Inula conizae (I. coniza)*
Privet	*Ligustrum vulgare*
Purple Gromwell	*Buglossoides purpurocarulea (Lithospermum purpurocaeruleum)*
Purple Moor-grass	*Molinia caerulea*
Quaking Grass	*Briza media*
Ragged Robin	*Lychnis flos-coculi*
Ramsons	*Allium ursinum*
Red Valerian	*Centranthus ruber*
Reedmace	*Typha latifolia*
Rock Stonecrop	*Sedum forsteranum*
Salad Burnet	*Sanguisorba minor*
Sea Campion	*Silene uniflora (S. maritima)*
Sea Carrot	*Daucus carota ssp. gummifer*
Sea Thrift	*Armeria maritima*
Slender St John's-wort	*Hypericum pulchrum*
Small-leaved Lime	*Tilia cordata*
Small Scabious	*Scabiosa columbaria*
Soft Rush	*Juncus effusus*
Solomon's Seal	*Polygonatum multiflorum*
Somerset Hair-grass	*Koeleria vallesiana*
Southern Marsh orchid	*Dactylorhiza praetermissa* (*D. majalis* ssp. *praetermissa*)
Spring Cinquefoil	*Potentilla tabernaemontani*
Spring Sandwort	*Minuartia verna*
Spurge Laurel	*Daphne laureola*
Starved Wood Sedge	*Carex depauperata*
Stemless Thistle	*Cirsium acaule*
Stinking Iris	*Iris foetidissima*
Sycamore	*Acer pseudoplatanus*
Thin-spiked Wood Sedge	*Carex strigosa*
Toothwort	*Lathraea squamaria*
Tormentil	*Potentilla erecta*

Wall Lettuce	*Mycelis muralis*
Wall-rue	*Asplenium ruta-muraria*
Water Chickweed	*Mysoton aquaticum*
Water Horsetail	*Equisetum fluviatile*
Water Mint	*Mentha aquatica*
Wavy-hair Grass	*Deschampsia flexuosa*
Wayfaring Tree	*Viburnum lantana*
Western Gorse	*Ulex gallii*
Whitebeam	*Sorbus aria*
White Horehound	*Marrubium vulgare*
White Rockrose	*Helianthemum appeninum*
Whitlow-grass	*Erophila verna*
Wild Carrot	*Daucus carota ssp. carota*
Wild Thyme	*Thymus praecox*
Wood Anemone	*Anemone nemorosa*
Wood Avens	*Geum urbanum*
Woodruff	*Galium odoratum*
Wood Melick	*Melica uniflora*
Wood Sanicle	*Sanicula europaea*
Wood Sedge	*Carex sylvatica*
Wood Spurge	*Euphorbia amygdaloides*
Woolly Thistle	*Cirsium eriophorum*
Wych Elm	*Ulmus glabra*
Yellow Archangel	*Lamiastrum galeobdolon (Galeobdolon luteum)*
Yellow Pimpernel	*Lysimachia nemorum*
Yellow Rattle	*Rhinanthes minor*
Yellow-wort	*Blackstonia perfoliata*
Yew	*Taxus baccata*

Proceedings of the Bristol Naturalists' Society (1995), **55**:19–26

ANCIENT PONDS AND FARM WATER SUPPLIES ON MENDIP

by W. I. STANTON

Kite's Croft, Westbury sub Mendip, Wells BA5 1HU

When, a few years ago, I became responsible for Brimble Pit Pool (Figure 1), above Westbury sub Mendip, I had given no thought to the question of how quite a large pond could exist high on the plateau, with swallet holes and limestone outcrops all around and the water table at least 100 m beneath it. True, the pool was on a thick deposit of clay, the bed of an Ice Age lake in a karstic 'closed basin' (Barrington & Stanton, 1977, p.224) which restricted leakage, but what was the water supply? A previous owner had told me there was a spring, so prolific that he had allowed a pipe to be laid connecting the Pool to a pond on the other side of the road, but I didn't believe him. The geology was wrong.

Soon all was clear. Water level in the Pool rose with every rainstorm and fell gradually in dry weather. One day, in heavy rain, I watched sizeable streams flowing down both sides of the road and leaving it at the lowest point to enter the Pool. The catchment, about 300 m of minor road, totalled about 1,500 square metres. Simple! Now that I knew what to look for, I spotted road runoff ponds almost wherever I went on the limestone plateau.

Why the interest? I was intrigued by the problems that had beset farmers on the streamless limestone plateau in the days before mains water came to Mendip top in the early decades of this century. Old Ordnance Survey maps show many small farm ponds on the plateau, but what supplied them?

Even more common than the road runoff ponds were the so-called 'dewponds', typically rectangular or circular, with a sloping impermeable floor of large stones set in clay that caught rainfall and stored it at the lowest point (Figure 2). The catchment was seldom more than 100 square metres, which on a wet day with 10 mm of rainfall (just under half an inch) would collect one cubic metre (220 gallons). This was enough to support a very few cattle or sheep – none in prolonged dry weather. Compare that with today, when every second field has its trough supplying unlimited water.

Ponds of ths kind close to farm buildings were adapted to receive the roof runoff and/or the runoff from the farmyard where this was paved. The input to such a pond could be five or six times that of an isolated field pond. Water from the farmhouse roof was often led to a huge covered tank beneath the house, from which it could be pumped up to the kitchen for household use. In 1977 I was shown such a tank, full of water, under the living-room floor of a farmhouse above Compton Martin which had been built as late as the 1940s. Atthill (1971, p. 3) describes the burning of Hazel Manor above Ubley in 1929: "The fire brigade, too, watched helplessly; for apart from a rain-water tank and a pond in the farmyard there was no supply of water..."

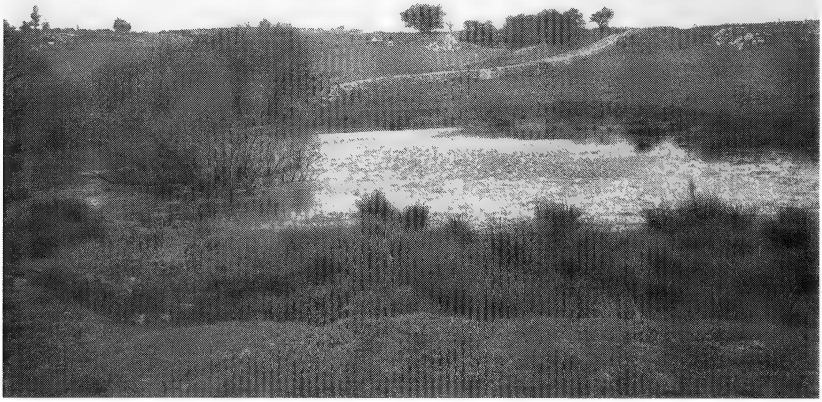

FIGURE 1. Brimble Pit Pool, on clay, fed by runoff from the road beyond it.

Notwithstanding my remark ending the first paragraph there are a very few examples of apparently natural springs on the limestone plateau. All are associated with large areas of clay subsoil. At Cross Swallet closed basin (ST 516500) three tiny streams rise on the lake bed clays and run into the swallet. One fills a pond en route. They all fail in dry summers. There are static ponds on the clay floors of closed basins further west: Bag Pit (ST 490525), Middle Down Drove (ST 485529) and Vurley (ST480534). In Gargill closed basin (ST522505) south of Priddy a pond was dug in the clay floor of a large sinkhole, but it is usually dry. North of the Yoxter camp a water seepage in a mining gruff (ST 511547) with no apparent clay deposit was led into a catchpit and lifted by windpump to a tank.

Of course, the Mendip plateau is not all limestone. The Old Red Sandstone monadnocks from Blackdown to Beacon Hill give rise to many streams that cross the outcrop of Lower Limestone Shales and vanish into swallet caves when they reach the limestone. Usually a dry valley extends beyond the swallet and in times past, especially in East Mendip, farmers dug channels to divert the stream past the swallet and along the dry valley to fill a string of ponds. If the stream opened up new swallets in its unnatural bed they were carefully plugged with rubble, soil and turves. Near Stoke St Michael, the East End Sink and Stoke Lane Slocker are unnatural swallets which still engulf streams that were diverted long ago from their natural sinkhole. Further

FIGURE 2. Round stone-lined 'dewpond' once fed by runoff where the road crosses a dry valley. Ubley Warren Nature Reserve.

east, the bed of Finger Stream in Mells Park is lined with rock slabs set in clay for much of its course across the limestone outcrop, but this was done not for water supply but to maintain the flow of a scenic artificial waterfall.

Water for the village of Priddy was obtained from two springs low on the flanks of North Hill (Old Red Sandstone and Lower Limestone Shales). The stream from Fair Lady Well in Priddy Mineries, which naturally flowed into St Cuthbert's Swallet, was diverted along an open channel in the dry valley floor past Lower Pitts Farm, possibly as far as Priddy Green. In contrast the copious springs feeding the stream that naturally vanished into Swildon's Hole Cavern were enclosed and their waters were led through buried pipes to a covered tank at the northern end of Priddy Green beside Fountain Cottage; buckets and barrels could be filled from a tap and the overflow ran into a roadside drinking trough and then vanished into the unnatural swallet of Priddy Green Sink. The supply was still flowing in the 1950s. An earth dam across the valley just downstream of the springs is possible evidence that it was preceded by an open channel supply.

The sandstone massif of Blackdown generates powerful springs. At the eastern end their flow was used by miners from Roman times onwards. In Longwood valley there are relics of an old open channel beyond the swallet that suggest agricultural diversion of the waters before Cornish miners, in 1847, led them along 1,800 m of wooden troughs or 'launders' to their lead works in Velvet Bottom.

In the north-central part of the plateau an area roughly centred on the Castle of Comfort Inn is underlain by Triassic and Jurassic strata and their partly silicified equivalent, the Harptree Beds (Stanton, 1981). Residual clay subsoil overlies Triassic limestones (including Dolomitic Conglomerate and pink marls) and swallets are common, but small ponds have been made on the clay and tiny streams gather on clayey fields and run off into swallets like Vee Swallet (ST 544538) and Fairman's Folly (ST 551527). One such stream, in a deep sinkhole at ST 555525, was lifted to a reservoir by a wind pump. Old-established farms are more common in this area than on the main Carboniferous Limestone plateau.

FIGURE 3. Stone-built rectangular pond still fed by runoff from the road at the head of Cheddar Gorge.

Over most of Mendip the water table in Carboniferous Limestone is so deep that it was effectively out of reach for farms on the high plateau (roughly from Axbridge Hill to Green Ore). Atthill (1971, p. 13) says of Hazel Manor: "Boring had been undertaken, but the only visible result was several hundred feet of circular sections of Mendip rock lying about in one of the fields". Eastwards along the flank of Pen Hill, however, the water table rises significantly (Barrington & Stanton, 1977, p. 207) so that some farms in the region of Binegar and Emborough obtained a good supply from wells. Emborough Pond, once called Lechmere Water, is a mediaeval monastic fishpond retained behind a dam on Coal Measures, not limestone.

It thus seems that most water supplies to fields on the limestone plateau came from ponds, of which the road runoff ponds were the most rewarding. Follow any road on the limestone plateau and you are likely to find, where it crosses a dry valley, a runoff pond on one or both sides of the road. Rectangular stone-built ponds are commonest, but some are mere hollows in clay subsoil. Usually, nowadays, they are empty through lack of maintenance (Figure 4) and may have been partly or completely filled in. Certain farms were advantageously located at valley crossings and boasted large ponds like that at Kingdown Farm (ST 508541) where three collector roads converge. Priddy Hill Farm (ST 514528), on the same road from Priddy to Charterhouse, is at a dry valley crossing and had a large pond. Both are now filled in.

Other Mendip roads following the axes of dry valleys have runoff ponds at intervals along their lengths. A good example is the B3135 road from Townsend Pool, Priddy (ST 518519) to Cheddar Gorge. There are runoff ponds on either side of the road at intervals of a few hundred metres down to ST485536, in the last agricultural field, where the large roadside pond (Figure 3) still fills with muddy water (from outdoor pig enclosures) when it rains hard. In contrast, the pond in Somerset Wildlife Trust's Ubley Warren Reserve (ST504552) no longer receives road runoff because road resurfacing has sloped the camber away from it (Figure 2).

FIGURE 4. Derelict stone-built pond once fed by runoff from the road down a dry valley. Kingdown Farm.

Road runoff ponds are not confined to the Mendips. Farmers created them on waterless limestone uplands elsewhere in southern England. Examples include Oatfield Pool (ST 508667), on Carboniferous Limestone near Bristol Airport, which stores runoff from 200 m of unsurfaced trackway, and Washer's Pit[1] south-east of Shaftesbury (ST897168), where the road from Ashmore to Fontmell Magna crosses a deep dry valley in Chalk; about 2,500 m of road drain to the pit. Even further afield, a large pond collects runoff from 1,500 m of the main road from Dorchester to Weymouth where it crosses the South Winterbourne, a chalk stream that is dry in most summers.

Ancient unsurfaced tracks generated almost as much runoff as modern asphalted roads, as can be seen on well-used farm tracks today. The flow down 200 m of gently sloping unsurfaced track near Brimble Pit Pool is so copious in wet weather that I diverted it into a small experimental pond dug for the purpose in the silty clay subsoil of the closed basin. The pond filled easily but the water seeped away in only a day or two.

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1 The modern word 'pool' or 'pond' sometimes appears to substitute for, or be added to, the older 'pit'. Thus Brimble Pit Pool is named 'Brimble Pit' on an Enclosures map of 1791, and on the same map the pond in Cross Swallet closed basin is shown and is reached via 'Ramspit Way'.

This raises the question of whether ponds like Brimble Pit Pool were puddled with clay, local or imported, to make them watertight. "In 1920 there was a clear tradition" wrote Clement Richardson to me in 1969, "that when Waldegrave Pond was formed the site was puddled with clay from Binegar". Waldegrave Pond (ST 546515) was created in the mid-19th century as a reservoir for the Waldegrave Lead Works; water was scarce but vital for the lead-washing process, so that the cost of bringing good puddle-clay to the site would have been justified. Part of the Pond was on limestone (Dolomitic Conglomerate) in which a swallet existed that was covered over and sealed. Richardson had helped Harry Savory to re-open the swallet (now called Waldegrave Swallet) after the seal failed, draining the pond in the 1920s or possibly earlier.

Puddliing was the method of making clay soft and impermeable. Early farmers were said to have penned a flock of sheep or herd of cows on the site to be puddled and added water until the trampled clay had reached the required consistency. The 'sheep's foot roller' used by civil engineers modernises the old process. Some clays are particularly amenable to puddling; the claypit in Jurassic mudstones at Bradford on Avon, opened for the Kennet and Avon Canal, was widely acclaimed.

Large stones set in puddled clay floored most Mendip ponds, effectively protecting the puddling. When stones were not used, as in Brimble Pit Pool, it is tempting to think that the Ice Age lake-bed clays, many metres thick, were effectively self-sealing once the initial puddling was achieved and the pool regularly trampled by cattle. Very old all-clay ponds like this have a characteristic form developed by centuries of 'pounding' by farm animals; they are roundish and very shallow with low but steep sides one to two metres in height. Two wide flat-floored dry depressions of this appearance in the dry valley just south-east of Starve Lark (ST 535559) are probably abandoned runoff ponds.

Not all runoff ponds were right beside the road or track supplying them. Runoff from the upper part of Stancombe Lane above Westbury sub Mendip was diverted along a channel embanked a metre above road level to a pond several metres inside the field. Some ponds are so far from any obvious source of supply that one wonders if wooden launders might have led water to them (but local wisdom has it that they could have been filled by tanker, and in this connection, Maurice Carver tells me this story of his father who worked on Combe Hay Farm, Westbury sub Mendip).

> "In dry summers, after the morning milking, he would load the cart with as many milk churns of water as the chestnut horse could pull up the long hill (about 65 gallons – if it were more the horse was inclined to bite) and drive with them to Cross Swallet closed basin. Here he emptied them into half of a great wooden cider barrel set in the ground, for the herd of 10 to 12 cattle to drink. He would then drive on to Priddy, refill the churns from the pump on the tank by Fountain Cottage and retrace his route via the barrel to Westbury, in time for the evening milking. In hot weather the barrel would be empty and the cattle waiting."

Another possibility is that an ancient trackway has been obliterated by cultivation - some of the roads indicated so boldly on post-mediaeval mining maps of Mendip (e.g. Savory, 1989, p. 62) are hard to trace on modern maps.

A few ponds of the 'dewpond' type were constructed, earlier this century, of concrete. They seem to have been fairly unsuccessful. Slight ground subsidence has tended to crack the concrete, so that rainwater is not retained for long. A modern round concrete pond on the hillside above Rodney Stoke (ST 499505) is cracked and usually dry, whereas higher up the same hill at ST 494510 an old round pond where three fields meet is floored with stones set in clay and usually has water in all three segments.

A new concept, that of 'biofiltration ponds', was born when I was discussing Brimble Pit Pool over lunch at a National Rivers Authority office with two colleagues, Tony Burch and Roger Saxon. We had been wondering how best to dispose of the contaminated runoff from trunk roads where they cross aquifers used for water supply. The worst risk is when a tanker has an accident and spilled liquid pollutants are washed into road drains. Soakaways draining directly into the rock have been the means, on such occasions, of serious pollution of springs and boreholes. We recommended forming a large shallow depression floored with half a metre of soil planted with grass, designed to receive and store large volumes of runoff which then leaks slowly down into the aquifer. The percolating water is filtered by the soil, and the biologically active zone of plant roots takes up nutrients and breaks down contaminants. Dorset County Council coined the term 'biofiltration pond' when they constructed them at both ends of a new dual carriageway at Yellowham Hill, on the Chalk east of Dorchester; they appear to be working well and developing a wetland flora.

Mendip has no examples, I think, of a type of farm pond to be found at a few places on the Chalk of Salisbury Plain and the Dorset Downs. The quaintly named Nine Mile River is a winterbourne that joins the Salisbury Avon at Bulford, just upstream of Amesbury. Spaced out for several kilometres along the valley floor is a series of bowl-shaped depressions as much as 5 m deep that are partly water-filled in the summer when the bourne (which bypasses them) is dry. Farmers long ago must have worked out that, instead of sinking a well and raising buckets of water for their animals, they could dig a wide hole of the same depth into which the animals could descend and drink for themselves. This was only possible where the summer water table was at a very shallow depth below the dry valley floor, as is rarely the case on Mendip. Another example is Bowldish Pond (SU033151) in the Chalk of Water Lake Bottom near Cranborne. Unfortunately, many of these reminders of times past are being filled with rubbish.

If the Mendip high plateau is still relatively wild and undeveloped, and the Mendip aquifer is still relatively unpolluted, the main reason is clear. Until a few decades ago, Mendip was effectively arid. Surface water was scarce and groundwater was too deep to be reached by wells. These restrictions on development no longer exist. Their legacies, Somerset's only major aquifer and the Mendip Area of Outstanding Natural Beauty, are vulnerable as never before.

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Proceedings of the Bristol Naturalists' Society (1995), **55**:27–38

PLANT GALLS OF MASCALL'S WOOD AND THE WESTERN MENDIPS

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ABSTRACT

This contribution contains a general introduction to British plant galls and describes some of the galls to be found in the Somerset Wildlife Trust (SWT)'s nature reserve at Mascall's Wood, with its associated Strawberry Field. An Appendix lists some galls from this site. Brief life histories are included of some of the gall-inducing organisms. are given.Reference is made to the West Mendip area in general, from Steep Holm to Priddy. Colour photographs of galls from Mascall's Wood are facing page 63.

INTRODUCTION

Galls are so numerous and widespread that most people are probably familiar with the sight of odd bumps and lumps and twisted leaves on plants without necessarily knowing much about them or what causes them. These distorted growths are often put down to disease or mechanical damage and passed by without further thought. However, some of these deformities may be due to the action of another organism which is manipulating the plant for its own ends – these growths are then termed 'galls'. Some galls are very simple, but many are fascinating structures, illustrating the most complex ecological interactions within a compact package. They can be attractive too, in their own way as attractive as flowers and fruits. Despite this, very little research has been done in the field of Cecidology (the study of plant galls), and it is difficult to understand why the subject has not attained the popularity it deserves. One of the problems may be that galls are not organisms in their own right but a manifestation of a reaction between two very different living organisms. They are not regarded as species and cannot be classified either with flora or fauna, but have to be named with reference to both the host plants and the gall-inducers. Naturalists tend to specialise in one or perhaps two particular orders, while gall-inducers come from a very wide range of orders and even different kingdoms. For example, the specialist in Hymenoptera may be interested in the gall-causing wasps and sawflies but may be understandably unenthusiastic about galls caused by fungi. The lack of comprehensive and accurate identification guides has also contributed to the problem. Only three identification books on galls have been published in this country since 1912 and these soon became outdated. About 1,800 gall types are already listed for the British Isles –

still more have only identification numbers and have yet to be named. The British Plant Gall Society is in the process of compiling a new, comprehensive guide to British plant galls, covering both identification and biology. This will succeed their Provisional Key (Stubbs, 1986), which is an excellent book for beginners and is still available from the Society.

Without accurate identification books, records have been unreliable, and a recording scheme has not yet been established. Hardly any research has been carried out on the Mendips, it is not possible at present to study gall distribution or examine population fluctuationsin detail; but this only adds to the thrill of gall-hunting – there is always a possibility of discovering something new.

WHAT IS A GALL?

This question is frequently being asked even by experts and the definition is constantly being altered. However, it is generally accepted now that a gall is an abnormal growth produced by a plant in response to the activities of another organism (Redfern & Askew, 1992). The organism may be a virus, bacterium, rust, fungus, plant or animal. There is usually an introduction of some specific physiologically active material into the plant, usually by oviposition or feeding, which initially stimulates the plant to increase and/or enlarge its cells, and subsequently regulates the development of the growth, providing shelter and food for the gall-inducer. In other words, even though a gall is composed entirely of plant tissue, its growth is totally outside the control of the plant; the gall-inducer not only initiates the gall but also controls the rate of its growth according to the inducer's own requirements. It is cell proliferation that contributes mainly to gall formation, although some enlargement of the cells occurs in most cases. Gall development ceases if the larva dies or pupates or stops feeding for some reason.

A gall induced by a particular organism always looks more or less the same, so that the small round woody marbles produced by oaks are the constant and specific response to attack by the cynipid wasp *Andricus kollari*, through the insertion of an egg into a bud and the continual feeding of the larva after the egg has hatched. It is amazing that this tiny, insignificant insect has the power to force a great oak tree to provide it with food and shelter on demand.

A community of great complexity can exist within the gall, particularly the larger kinds such as the Oak Apple or the Robin's Pincushion. The gall inducer may have parasitic larvae within its own body, which will eventually kill it, and these larvae may themselves be parasitized by hyperparasites. Other organisms may inhabit the gall as lodgers or 'inquilines', sharing the food and shelter and possibly, though not necessarily, killing the original inducer by starvation. These inquilines may have their own parasites and hyperparasites. Predators of all kinds from beetles to birds may eat any of the occupants of the gall, and 'successori' may invade and colonise, taking advantage of the food and shelter, either before or after the inducer has left

Many gall inducers are restricted to one family, one genus or even one species of host. Only a few are less selective, such as the nematode worms, where a few gall-forming species affect a wide range of hosts. Algae, fungi, lichens, mosses, liverworts, ferns and conifers all support galls, although by far the greatest number and variety are found on flowering plants. Galls have been recorded on most species of flowering plants, but some species seem to be more susceptible to attack than others.

Some deformities do not conform to the above definition of a gall, but may be caused by the reponse of the plant to physical damage or constraint, climatic conditions or pollutants. For instance, no gall is formed when a leaf is folded by a caterpillar or spider, because the role of the plant is passive and no abnormal growth is produced.

DISTRIBUTION

As mentioned before, there have been problems with accurate identification and recording of galls, so very little information is available concerning their distribution and abundance. Therefore it is hard at present to assess the richness of a site or an area in terms of gall-producing species. All one can say at this stage is that Mendip is potentially a very good area, with its famous limestone hills supporting a great diversity of plants which in turn may become hosts for a great variety of gall-inducing organisms.

Habitats include areas of limestone grassland, ancient broad-leaved mixed woodland, conifer plantation, lowland heath and coast. There are areas, especially on Nature Reserves, where there has been a long continuity of habitat, with hedgerows and wide headlands alongside dry stone walls, but there are also plenty of newly-developed sites with ruderal plants. All these habitats support different plant communities and different associated communities of gall-inducers.

The southern slopes of Mendip are generally too steep and the soils too shallow for intensive agriculture to be economically viable, so the area has escaped large applications of chemicals which would have had an adverse effect on plants and galls alike. The warmer climate here in the south of the country is generally more conducive to insects than the cooler conditions further north. Add to this the steep south-facing slopes of the Mendip ridge with its warm areas of exposed rock, and one could suppose that conditions here are ideal for a large number of insects of all kinds, including gall-inducers.

It has been suggested that plants under stress may be more liable to attack from gall-inducers than plants which are thriving. This seems to be the case at Mascall's Wood, the top of Cheddar Wood, Pratt's Wood and Dolebury Warren, where the steep slopes and thin soils covering the underlying porous carboniferous limestone rock of the Mendips often give rise to mature trees which are stunted by the thin substrate, poor nutrients, lack of water and exposure to harsh conditions at a height of up to 300 m (1,000 ft). Trees growing here, particularly oaks, support unusually large numbers of galls. (Is there a parallel here, since our chances of developing cancer are said to be higher if our immune system is affected by stress?)

It is essential for invertebrates to encounter others of the same species at the time when they are ready to reproduce. Synchronised emergence is a feature of many gall-inducers and the **Picture-winged Flies** (Urophora spp.) are known to produce a sweet-smelling pheromone to keep the colony together. Mites, hoever, do not have this problem since their mobility is so limited. They are so tiny that a trip from one suitable leaf to another must constitute a major effort, and they may well spend their whole lives in one 'erineum' or patch of hairs only 2 mm across. This means that, for gall-inducers in general, dispersal is restricted, and often a thriving colony may be found on one plant while the adjacent plant has none. One branch of a tree many support many galls, while the rest of the tree is unaffected. The reason for this may be that gall-inducers, like many invertebrates, may need very specific conditions in which to thrive, and one branch may not be as similar to another as it appears to us at first glance .

On the other hand, the relative success of 'sleeving' (the introduction of gall-inducing invertebrates to a suitable host) suggests that some species, at least, are not too particular. Rearing adult invertebrates from galls is also not difficult, but here it seems that the key to success is to take the gall as near as possible to its maturity, in which case the creature is largely self-sufficient, perhaps even in a pupa, and less affected by outside conditions than it would be in its larval stages, when it depends on the host plant for nutrients. Interestingly, the only study of galls on Mendip which has come to light while researching this account was a dissertation on the effect of prevailing winds on the distribution of marble galls and cola-nut galls at Dolebury Warren (Dunleavy, 1989). Unfortunately no satisfactory conclusions could be drawn..

EFFECTS ON THE HOST PLANT

There is some debate as to whether the plant itself derives any benefit from the presence of galls. Only one known gall-inducer is definitely beneficial to its host – the nitrogen-fixing bacteria of the genus *Rhizobium,* which induce root-nodules on legumes and promote plant growth. It has been suggested that it might be advantageous to the host plant to encapsulate its attackers and so restrict their activities to one place. There does seem to be a disadvantage for the gall-inducer in being housed in a visible and easily recognizable structure on a plant, which must be an obvious target for predators and parasites, although the reddish colouring that many galls acquire on exposure to sunlight may be a form of warning coloration. Generally speaking, it seems that the gall-inducer has most to gain from the arrangement. It induces the host plant to provide nutritive tissue for food and a physical covering to protect it from adverse weather, predators, parasites and diseases; while the plant is forced to divert nutrients to the formation of the gall which it would otherwise invest in growth or seed production.

Plants never seem to be so badly galled that they are unable to reproduce at all – perhaps because it would not be in the interest of the gall-producer to wipe out its host. There is one possible exception, and that is the heavy infestations of **Knopper Galls** caused by the agamic generation of the cynipid wasp *Andricus quercuscalicis*, which destroy the acorns of English Oak *Quercus robur*. This wasp reached this country from the continent in the 1960s, probably with the introduction of the host of its bisexual generation, Turkey Oak *Q. cerris*.

There is some evidence that plants are able to restrict the activities of gall-inducers using the natural defences of their endophytic fungi (*BBC Wildlife*, October 1996).

HUMAN FACTORS

Humans have occasionally played a large role in gall distribution, as in the 1830s when the **Oak Marble Gall** was deliberately introduced into Devon from the Middle East for its high tannin content, which was used for medicines, the dyeing of cloth and hair, and the manufacture of ink. The species had spread as far as the north of Scotland by 1860. There was an outcry at the time of the introduction because pig farmers feared for a detrimental effect on their acorn crops; in fact their fears were unfounded.

The **Knopper Gall**, introduced in 1960, is having a much more serious effect on acorns and the fertility of oaks, as mentioned earlier. The **Cola-nut Gall**, which is similar to a marble but much smaller and not smooth, is of even more recent origin (1972) and has now been recorded as far north as Cheshire.

While several gall-inducers are pests, such as the all too familiar **Club Roo**t of brassicas and **Big Bud** of blakcurrants, some have been very useful to humans and are likely to be used more in the future. Some gall insects have been used in biological control programmes to reduce weeds such as Creeping Thistle *Cirsium arvense*, where gall-inducing species reduce the reproductive success of the plant.

WHERE AND WHEN TO LOOK

Galls may be found at any time of year, particularly those which are hard and woody and persist on the plant. Old galls are never recolonised by the inducer, each generation making a fresh start, although other organisms or 'successori' sometimes take advantage of the shelter of the old gall. The best time to look is in mid to late summer, but some generations of oak galls which affect the buds or catkins must be searched for in the spring. Galls may be found anywhere, but neglected hedgerows, woodland edges and rough vegetation alongside tracks and lanes tend to support the widest range.

A site where around forty different types of gall could be recorded would be considered very productive. Given that gall-inducers are generally host-specific, one would expect to find more galls on a site having a wide variety of plants within a small area. This means that disturbed areas with their wide variety of ruderal plants are often more productive of galls than are nature reserves. The importance of such sites for invertebrates in general has yet to be fully recognized.

Any part of a plant may be affected, from root to seed capsule, although leaves are the most common site. Some individidual plants support huge numbers of galls while the adjacent plant remains unaffected. Occasionally the gall inducer is not present in the gall, but may be found at a distance from the visual signs of abnormal growth. Nematode worms, for instance, attack the roots of a plant, which causes deformities on another part of the plant.

Galls on herbaceous plants suffer particularly badly during drought conditions, while those on shrubs and trees fare slightly better. The years 1995 and 1996 were poor for galls, due to the hot dry summers which dried up many of the host plants early in the season. There was a late burst of development especially on trees, after the autumn rains, when **Spangle Galls** *Neuroterus* spp. in particular began to swell properly. It will be interesting to note the long-term effects of the drought on the galls in this area.

MASCALL'S WOOD NATURE RESERVE

While the target of forty gall species has not yet been reached at Mascall's Wood, this is still one of the most productive sites in the West Mendip area. The Reserve is situated at Bradley Cross, Cheddar (grid reference ST471536). Access is not easy but there is limited parking for one or two cars on the road verge at Bradley Cross, and official car parks in Cheddar, though using these would mean a fairly long walk up the lane before reaching the access track to Owley and then on into the wood. The Reserve consists of 5.4 ha (13 acres) of mixed broad-leaved woodland on the south-facing slopes of the Mendips, with a former strawberry field on its southern edge.

MASCALL'S WOOD

Within the wood there is a good variety of tree species including Ash, Hazel, Small-leaved Lime, Cherry, Oak, Sallow, Beech and Field Maple, with Holly and Blackthorn. A mortared wall and a line of Yew trees, probably planted in Victorian times, mark the northern boundary. There is a level path along the southern edge of the wood, but the only official right of way is a footpath from the entrance to the reserve, which climbs steeply up through a glade to the north-eastern edge of the wood and eventually rejoins the West Mendip Way at the top of Cheddar Gorge.

The ground flora within the wood is dominated by Ivy and is not particulaly interesting, apart from a small patch of Purple Gromwell *Lithospermum purpurocaeruleum.* The shallow soils tend to drain very rapidly on the south-facing calcareous slopes, leaving conditions at ground level rather dry. Although the wood does not have SSSI status, the SWT was very pleased to take on the ownership in 1975, and to manage it as a Nature Reserve, together with a narrow strip of field on its southern edge.

THE STRAWBERRY FIELD

This field had been used by several different strawberry growers, who each owned a fairly narrow unfenced strip of about 1/7 ha (1/3 acre). When strawberry growing in Cheddar became less lucrative in the early 1960s, the strips were left uncultivated and a wide range of plants colonized the field, together with invertebrates which enjoyed the warmth, the great variety of food plants and the sustained supply of pollen and nectar throughout the season. The structure of the habitats is equally diverse, ranging from stunted English Oaks *Q. robur* and bramble *Rubus fruticosus* agg. to short rabbit- grazed areas and bare ground. Piles of stones removed from the cultivated areas and heaped up, sometimes in the shade of the wood edge and sometimes in full sun, provide yet more habitats for invertebrates.

Soon after acquiring the Reserve the SWT purchased two more strips, but the Reserve was fragmented and strip boundaries were sometimes disputed, which made management very difficult. In 1997 the SWT hopes to acquire most of the remaining strips, which should make management a great deal easier. The site would benefit from a little light grazing by sheep and selective cutting, to retain the mosaic effect and ensure the continuation of the diversity of habitat. The field is bounded on the south by the West Mendip Way footpath.

EXAMPLES OF GALLS FOUND AT MASCALL'S WOOD

Perhaps the first gall to be recorded may be seen from the approach track to the Reserve, in the orchard belonging to Owley, the last house and the home of the Reserve Manager, Wendy Barritt. The apple trees there support good examples of **Mistletoe** *Viscum album*, a parasitic plant which induces the host tree to produce a swelling or gall where it taps into the bark.. It is the xylem of the host which which provides water and carbohydrates to the parasite, not the phloem as was originally assumed. Mistletoe can occur on several species of tree such as lime *Tilia* sp., poplar *Populus* sp. and hawthorn *Crataegus* sp., and it has been occasionally recorded on oaks. As one might expect, Somerset, renowned for its apple orchards, is particularly rich in Mistletoe, but it seems to be absent from Mascall's Wood itself.

The track forks into two paths: one continues north into the wood itself and one turns west into the ex-strawberry field, where the ground opens out to the north. Although the field is mainly rough grassland, there are some stunted oaks ihere which support a wide variety of galls, mainly induced by wasps. There is a great advantage in looking at stunted trees, because a larger proportion of the canopy is within easy reach!

GALL WASPS

Gall Wasps, especially those associated with Oaks *Quercus* spp., have life cycles and reproduction methods which are among the most complicated and fascinating of all the gall-inducers. More has been written about the alternating sexual and asexual generations and the different types of gall they induce on oaks than on any other aspect of gall ecology. For example, the female cynipid wasp *Neurotus quercusbaccarum* lays her fertilised eggs into oak leaves in July, and this stimulates the formation of **Common Spangle Galls** on the underside of the leaf. These Spangle Galls are disk-like, 6 mm in diameter and yellow with pink hairs. There may be as many as a hundred on any one leaf, but each disk contains only one larva. The Spangle Galls remain on the tree until September or October, when most become detached from the leaf or fall with their leaves to the ground, where they continue their development through the winter in the moist leaf litter.

In April, agamic females emerge from the spangles on the ground and fly up to lay unfertilized (parthenogenetic) eggs in the developing oak catkins. This results in the formation of the aptly-named **Currant Galls**, either hanging in strings with the catkins or occasionally growing on the tiny new leaves. The galls look just like fruit, starting green and turning a beautiful deep, succulent red colour as the single wasp larva within becomes mature. In June or July, both males and females of the bisexual generation emerge from the Currant Galls. They mate, and the females start to lay fertilized eggs inside the oak leaves. Either when the eggs are inserted or when the newly-emerged larvae start to feed, the tree begins to pruduce the disk-like swellings that will become Spangle Galls, and the cycle starts all over again.

Currant Galls have been recorded at many sites on Mendip, including some semi-improved fields at Shipham, but this generation is not as easy to find as the Common Spangle Galls, which seem to be ubiquitous. Of course, the Currants develop very rapidly and fall to the ground with the catkins, while the Spangles take much longer to develop and remain on their leaves for several weeks. Until comparatively recently, two generations of the same species of gall wasp were often thought to be two separate species and were named accordingly, which makes studying old literature a little difficult.

Shipham is also a good site for **Oak Apples**, which are caused by another cynipid wasp, *Biorhiza pallida.* Oak Apples are much larger (up to 30 mm diameter), softer and less spherical than Oak Marbles and can each contain up to 150 larvae, often of only one sex in each gall. The agamic (asexual) generation of this species causes galls on the roots of oak trees.

Gall-wasps are not restricted to oaks but affect other plants such as Ground Ivy *Glechoma hederacea*, Cat's Ear *Hypochaeris radicata* and Dog Rose *Rosa canina*. Among these is perhaps one of our most familiar and attractive galls – the **Bedeguar** or **Robin's Pincushion** on *Rosa* spp., which is the logo of the British Plant Gall Society. The inducer in this case is the wasp *Diplolepis rosae*, whic lays upto 30 eggs in the developing leaf buds between May and early July. The process may take hours while she moves round and round, inserting her long ovipositor into the midribs of the young leaves. After a week the larvae hatch and tunnel into the leaflet, leaving their eggshells behind. The plant immediately responds to their feeding by producing a wonderful ball of leaf tendrils, which is at first green but soon turns bright pink in the sunlight. By the end of October the larvae are fully fed and the gall turns brown. It stops growing as soon as the larvae stop feeding, but they remain in the ball throughout the winter. They pupate in April and emerge soon afterwards, using their strong jaws to bite their way out. Examples of this gall have been found all over Mendip, including Crook Peak and Mascall's Wood.

OTHER GALL-INDUCERS

At the top of the field, where the wood is encroaching on to the grassland, the young Ash *Fraxinus excelsior* saplings are host to a **hemipteran** or **true bug** *Psyllopsis fraxini*, which lives inside a rolled leaflet, causing it to swell and turning the veins bright red. These jumping plant lice or Psyllidae are very appealing little insects, similar to aphids but somewhat flattened and often covered with a waxy substance.

Scale insects or Coccidae also occasionally induce galls. The females are degenerate insects which remain fixed in one place on a plant to feed and a simple gall forms around them. The males have wings so that they can fly in search of females with which to mate, but their mouthparts are non-functional, so they are unable to feed.

Aphids, on the other hand, induce amazingly complex galls, always with alternating sexual and asexual generations, often producing one type of gall in their woody host while overwintering, and another type of gall on their herbaceous host in the summer.

Blackthorn *Prunus spinosa* is also encroaching into the field and provides support for the non-indigenous Tuberous Pea *Lathyrus tuberosus.* Sometimes the Blackthorn bushes have small yellow banana-like fruits instead of the normal sloes. One might expect to find an insect larva inside the strangely deformed berry but there is no sign at all of the inducer because the galls are produced by a **fungus,** *Taphrinus padi.* A closely-related fungus is responsible for the familiar galls known as **Witches' Brooms** commonly seen hanging from the branches of trees. On birch *Betula* spp. these are caused by the fungus *T. betulinae* and are common and widespread on Mendip.

Another eye-catching gall may be found on Nettle *Urtica dioica,* initially appearing as an orange spot on the stem or leaf and eventually developing into a large, bright orange swelling with pustules which involve the whole leaf. Again, there is no invertebrate culprit involved, but a gall-producing **rust**, *Puccinia caricina..*

Creeping Thistle *Cirsium arvense* is an all too common sight on rough grassland, and the Strawberry Field is no exception..A **picture-winged fly**, *Urophora cardui,* causes the familiar large swelllings on the stems. This species is locally common in southern England as far north as the Midlands, East Anglia and South Wales. The woody swelling may have several chambers inside, each containing one larva. The gall appears in July and is fully developed by September, but the larvae pupate in the gall on the ground during the winter and emerge the following May to July. This beautiful fly, with the characteristic dark zig-zag pattern on its wings, is particularly difficult to rear, since the gall must become soft and rotten to enable the delicate adult fly to emerge successfully.

Harebell *Campanula rotundifolia* is sometimes attacked by a **weevil** *Miarus campanulae* which makes the seed capsules swell a little. Although the host plant occurs on the Strawberry Field and is abundant on Mendip and the weevil is common, these galls seem to be difficult to find perhaps because the affected seed capsules are difficult to distinguish from normal ones. Most gall-inducing beetles are weevils, mainly *Apion* species, although some galls are produced by **longhorn beetles**. However, beetle galls are not common and their structures are simple.

Marjoram *Origanum vulgare* is everywhere in the strawberry field and in some years an amazing proportion of the inflorescences are swollen and furry with galls induced by the **mite** *Aceria origani.* Mites are responsible for large numbers of galls, including many on leaves of trees. Again, most are host-specific so the wide range of tree species within Mascall's Wood supports a wide range of mite galls. There is an opening from the top edge of the strawberry field leading to the permissive path within the wood itself. Here, the leaves of many species have felted patches, thickened veins or raised pimples scattered on the surface. Some of the pouch galls are induced by mites and are usually filled with hairs on the underside. The mite *Eriophyes macrorhinchus* (*E. m. cephalonea*) induces the very common green or red pimples on the upper leaf surface of Sycamore *Acer pseudoplatani* and its relative Field Maple *Acer campestris.* The galls are an extremely common and attractive sight and have even been recorded on Steep Holm island

Mite galls have been found in large numbers on Field Maple growing at the edge of the glades or along paths in Mascall's Wood. The female mites spend the winter in crevices and emerge in spring as soon as the new leaves are formed. They wander underneath the leaf, feeding from individual cells, and in those spots the leaf bulges upwards and grows into tiny pouches. One female may cause as many as 20 pouches on one leaf. She returns in late May to lay eggs in them; the feeding of the hatchlings, sucking the plant sap from the little hairs inside the pouch, stimulates the galls to develop further. Those without eggs stop growing at this point. The larvae are miniature versions of their parent; they are shaped rather like ice cream cones, with only two pairs of legs, and are difficult to see without a microscope. Their sexual organs develop a little more with each successive moult until finally they become adult. Males are rare and reproduction is commonly by parthenogenesis (i.e., without fertilisation of the egg). Slightly larger, rounder mites with eight legs frequent these galls too, but these are predators on the gall inducers, and are more easily visible with a hand lens.

The permissive path runs east-west inside the southern edge of the wood. Turing east, the path emerges at the main glade and connects with the official footpath just inside the entrance to the Reserve. The footpath leads north through the glade and here the ground is damper, allowing ferns to flourish.These may be attacked by a gall-inducing **fly** *Chirosia betuleti,* which induces the attractive **Roll-mop Gall** on the tips of several species of ferns. It has been found on Male Fern *Dryopteris filix-mas*, Lady Fern *Athyrium filix-femina* and Broad Buckler Fern *Dryopteris dilatata* in Black Rock Nature Reserve near Cheddar for several years, and seems to prefer woodland sites alongside paths where there is more light.

Many flies induce galls on plants, including **leaf mining flies** such as *Phytomyza illicis* which forms yellow/red blotches in the centre of leaves of Holly *Ilex aquifolia.* This species is so common that it is often easier to record where it does not occur than where it does. However, it is not certain that it should be classified as a gall-inducer under the definition given previously, because the gall-fly larva does not actually eat the extra tissue provided by the plant, unlike the small number of gall-inducing micro-moths, which include Nepticulidae. These are leaf miners which feed on callus tissue produced by the plant to fill tunnels excavated earlier. However, the majority of leaf miners are not gall-inducers, merely specialist herbivores feeding within the thickness of the leaf, some of which leave scar tissue while others do not.

There are willows *Salix* spp. growing here in the main glade, but these trees seems surprisingly unaffected by galls. **Sawflies,** in particular *Pontania* spp., induce many different galls on willows. Some of the most obvious are the bean-like galls on the leaves of Crack Willow. Sawflies, like wasps, are hymenoptera, but they have no waist and their ovipositors are modified to form saw-like structures which are usually withdrawn into the abdomen when not in use. The larvae resemble lepidoptera caterpillars but they have nine or more pairs of legs instead of eight pairs or fewer, and they have a single large eye on each side of the head instead of a group of small eyes. *Salix* is second only to *Quercus* in the number of gall-forming organisms it supports.

Continuing through the glade and up the footpath to the northern boundary of the Reserve, one cannot miss several fine old Yew trees *Taxus baccata.* Little bunches of leaves on the tips of the branches, which may appear at first glance to be next season's shoots, are in fact **Artichoke Galls** caused by the **midge** *Taxomyia taxi*, which is common in southern Britain. The adults are large, orange-coloured cecids with dusky, hairy wings. Emerged in late May or June, the female mates immediately and lays up to 160 bright orange eggs individually on the underside of new elongating shoots. The eggs hatch in 1-2 weeks and the orange larva crawls towards the tip of the shoot and burrows into the terminal or sometimes the auxiliary bud. Externally there is no sign of activity but inside there may be intense competition, since many larvae may choose the same bud and only one can survive. The galled bud remains as a tight bunch of leaves when the ungalled buds start to develop in the following spring, and the larva continues to grow throughout that summer and the subsequent winter until the following April, when it pupates inside the gall. It emerges in late May to start the cycle again. If the life cycle of these midges always took two years, two independent populations would develop on the tree, resulting in an unstable population, with the probable eventual extinction of one or both of them. However, each year a certain proportion of the eggs laid develops in a single year, thus allowing genetic exchange between the two populations.

CONCLUSION

Once bitten by the gall bug it is difficult to pass by any deformity in a leaf or twig - a bulge or a twist or a lump. No longer will you be able to pass it off as disease or drought or browsing damage by animals. Inside the bulge there may be a tiny creature which has managed to manipulate the helpless plant to its own advantage and has a fascinating life story to tell. Many questions remain unanswered and new discoveries are sure to prove interesting and exciting. The British Plant Gall Society and, more locally, the West Mendip Invertebrate Group would welcome new members with an interest in galls and would be happy to assist with any problems of identification.

Janet Boyd is a member of the West Mendip Invertebrate Group, and is the Mendip Area Representative of the British Plant Gall Society.

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APPENDIX

Plant galls recorded in Mascall's Wood and on Field Strips near Cheddar

Gall inducer		*Host Plant*	*Gall Name*
Aceria origani	Gall Mite	Marjoram	
Andricus anthracina	Cynipid wasp	English oak	Marble
A. fecundator	"	"	Artichoke
A. kollari	"	"	Marble
A. lignicola	"	"	Cola Nut
A. quercuscalicis	"		
Biorhyza pallida	"	"	Oak Apple
Cynips quercusfolii	"	"	Cherry
Dasyneura acrophila	Gall Midge	Ash	
D. crataegi	"	Hawthorn	
D. fraxini	"	Ash	
D. glechomae	"	Ground ivy	Lighthouse
D. urticae	"	Stinging nettle	
D. viciae	"	Common/bush vetch	
Diplolepis nervosa	Gall wasp	Dog rose	Spiked/
D. rosae	"	"	Bedeguar gall
Ditylenchus dipsaci	Nematode	Ribwort plantain	
Eriophyes avellanae	Gall midge	Hazel	Big Bud
E. goniothorax typicus	Gall mite	Hawthorn	
E. macrorhynchus	"	Field maple	Nail
E. nervisequus	"	Beech	
E. padi	"	Blackthorn	
E. similis	"	"	
E. tiliae nervalis	"	Small-leaved Lime	
Jaapiella veronicae	Gall midge	Germander Speedwell	
Liposthemus latreillei	Gall wasp	Ground-ivy	
Macrodiplosis dryobia	Gall midge	English Oak	
M. volvis	"	"	
Neuroterus albipes	Cynipid wasp	"	Smooth spangle
N. numismalis	"	"	Button
N. quercusbaccarum	"	"	Common spangle
Psyllopsis fraxini	Psyllid	Ash	
Taphrina padi	Fungus		
Taxomyia taxi	Gall midge	Yew	Artichoke

Proceedings of the Bristol Naturalists' Society (1995), **55**:39–43

DRAGONFLIES ON MENDIP

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The western part of the Mendip Hills, which is the part I know best, adjoins the Somerset Levels and so it is not surprising that there is considerable interchange of dragonflies between the two, particularly of the larger and stronger flying species, and that many species are regularly found on both. However, the make-up of the populations is very different. Someone once described Mendip as like a sponge sitting on a saucer. The sponge is of course the limestone area, which is permeable to water and the saucer is the underlying sandstone, which is not. There is, therefore, very little standing water as the rain disappears rapidly down through the sponge and eventually overflows the edge of the saucer. Draycott, where I live, is on the edge of the saucer and after heavy rain water tends to flow up through the gratings in the road rather than down through them.

Such water as there is on the surface of Mendip is all on the outcrops of the sandstone, or where it has been caused by man, particularly where mining has disturbed the surface or where other artificial pools have been made. The last-mentioned include the dew ponds or other ponds made for stock (see Stanton, 1997), although many of these have fallen into disuse as piped water is now available and more reliable.

For the same reason the Mendips have very little running water. However, there are three small streams running down the north side of Black Down (see Crabtree, 1997), which is an outcrop of Sandstone (most of the limestone cover having been eroded), but even these streams are discontinuous, disappearing at times under the relics of the old limestone before vanishing into it completely lower down. Compared to the Levels, however, Mendip has more trees and hedges, and in their lee these create hunting space for dragonflies after the flying insects which congregate there. The Levels have much less cover except for the sides of the rhyne banks; these are sufficient for Damselflies and the other low-flying species, e.g. Chasers, Darters etc but not for most of the Hawkers. Plenty of water but limited hunting space gives the Levels ample Damselflies, Chasers and Darters, which can be found in all the rhynes or rivers where the state of the vegetation is at a suitable stage between keechings. However the Hawker dragonflies are present in very limited numbers, as only the Hairy Dragonfly *Brachytron pratense* hunts below bank level. This is the reverse of the situation on Mendip, where every available piece of water holds numbers of big dragonflies but, probably because of competition from these, there are comparatively fewer damselflies.

The eastern part of Mendip does have surface rivers and streams. The faster-running ones have the Beautiful Damselfly *Calopteryx virgo*, usually in small numbers, and the slower ones have the Banded Demoiselle *C. splendens.* Neither of these breeds in the western part of Mendip, because the right habitat is not there. However, in the eastern part I have found very few pools - and most dragonflies need water with little or no movement. There are a few pools in the old coal mining areas, but they have very few dragonflies as the coal seems to inhibit aquatic life. Many of the old quarries have pools but most of these are comparatively freshly closed and are very deep and cold, with vertical sides, so that they support very sparse vegetation and in consequence minimal numbers of aquatic insects. The only dragonflies I have found in them are Common Blue Damselflies *Enallagma cyathigerum.* It is possible that vegetation may increase in these pools but it must, I think, remain limited as the water will always be cold. More-over these quarry pools are clearly dangerous, particularly to children, and are likely to remain as securely closed as they are now. However, I do not know the eastern part of Mendip very well, and there are probably pools which I have not found.

Undoubtedly the gem of West Mendip pools is at Priddy Mineries, which is a Somerset Wildlife Trust Reserve, of which I am Reserve Manager. It lies mostly at a height of 250 metres and the whole site is in its present state as a result of lead mining from pre-Roman times to the beginning of this century (see Martin & Fawcett, 1997). It has two large pools, a shallow one (the Waldegrave Pool) of about 1½ acres and a deeper one (the Mineries Pool) of about 1 acre. There is also a small pool, on the hill, which dries out in hot summers. In the 14 years in which I have been responsible for the Reserve, I have recorded 22 species of Odonata, although the one male Beautiful Demoiselle and the one male Banded Demoiselle were clearly only vagrants. There are small but stable populations of the four common damselflies - the Large Red *Pyrrhosoma nymphula,* Common Blue-tailed I*schnura elegans,* Azure *Coenagrion puella* - mostly in the Waldegrave Pool and the Common Blue Damselfly *Enallagma cyathigerum* - mostly in the Mineries Pool. All these emerge in May or early June.

However, easily the most numerous of early dragonflies is the Four-spotted Chaser *Libellula quadrimaculata,* which appears in hundreds in mid-May. A few years ago over 1,500 exuviae were counted in the Waldegrave Pool, and there were certainly smaller numbers from the other pools. The newly-emerged dragonflies usually move into the nearby Forestry Commission plantation, where they hunt until they are sufficiently hardened off to return to the pool. Of course, nothing like the full emerged population is ever seen over the pool. Of the males, only those strong enough to obtain a territory will be there, perhaps less than 10% of all males, the rest leaving to seek their fortunes elsewhere. The females do not return to water until they are ready to mate and lay eggs.

Also in May (usually early) will appear the Downy Emerald *Cordulia aenea.* This species has a limited and rather curious distribution, with strongholds in the south-east of England and in the Highlands of Scotland, and with small colonies across the south of England. Priddy Mineries is near the western limit of its range. The population is extremely small and vulnerable. In hot summers the water level in the Waldegrave Pool drops dramatically, and this species seems to suffer, but numbers recover when there is a better summer water level. Steps taken to improve the level in summer have helped to some extent and are continuing.

The Hairy Dragonfly *Brachytron pratense* which is widespread on the Levels, is also found on the Reserve. I have seen egg-laying but not larvae or exuviae, and I doubt if it breeds on the Reserve, or at any rate not regularly. The Broadbodied Chaser *Libellula depressa* and the Black-tailed Skimmer *Orthetrum cancellatum* both occur regularly, but usually only males, and I have found no evidence of breeding.

The Emperor Dragonfly *Anax imperator* has increased in North Somerset in the last few years and is now regularly found on the Priddy Mineries Reserve, very often with males over all three pools at the same time. Females mating and egg-laying, larvae and exuviae are all being recorded.

The Red-eyed Damselfly *Erythroma najas* is a species which I had only found once in Somerset (in the River Frome near Lullington) before 1982. It was always reasonably plentiful in Wiltshire; then in 1982 it appeared in at least five different places in North Somerset. It requires vegetation with leaves floating on the water surface (Water Lily leaves are ideal) as the males take up station on them. Some of the sites were not suitable, for this reason, but the species became established in two sites, where it still is. In 1983 it came to the Mineries Pool and is still there in small numbers and on the Levels sometimes in large numbers.

The Brown Hawker *Aeshna grandis* is another species near to its western limit in North Somerset. It seems to me to be increasing, but it is not really established anywhere here; twice in the last fifteen years I have seen females egg-laying at Priddy Mineries, but in neither case was any outcome seen. However, both the Common Hawker *A. jimcea* and the Southern Hawker *A. cyanea* breed on the Reserve, the former in much greater numbers. Some years ago, after several not very hot summers, there was a big emergence of this species from the little pool on the hill to which I have referred; this is about 170 square metres in extent and over 170 emerged exuviae were found. Regular breeding in this pool must be inhibited by the fact that it dries out so often and both Common and Southern Hawkers have a normal larval period of two years. Once the pool dried out in June and by the end of July seemed as hard as a pavement; nevertheless two Common Hawkers emerged in August. Dragonfly larvae are known to be able to survive for several weeks in wet mud; no wet mud was apparent on this occasion but they presumably found someunder the shelter of the bank. The Migrant Hawker *Aeshna mixta* bred successfully here three years ago; it has, of course, a very short larval period which much increases its chance of breeding successfully in this pool.

Species appearing later in the year at Priddy include the beautiful Common Emerald Damselfly *Lestes sponsa*, which has increased considerably in the last few years. It can now be counted in hundreds - upwards of 500 in 1992. Both the Common Darter *Sympetrum striolatum* and the Ruddy Darter *S. sangucheum* breed regularly. Curiously, a few years ago the Common Darter was the more numerous but the Ruddy Darter has increased for several years and in 1996 at least, was much the more numerous. The Black Darter *S. danae* also breeds in the Waldegrave Pool, in numbers which have increased and which usually rival those of the Common Emerald Damselfly.

There are other pools, made during the lead mining period, at Black Moor near Charterhouse and at Smitham which have breeding populations of many of the species found at Priddy Mineries, namely, Common Blue , Large Red, Common Blue-tailed and Azure Damselflies, Four-spotted Chaser, Emperor Dragonfly, Common and Southern Hawkers and Common Darter. Black Moor also has Red-eyed Damselfly, and Smitham also has Common Em

erald Damselfly and Black Darter.

There is also a pool on the top of Black Down, originally made as two adjoining pools by the Forestry Commission for fire-fighting purposes. The deeper of the two pools had rare newts and water bugs, and the shallower had a very interesting flora. Between them they produced a very large number of Hawker dragonflies; one year there were over 320 emerged exuviae, about one-third Common Hawkers and two-thirds Southern Hawkers. This is curious, as in Somerset the Common Hawker is an insect of higher ground, approximately 180 m (600 ft) and upwards while the Southern Hawker is the common large dragonfly of the Levels. This pool is virtually on the 300 m (1,000 ft) contour and it is interesting that the Southern Hawker larvae were noticeably bigger than those of the Common Hawker, suggesting that the former may have had a three-year larval period instead of their normal two years. There were also good numbers of the four common Damselflies and of the Common Emerald Damselfly and Black Darter, with some Common Darters. The pool was also regularly visited by Emperor Dragonflies and Broad-bodied Chasers, the latter certainly breeding, as larvae and exuviae were present.

Unfortunately the bank dividing the two pools was dredged out to make them one, and – what was worse – the bank against the track to the west, which had a drop of several feet into the water, was also dredged out as someone had heard the obnoxious theory that 'all pools must have sloping sides'. This was a disaster, as many horses are ridden along the adjoining track and they commenced to ride into the pool, which was previously impossible. This had the effect of keeping the water continuously turbid, greatly reducing the aquatic flora and the invertebrate population. All the species of dragonfly previously found are still there but their numbers are considerably reduced. As a result of appeals there seems to have been some improvement recently.

Not far from the pool referred to above, the three small streams mentioned earlier run down the north side of Black Down to vanish eventually into the limestone. I was long puzzled by the appearance of very small numbers of Golden-ringed Dragonflies *Cordulegaster boltonii* in the area, as the habitat seemed unsuitable. In its larval stage the species inhabits fast-running streams, usually very small, and the nearest breeding place that I know of is on the Quantocks. However, the dragonflies appeared almost annually and in 1993 we found a larva, proving breeding. The population must be very small – often the case with this species, outside its stronghold along the Atlantic seaboard.

The only pools in the western part of Mendip are the small ponds made for stock or ornamental ponds. Mendip's many dewponds have already been mentioned, and there are a few ornamental ponds of fairly recent origin. Very few of the dewponds are still used for their original purpose of cattle watering, or have water in them. Some have been renovated, mostly for conservation purposes. Most, if not all, were quickly colonised by the broad-bodied Chaser, as are garden ponds. My own garden pond had an emergence of this species in the first May after it was completed. Although this species is supposed to have a two-year larval stage, some of the repaired dewponds also produced adults a year after completion. I know of other cases where new ponds have had rapid emergences of other species with a normal two-year cycle. I believe that this is very likely to happen with new ponds, as initially there will be no competition from older larvae, so that the stronger of the first-year larvae are likely to grow much faster. Moreover, it does not seem that any species can have a rigid two-year cycle, without the prospect of alternate years eventually producing different species.

CONCLUSION

Mendip has, therefore, much of Odonata interest, and in addition there is always the possibility of something new. Thus in 1996 there was the bonus of a share in the invasion from the Continent of the Yellow-winged Darter *Simpetrum flaveolum.* This appeared at Priddy Mineries, where estimates varied between four and twelve individuals, with some at Black Moor. As far as I am aware, no females were seen, so it seems unlikely that the species will breed at either place. However, if global warming is real, there may be repeats of this invasion, and perhaps of other Continental species.

Proceedings of the Bristol Naturalists' Society (1995), **55**:45–54

CREATURES UNDER LOGS AND STONES

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INTRODUCTION

The most obvious and frequently-studied habitat for invertebrates is among herbage or at bush-level, where flying creatures pitch and movement may most easily be seen. An equally fascinating area lies well below eye-level, where it is uncomfortable for us to search, with resulting stiff joints and neck. Unless this special effort is made, it is difficult to realise what a wealth of life lies in the leaf-litter, beneath dead logs and twigs on the ground or under stones. Comparatively little is known about this animal life and it is beyond the scope of this account to talk authoritatively on rarity or abundance,

except from limited personal observation.

The West Mendip Invertebrate Group has, for a number of years, gone out "insecting" each Saturday night of the year, weather permitting, even in winter. It is then that we have concentrated our observations on this twilight world and it has been most rewarding. In winter, few insects are seen flying and if you are to continue studies out of doors, this is the zone onto which to cast your eyes. You will not be disappointed.

Mendip lends itself well to these studies. There are varied and extensive deciduous woods, largely undisturbed and often managed by conservation bodies such as the Somerset Wildlife Trust. Many fallen trees and branches have been left to rot where they fall and plenty of undergrowth encourages diversity. The wetter dead branches seem to harbour the highest populations of invertebrates, though these vary according to the variety of wood. Dry birch branches have much smaller populations than, for instance, oak lying damply, half buried under leaves. Turning a branch over will reveal pockets and "caves" in the earth beneath, and tunnels in the decaying wood. Where the bark hangs loose, yet another assemblage of small creatures will be found within.

There are many sites with rocks and stones on Mendip, especially in the western part, where limestone or sandstone lies on the surface. The main source of creatures is the larger stone which has become dislodged at some time and lies loosely buried in the soil. There will often be pockets beneath, and teeming life may be found. A quick lift of the stone at one end often reveals a scurry of movement down secret tunnels, while other creatures play dead.

Afterwards, all must be replaced as it was found. If any bark on a large trunk is disturbed, it must be tied back or wedged in position. Re-cover exposed "cavelets" in the earth and allow the creatures to resume their lives once more. The sheer volume of living things will amaze, and many of these creatures will allow close examination without appearing to be disturbed by your presence. It is a fascinating study, which really only requires a good entomologist's glass to see the detail.

The following sections touch on some of the groups of animals regularly found. They all need a great deal of further work done on them. A recently published book on these groups (Wheater & Read, 1996) will perhaps give impetus to this neglected area of invertebratology.

SPRINGTAILS & THEIR RELATIVES

Among the most obviously numerous animals found in leaf litter or logs are springtails and their close relatives, bristletails. They vary in size from a couple of millimetres to several times that length and can often be seen to be brightly-coloured when viewed under a lens.

Springtails or collembola have a most effective mechanism under the body which, when it is activated, flicks the body high into the air, to escape their predators. These creatures perform a most valuable function by cleaning up much of the detritus in the top layers of decaying matter. They need the high humidity of wet soil and litter. There are four groups of springtails which vary considerably from one another. They have single eyes (ocelli) and are wingless. They are well illustrated in the Field Guide by Chinery (1996).

Bristletails or thysanura are wingless insects. They are larger than the next Order at up to 18 mm, though most are much smaller. They are notable for their splendid 'mother-of-pearl' scales, which catch the light and glisten in different colours. Thysanura have three long tails which look like segmented antennae. These animals tend to inhabit drier areas than springtails. They have large compound eyes.

Two-pronged bristletails or **diplura** are much smaller than the last Order, below 5 mm. in length,with twin, segmented tails. They are wingless and more suited to humid conditions. They are completely devoid of any sort of eyes.

GNATS & FLIES

It is surprising how many **flies** or diptera are found in the dark corners and layers of the environment described, the adults settling down comfortably in the darkness for the winter or working their way through the interstices in search of food. Their larvae are found in cracks in rotting bark or in cavities in the soil, sometimes solitary and in other places in colonies, like those of the St. Mark's Fly, *Bibio marci*.

Fungus gnats, the Mycetophilidae, feed on underground fungal mycelia and are found everywhere. They are delicate little creatures, well worth examining through the lens, with a forked vein in the wing and humped thorax. Muscidae, members of the **house-fly** family, are sometimes found in the dark, under a log, their eyes beaded with water drops, waiting out the winter in the reasonably constant temperature to be found in this type of habitat.

ANTS, BUMBLEBEES, WASPS & OTHERS

The most likely members of this Order to be found under stones and dead branches are the **ants**, the Formicidae, though other members of the Order Hymenoptera may be seen. In 1994, under a log in Cheddar Wood, the West Mendip Invertebrate Group exposed a hibernating queen of a large hornet-like **wasp**, *Dolichovespula media*, only recently found breeding in England.

In summer, **bumblebee** nests are often located with entrances by or under logs, though you have to be lucky to spot the narrow hole. If it is too obvious, a badger will spot it also and dig it out, as we found one morning. The nest of *Bombus terrestris* was some 45 cm below ground, but all that was left was a cluster of broken cells and a clump of bewildered worker bees who had come back to find this destruction. We have also found the exotic **Velvet Ant**, *Mutilla europaea*, parasitises bumblebees; the female ants are wingless and the less-frequently seen males are fully winged.

Ants are the most likely members of this group to be found, and Mendip has a fine collection. Draycott Sleights, in particular, is known for the number of species and their abundance. **Red ants** are well represented, with *Myrmica rubra*, *M. ruginodis*, *M. scabrinodis*, *M.sabuleti* and *M. schenki* amongst these, while the **black** and **grey ants**, *Lasius niger* and *L. alienus*, are common, together with *L. flavus* and occasionally *L. mixus*.. Of these, *Myrmica sabuleti* is particularly important as the guardian of, and host to, the larvae of blue butterflies, which it tends and milks for their sweet secretions. If the Chalkhill Blue *Lysandra coridon* and the Adonis Blue *L. bellargus* are to survive, they both need this ant as well as the flowers of the Horseshoe Vetch, *Hippocrepis comosa*, also found on Mendip.

Our most exciting find recently was in woods near Cheddar, where we came upon a tiny nest of *Stenamma debile*, recently pronounced to be the correct specific name for what had previously been classifed *as S. westwoodii*. It is rare in this area. The nest was discovered when we lifted a largish, flat, partly-buried stone on the edge of the wood. As so often, the immediate view was of individuals vanishing down holes, but one or two stayed long enough for us to photograph and identify them. The long, flexible petiole was unmistakeable.

Ants are fascinating, disciplined, well-organised creatures yet there is a great deal more to be learnt about them. Some live within the nests of other ant species and so they are rarely to be seen. Some grow and harvest fungi, others herd and milk aphids; still others, as mentioned above, guard and milk butterfly larvae.

BEETLES

Beetles abound in this hidden world. We count finding **Glow-worms**, *Lampyris noctiluca*, as among the more rewarding moments in our searches on Mendip – we find one or two each year. The male Glow-worm is winged and inconspicuous but the female is wingless, and the adult looks like a longer version of the larva. Once Glow-worms have been lost from a habitat, it is difficult to see how they can re-colonise it; the area must be within marching distance, so to speak.

A great variety of beetles may be found, from lumbering **Bloody-nosed Beetles**, *Timarcha tenebricosa*, with fused elytra, to the tiniest brown weevils feeding among the grain of rotting wood. A number actually hibernate under the bark or flaking wood, including that beetle common on willows and sallow, *Gallerucella lineola*.

Among the most exotic finds are the various **long-horn beetles**, so-called from the length of their antennae which are often curled back along the body. One particularly beautiful species we found, on eastern Mendip, was the golden-coloured *Rhagium mordax*, found in a cell under a dead branch on the ground. It was photographed in pouring rain and then carefully covered up again

SPIDERS AND THEIR KIN

Arachnida are a large and varied class and many are found in the twilight world under logs and stones or under leaf litter. The best known, forming the largest part of the class are the **spiders**, varying from larger creatures such as *Drassodes lapidosus*, often found guarding its egg-sac beneath a thick blanket of silk stretched over a hollow in the ground, to tiny money-spiders, one or two millimetres long. These money-siders are found in large numbers in this environment, hunting tiny invertebrates. They are the spiders whose silk sometimes covers meadows like a sheet of gleaming water and whose young are distributed by streams of silk, from which they hang as they are wafted through the air. This family, the Lyniphiliidae, is large and because the animals are so small, comparatively little is known about their lives. Further studies are always welcomed by specialists.

Closely related to spiders are the **harvestmen**, Opiliones, long-legged creatures with one-piece bodies, which stalk through the litter looking for their prey. Another related group is the Acari or **ticks and mites**. These are abundant in this layer and serve to keep the litter clean; but elsewhere others are responsible for horrendous diseases round the world. Spiders and harvestmen have eight legs, and mites and ticks have eight legs except in the larval stage, when they have six. Insects always have six legs.

In these parts, we must beware of the tiny larvae and the adults of the **Sheep-tick**, *Ioxodes ricinus,* which have become more mumerous with the spread of the Roe Deer, *Capriolus capriolus,* throughout the area. These ticks are carriers of Lyme disease, which is like an extremely unpleasant form of flu combined with arthritis. Luckily, it can be treated with antibiotics but it is well to protect legs with gaiters or socks tucked over trousers, when searching undergrowth.

The strangest small animals of this class are the False-scorpions, Pseudoscorpiones, found in the leaf-litter and on logs. They have long claws like a lobster and give the appearance of a tail-less scorpion. They range from just over 1mm in length to 4.5 mm. Their small size and generel camouflage, make them difficult to find but they are most attractive when seen. This is another group where more information is eagerly sought.

WOODLICE

Members of the Suborder Oniscidea, or 'granfers' as they are known in my part of Somerset, abound in the rotting heart of logs and other ground-level habitats. There are well over thirty species, which vary considerably. An excellent AIDGAP key (Hopkins,1992) makes their identification relatively simple and increases the interest to be found in studying them.

Some woodlice are drab and appear featureless, others are full of character. For instance, one is as colourful as its name suggests. The **Rosy Woodlouse**, *Androniscus dentiger,* is found on many of the Mendip slopes, liking scree and stones. A **white woodlouse**, *Platyarthrus hoffmannseggi,* very small and almost transparent, inhabits ants' nests, where it cleans up detritus and does not appear to be worried by the ants.

This is a particularly fascinating yet accessible group, which is fun to study and there are many species locally. As you progress, it is surprising how apparently identical woodlice key out into separate species and it is soon possible to build up a respectable list. Again, there is a great deal to be learnt about their behaviour and life-style.

CENTIPEDES AND MILLIPEDES

Under logs, stones and in leaf-litter, the place is alive with these two similar yet distinct Orders. **Centipedes**, Chilopoda, are carnivorous and help to keep down the myriads of other litter-dwelling invertebrates, while **millipedes**, Diplura, are vegetarians and designed to defend themselves against predation.

Centipedes have one pair of legs to each segment and have their legs counted in tens, while millipedes have many more legs, set two pairs to each segment. Identification of members of each of these Orders is tricky and takes a great deal of time, while guides are not easy to obtain and certainly not 'popular' in their approach. Great concentration is needed while looking at minute details. Nevertheless, they form an interesting area of study, giving great satisfaction once a proper identification is made. They are most interesting to see in close-up, under a powerful lens.

SLUGS AND SNAILS

The Class Gastropoda includes a diverse collection of creatures, many of which are found in our selected environment. Most people have no idea of the variety of shapes, sizes and colours of snails until they start serious study of the books and then of the creatures themselves, which range from the tiny, like the **Prickly Snail**, *Acanthina aculeata*, 2 mm long and with whorls of bristles on the curl of the shell, to the edible **Roman Snail,** *Helix pomatia*, which may be up to 45 mm. long. On Mendip, it is possible to find some unusual and interesting species which are not well known by the public, who see snails in the shape of the common **Garden Snail**,*Cepaea hortensis*. Another curiosity is the **Blind Snail**, *Cecilioides acicula*, which normally lives deep underground but is brought to the surface in loose earth at the top of mole-hills or ants' nests on the types of calcareous slopes which are common on Mendip. This snail is almost transparent, long and slender but small, under 5 mm. in length. We have spent many an hour looking for, and eventually finding, traces of this elusive creature.

There are more **slugs** than most people imagine, and the number increases regularly as scientists sub-divide species. Some species are easily distinguished from one another, while much effort has to be put into separating others. As with grasshoppers, too much reliance must not be placed on colour.

SOME NOTABLE OR REGULAR FINDS

Flies		Snails	*Discus rotundatus*
Fungus gnats			*Oxychilus alliarius*
			Pyramidula rupestris
Ants	*Formica fusca*		*Trichia hispida*
	F. rufa	Springtails	*Tomocerus longicornis*
	Lasius alienus		also Family Sminthurida
	L. flavus		
	L. umbratus	Beetles	Burying beetles
	L.*niger*		Click beetles
	Myrmica sabuleti		Dung beetles
	M. scabrinodis		Glow Worm
	M. rubra		Ground beetles
	M. ruginodis		Rove beetles
	Stenamma debile		Weevils
Bumblebees	*Bombus terrestris*	Spiders	Large numbers, many families
Wasps (queens)	*Dolichovespula media*		
	Vespula vulgaris		

CONCLUSION

This account by no means covers everything to be found at ground level. **Bugs, solitary wasps** and **solitary bees**, **craneflies**, **micro-moths** and numerous others, many of them hibernating for the winter, may also be examined in the layers beneath our feet. However, those mentioned are the most likely to be found in normal searches.

Searching at ground level is, basically, a winter occupation, filling the otherwise barren months when winged insects no longer fly and the entomologist might be tempted to sit indoors and just write up notes or look at photographs. The West Mendip Invertebrate Group counts the winter among the more fruitful and interesting periods for study. In general, comparatively little is known about the animals described here, so it can be especially rewarding if one can make new records of behaviour or find new locations.

APPENDIX

HAND LENSES

Folding pocket magnifiers, essential for seeing detail in the smaller creaturs, may be obtained from microscope suppliers. Best magnifications are between 8 times and 20 times. The higher magnifications can be tricky, as the distance between the eye and the animal is minimal, cutting out the light. Our Group tends to use a combination loupe with lenses of ×8 and ×15 magnification.

POCKET MICROSCOPES

A low-cost pocket-microscope with ×30 magnification and a built-in, battery-powered light may be obtained from the Science Museum in London and is excellent for ultra close-up work in the field.

SOME RECOMMENDED IDENTIFICATION GUIDES

In common with many others, I have found that the biggest problem in studying invertebrates is identification. Unless you can identify down to at least family level, and preferably to species, all the effort involved may not seem worth while, and it is easy to be put off this fascinating study.

Keys and identification guides vary widely in their ease of use; I consider those listed below to be in the more practicable category. It is worth saying that, with practice and with understanding of the more technical terms involved, come skills allowing better use of the less 'user-friendly' keys and guides and the ability to identify more and more different creatures. In other words, 'practice makyth perfect'. There follow notes on recommended guides, with full bibliographic details to enable you to trace them in libraries or, where still in print, through book-sellers.

COLLINS GUIDE TO THE INSECTS OF BRITAIN AND WESTERN EUROPE, by Michael Chinery, first published in 1993 by Collins, reprinted as COLLINS POCKET GUIDE ... by Harper/Collins. Quite the best general guide, with excellent pictures. Do not confuse it with the less friendly FIELD GUIDE TO THE INSECTS OF BRITAIN AND NORTHERN EUROPE, also by Chinery, published in 1986 by Harper/Collins, which has notably inferior pictures.

A KEY TO THE MAJOR GROUPS OF BRITISH TERRESTRIAL INVERTEBRATES, by S. M. Tilling. This is one of the AIDGAP keys produced by the Field Studies Council. It was published in 1987 as FSC Publication No. 187. This is the perfect introduction to the world at foot level, inexpensive and and an object lesson to producers of keys. If you carry nothing else, this is it, ideally with Chinery's 1993 GUIDE.

A KEY TO THE FAMILIES OF BRITISH DIPTERA, an AIDGAP key by D. M. Unwin, published in 1981 by the Field Studies Council as FSC Publication No. 143. This is cheap and first class but takes identification only to family level.

BEES, ANTS AND WASPS - THE BRITISH ACULEATES, by Pat Willmer. Another AIDGAP key, this was published in 1985 by the Field Studies Council as FSC Publication No. 7 and is an excellent key to genera..

BUMBLEBEES, by Oliver E. Prŷs-Jones and Sarah A. Corbet, published in 1987 by Richmond Publishing as No. 6 in its Naturalists' Handbook series.This is a first class introduction to the subject, as this series always provides. Available as a cheaper paperback.

THE FORMICIDAE OF FENNOSCANDIA AND DENMARK, by C.A. Collingwood, published in 1979 by Scandinavian Science Press as Fauna Entomologica Scandinavica No. 8. This series is now published by E.S. Brill, Leiden, The Netherlands. A first class volume, which keys out all the British species. It is written in English by one of this country's leading ant experts and has especially clear drawings. Expensive but the best, though, sadly it has recently gone out of print.

A FIELD GUIDE IN COLOUR TO BEETLES, by K. W. Harde and P. W. Hammond, published in 1984 by Octopus Books. Cheap but long out of print. Worth searching out secondhand, as it has over 1,000 fine colour illustrations as well as descriptions of habitats.

COMMON GROUND BEETLES, by Trevor G. Forsythe, published in 1987 by Richmond Publishing as Naturalists' Handbook No. 8. anothe rexcellent introduction with ideas for further study.

A GUIDE TO SPIDERS OF BRITAIN AND NORTHERN EUROPE, by Dick Jones, published in 1984 by Newnes. A quite superb guide with photographs of the majority of species and very good descriptions of habitats and locations. A second edition, published by Hamlyn in 1989, is even better.

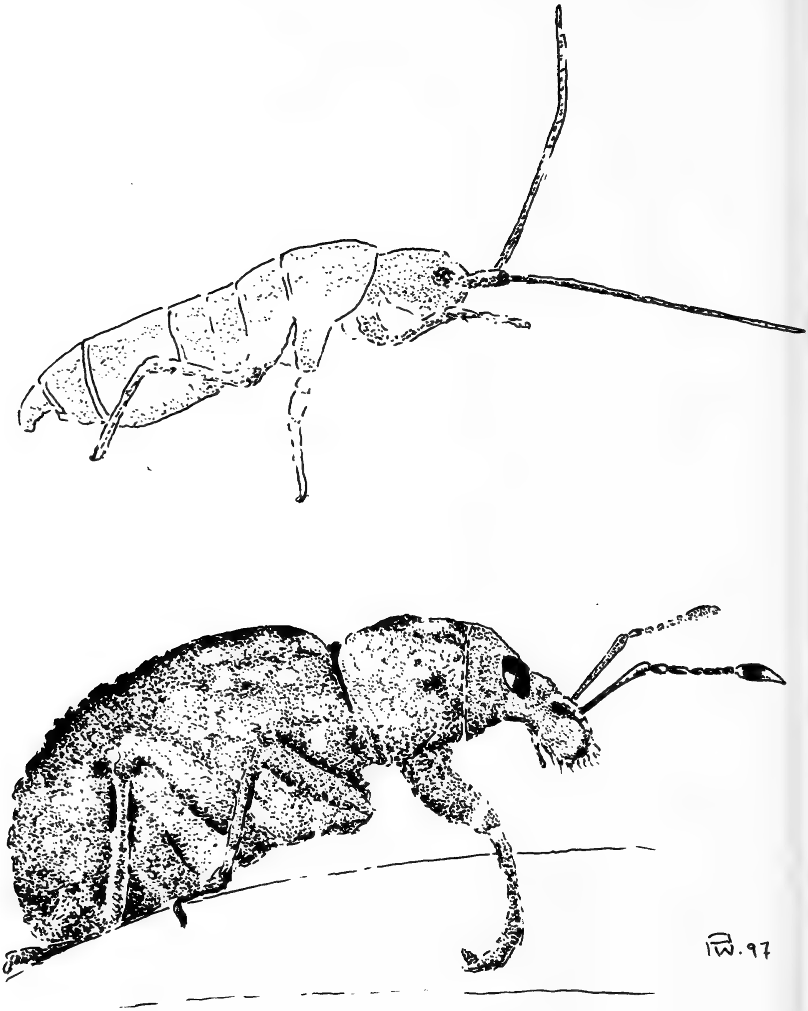
PSEUDOSCORPIONS, by Gerald Legg, published in 1988 by the Linnean Society of London as Synopses of the British Fauna No. 40. Fascinating, with ideas for study, good keys and fine drawings.

A KEY TO THE WOODLICE OF BRITAIN AND IRELAND, by Stephen Hopkin, published in 1991 by the Field Studies Council as FSC Publication No. 204. An AIDGAP key, perhaps the finest of the series, with easy keys and photographs of all species.This book makes the study of woodlice worthwhile in its own right.

MILLIPEDES, by J. Gordon Blower, published in 1958 by the Linnean Society of London as No. 11 in its Synopses of the British Fauna series. Beautifully produced, it gives you everything you need to study these creatures, but they are hard work.

THE ILLUSTRATED GUIDE TO MOLLUSCS, by H. Janus, now published by Harold Starke. Originally published in 1965 by Burke, in slightly shorter form, as THE YOUNG SPECIALIST LOOKS AT MOLLUSCS. Do not be put off by the original title. This is available as a cheap paperback which gives you everything you need to study slugs and snails.

A FIELD KEY TO THE SLUGS OF THE BRITISH ISLES, by R. A. D. Cameron, N. Jackson and B. Eversham, published in 1983 by the Field Studies Council as FSC Publication No. 156. This is an AIDGAP key. It is somewhat out of date but is soon to be updated. Simple and easy to follow.



Upper: A Springtail, *Tomocerus* species. Length *c.*5mm.

Lower: A Weevil, *Otorhynchus* species. Length *c.*10 mm.

Proceedings of the Bristol Naturalists' Society (1995), **55**:55–61

REPTILES AND AMPHIBIANS ON MENDIP

by ROGER AVERY

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INTRODUCTION

Naturalists who wish to observe or study reptiles or amphibians on Mendip are privileged, because all of the indigenous species which are widespread in Britain may be found there. All of them except for the great crested newt can be regarded as abundant and, so far as one can tell, none has undergone significant population changes in recent years (there have been no detailed surveys, but it is to be hoped that the newly formed Avon Reptile and Amphibian Group - ARAG - and Reptile and Amphibian Group for Somerset - RAGS - will rectify this). Data will also become available for the pond at Charterhouse at grid reference ST 505558, since this is a site in English Nature's Amphibian long term monitoring scheme (Swan & Oldham, 1992). A number of other British species of reptiles and amphibians have very localised distributions, but none of them occur naturally in Avon or Somerset and so cannot be expected on Mendip.

The purpose of this contribution is to discuss the distributions of the four species of reptiles (lizards and snakes) and five species of amphibians (frogs, toads and newts) which occur naturally on Mendip, and to attempt to explain them. The observations on distribution are unquantified: they are based on my knowledge of these animals, built up during many visits over the past forty years. My main justification for attempting to explain the ways in which these animals are distributed is that this will highlight important gaps in our knowledge of their ecology. I hope that others may attempt to fill these by further observations and perhaps with appropriate experiments.

COMMON LIZARD *Lacerta vivipara*

There are two key factors which help in understanding the biology of reptiles such as lizards. The first is that, unlike amphibians, they do not need to lay their eggs in water, and they have no tadpole stage. The second is that the majority of species can raise their body temperatures to quite high levels (often slightly hotter than human blood heat, even in cool climates such as that of Mendip) by lying in the sun or pressing themselves against sun-warmed substrates. This process is called behavioural thermo-regulation. Common lizards, which are abundant on Mendip, behave in this kind of way (Avery, 1971a). They are usually active only when the sun is shining - although hazy sunshine will do. If a lizard is basking in the sunshine, or running over open ground, it may be readily visible; but for much of the time for which it is active, an individual will be amongst dense vegetation, searching for the insects and other invertebrates which are its food. During this time it will be cooling, and eventually it will need to seek the sun again in order to warm up. The best time to look for common lizards is between 9.30 and 11.30 am on a cool but sunny summer morning (these times are BST), especially if the sunshine is intermittent, because they will then be spending especially long periods basking (Avery & McArdle, 1973).

Suitable habitats for common lizards must provide adequate food (so the ground level vegetation needs to be fairly dense and diverse), adequate shelter from predators (another reason for fairly dense ground cover) and adequate availability of sunshine (so lizards will not be found in thick deciduous forest or conifer plantations). There are many habitats on Mendip which satisfy these requirements. They include both acidic and limestone heathland (especially heather moor, areas of gorse scrub and areas dominated by purple moor grass *Molinia caerulea*, but not areas with dense stands of bracken), rough unimproved grassland and "gruffy ground", and grass roadside verges. I have the impression that common lizards are more abundant in rough grassland, especially adjoining drystone walls (which provide shelter), than on heathland. This may, however, be a consequence of the fact that roadside verges and the edges of drystone walls are much easier to search than areas without such linear features. Common lizards in The Netherlands are said by Strijbosch (1988) to be particularly abundant in areas dominated by purple moor grass. Although there are no precise measurements, population densities of common lizards on Mendip do not appear to reach levels recorded in parts of France, e.g. 400-1000 lizards/ha at Mont Lozère (Pilorge, 1987).

Common lizards on Mendip have been extensively studied; aspects of their biology which have been investigated include food and feeding – they eat a wide range of invertebrate prey, but especially spiders, homopterous bugs and aphids (Avery, 1966); food consumption and energetics – they eat about twice their body weight per year (Avery, 1971a); fat deposition and the use of fat during hibernation (Avery, 1970, 1974); clutch size – it averages 7.7 (Avery, 1975a); and the accumulation of heavy metals in the bodies of individuals from areas of past lead mining activity – concentrations of lead can exceed 200 mg/g, but do not appear to harm the animals (Avery *et al.*, 1983). Longevity, estimated from visual census of lizards at Velvet Bottom, has also been studied (Avery, 1975b). Of animals which are born in July-August, 90% die within their first year of life, but thereafter annual mortality is about 20%, although later work in Belgium and France suggests that the latter estimate may be too low.

SLOW WORM *Anguis fragilis*

Slow worms are legless lizards. I regard them as one of the enigmas of British natural history. Although they are abundant throughout England (Arnold, 1995), they are not often seen, and there have been very few serious studies of their biology. Many quite elementary features of their ecology are not known. All that one can say about slow worms on Mendip is that they can be found in a wide variety of habitats, including heathland, rough grassland and "gruffy ground", hedgerows, roadside verges, gardens, open deciduous woodland, scrub, orchards and around old buildings.

There are a number of reasons why so little is known about slow worms. One is that they hunt mostly at dawn and dusk, when their preferred prey – especially the grey slug *Agriolimax agrestis* (see Simms, 1970) – are most active. Much of their time is spent burrowing, in loose soil or leaf litter. Individuals sometimes expose themselves to sunshine to bask during the day, and a wide range of body temperatures have been recorded (Patterson, 1990). Males often bask in the spring (presumably the high body temperatures speed the maturation of spermatozoa in the testes), females in summer (to speed the maturation of the young in the uterus). Slow worms may sometimes be seen basking in the open at other times of the year, but there seems to be no consistent pattern in the behaviour. Much more frequently, slow worms thermoregulate when the sun is shining by contact with the under-surfaces of flat stones, or sometimes pieces of metal such as corrugated iron (Patterson, 1990). Turning over flat stones is a particularly effective way of finding slow worms – they often seem to be particularly associated with stony places, but this is almost certainly because they are easier to find in such habitats. A number of pieces of sheet aluminium which I placed at various locations at Priddy Mineries in the 1970s (to help to capture newts during their terrestrial phase) quickly attracted slow worms.

GRASS SNAKE Natrix natrix

Grass snakes feed mostly on frogs, newts and fish (Frazer, 1983), often in the water. They are widely distributed on Mendip, but are commonest in the vicinity of ponds (for example at Priddy Mineries). Although they raise their body temperature by exposing themselves to sunshine during the spring and summer months, they do not regularly return to the same spot to bask, and so are not often seen. Measurements with small implanted radio transmitters have shown that grass snakes in central Germany move quite large distances – one travelled 460 m in a single day (Mertens, 1994). South-facing banks around the disused pools associated with lead workings, for example at the western end of Velvet Bottom, are particularly good places to look for grass snakes. The slopes enable them to bask effectively and the marshy pool bottoms provide food.

ADDER or VIPER *Vipera berus*

Adders are abundant on Mendip. They usually move about much less than grass snakes, and an individual will often return to the same basking spot from day to day. This is frequently near a drystone wall or pile of stones (e.g. on Dolebury Warren), providing shelter and security. Adders may sometimes be seen on top of drystone walls, especially where the spot is overhung with vegetation such as brambles, as along the road from Hill Grove to the Hunter's Lodge Inn. In areas where adders and grass snakes co-exist (e.g. in the southern part of the Priddy Mineries nature reserve or around the ponds at Charterhouse), the two tend to occupy different habitats. Grass snakes are commoner in the lower, marshier parts, adders on the surrounding slopes.

The best time to find adders is in early spring, when the sun is not too intense and the air cold, because the snakes must then lie basking for long periods to warm up to a temperature suitable for activity. If you are extremely lucky you may see the ritualised "contest" between two or more male adders (Frazer, 1983); I have seen this twice, on both occasions in Velvet Bottom during early April.

Adders are venomous and no attempt should be made to capture or handle them. Several people have been bitten on Mendip (including me!), but to the best of my knowledge there have been no fatalities, at least within the past one hundred years. A very small number of people die from adder bite in Britain as a whole (Reid,1976), but the average is less than one per year. More people are killed by wasps or lightning.

COMMON FROG *Rana temporaria*

Common frogs occur throughout the British mainland. Numbers appear to have declined in many areas but they are still plentiful on Mendip. Their most important ecological requirements (they are amphibians) are a suitable pond for breeding and suitable terrestrial habitat for the non-aquatic phases of life. Neither of these has received detailed study, although Swan & Oldham (1992) attempted to quantify suitable habitats on a statistical basis from answers to questionnaires. Many Mendip ponds are used for breeding, and a wide variety of habitats are used for terrestrial life, including heathland, rough pasture, "gruffy ground", hedgerows and gardens.

There has been concern about what appear to be increasing levels of mass mortality in frogs in their breeding ponds, and also amongst tadpoles. Many reasons have been suggested, including pollution and diseases caused by bacteria and viruses. I am not aware of any instances of such mortality on Mendip, but if one should come to your notice, please contact the Frog Mortality Project, PO Box 1, Halesworth, Suffolk IP19 9AE, tel. 0198 684 518.

COMMON TOAD *Bufo bufo*

Common toads, like common frogs, are found throughout the British mainland in a wide variety of habitats. They are abundant on Mendip, often spawning in the same ponds as frogs (e.g. at Priddy Mineries and in the pond in East Harptree Wood), although very shallow ponds usually attract only frogs, and deeper ponds only toads (Frazer, 1983). Otherwise, a very wide range of ponds are used, including those with either acidic or alkaline water.

Toads are especially vulnerable during their spring migrations to the breeding ponds This happens later in the season with toads than with frogs (Frazer, 1983). There are now more than 400 sites in Britain where warning signs are erected in spring, under the Department of Transport's Toad Warning Sign Schedule, 1993, to alert motorists to the danger of squashing animals which are attempting to cross a road which lies in the path of their migration route. There are several of these on Mendip, e.g. at Shipham, Temple Cloud and Winscombe

PALMATE NEWT *Triturus helveticus*

These are the most abundant newts on Mendip. They are very common (together with smooth newts) in the shallow pond nearest to the road at the Priddy Mineries nature reserve. The dense growth of pond horsetail results in a deep layer of dead stems on the bottom, and this houses a rich and diverse invertebrate fauna. Studies of the food of both smooth and palmate newts in this pond showed that they are opportunistic feeders; the diets of the two species are almost identical. Both eat large numbers of the larvae of chironomid flies, but neither eat many water boatmen or dragonfly larvae, both of which are common in the pond (Avery, 1968). The newts in this pond are very heavily infected with a number of species of parasitic worms, but these do not appear to cause their hosts much harm (Avery, 1971b).

Many adult palmate newts at this pond remain in the water over winter, although they may seek alternative food at night on land in mild weather. They do not appear to hibernate, remaining active and feeding (in water) in all but the coldest weather. Smooth newts may also remain in the water for the whole year, but in much smaller numbers. Newts of all three British species studied at a pond in Sussex since 1978 have undergone the breeding migration at progressively earlier times; in the late 1970s the migration was usually towards the end of February, now it is usually early in January or even at the end of December. This is possibly a result of global warming (Beebee, 1995). It would be most interesting to determine whether there are any changes in the migration times of those newts which hibernate on land at the Priddy ponds.

A proportion of the tadpoles of palmate newts in the pond at Priddy Mineries do not complete their development by the end of their first summer, and also remain in the water over winter. Some of them still have not metamorphosed by the time that they have reached adult size, and these retain their external gills. This phenomenon is known as neoteny, and is well known in many species of amphibians (Frazer, 1983). I have occasionally found neotenous palmate newts in other high-altitude ponds on Mendip (for example, at Charterhouse and Rowberrow Warren). Neoteny can be caused by a number of factors, including low temperature, but also a lack of iodine in solution in the water. It is not known which of these factors is responsible for the high level of neoteny in Mendip palmate newts – it might, of course, be both. There are records in the literature that neotenous newts have succeeded in breeding (Frazer, 1983), but it is not known whether this happens on Mendip.

SMOOTH or COMMON NEWT *Triturus vulgaris*

Smooth newts are found in many ponds on Mendip during the breeding season, and at higher altitudes a few individuals may remain in the water throughout the year, although they may emerge onto land to feed at night. They usually co-exist with palmate newts in larger ponds on Mendip, although in other parts of Avon and Somerset there are many ponds which contain one species, but not the other. The precise reasons for this are not fully known, although smooth newts appear less able to tolerate extremes in concentrations of some chemicals in solution in the water (Cooke & Frazer, 1976).

GREAT CRESTED NEWT *Triturus cristatus*

Great crested newts receive a higher degree of protection under the Wildlife and Countryside Act (1981) than the remaining species of amphibians and reptiles on Mendip. They may not be killed or injured, and section 9 (4) of the Act protects their habitats. They have a very localised distribution. They are not found in the shallow pool near the roadside at the Priddy Mineries nature reserve, where smooth newts and palmate newts abound. I have, however, occasionally found great crested newts in the small pond which lies furthest from the road, at map reference ST 545511. They used to be very abundant in a pond at the village of Evercreech, but I have not checked recently whether this is still the case. Fresh water lice (*Asellus*) and water snails formed the major part of the diet of great crested newts in this pond, whereas smooth newts and palmate newts concentrated on the larvae and pupae of various dipterous flies. The tadpoles of all three species fed mostly on small crustaceans, especially copepods and ostracods (Avery, 1968).

CONCLUSIONS

Mendip can be regarded as a haven for the survival of the commoner species of reptiles and amphibians in Britain; they have not undergone the declines in numbers caused by habitat loss, disturbance and pollution that have been seen in many other parts. Since much of their habitat is protected in various ways, this happy situation is likely to continue. The only major threat is to populations of snakes, which are killed through ignorance or (at least in the case of grass snakes) collected as pets. Mendip is therefore an ideal place to observe these animals, and to study them to help to fill many of the gaps in our knowledge of their lives and ecology, some of which have been highlighted above. It is to be hoped that many people will be encouraged to do so.

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COLOUR PLATES

Facing this page: photographs by Dr K. C. Allen of Mendip plants.

From top: Marsh Violet, *Viola palustris*;

Greater Tussock-sedge, *Carex paniculata;*

Bog Asphodel, *Narthecium ossifragum*;

Southern Marsh Orchid, *Dactylorhiza praetermissa*;

the fern Moonwort, *Botrychium lunaria.*;

Spring Sandwort, *Minuartia verna..*

Facing page 63: Photographs by Janet Boyd relating to galls in Mascall's Wood.

From top: The gall wasp *Neuroterus quercusbaccarum* laying fertilized egg in under-side of leaf of English Oak, *Quercus ruber.*

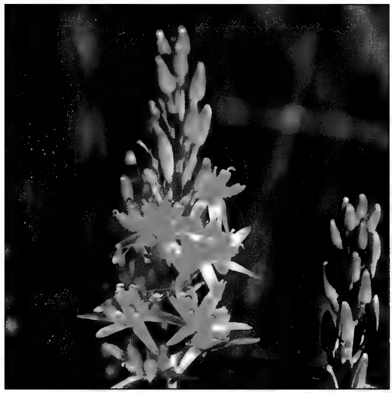
Common Spangle galls on underside of an English Oak leaf, induced by the agamic generation of *N. quercusbaccarum.* Here a parasitoid, a chalcid wasp, is laying eggs into the larva within a spangle gall. The developing larvae will feed on the inducer larva.

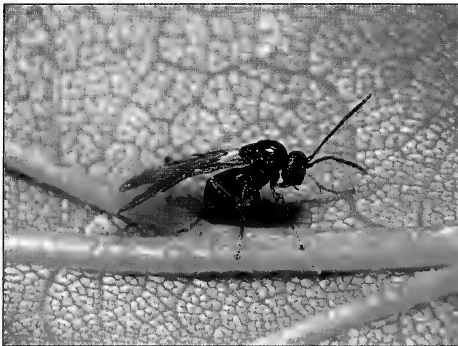
Close-up of a Currant Gall on English Oak, induced by the bisexual generation of *N. quercusbaccarum.* Here, a wasp *Synergus* sp. is laying an egg into the Currant Gall. This species is an inquiline – its larva will harm the inducer's larva only if it uses up the available food.

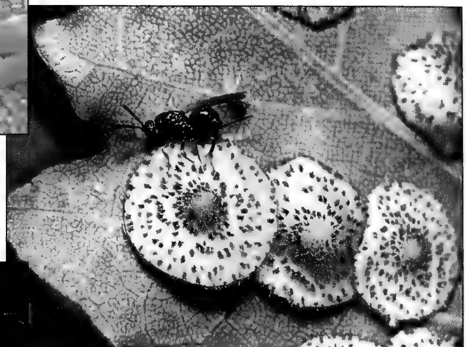
Two marble galls induced by the gall wasp *Andricus kollari* on a bud of English Oak.. Here a parasitoid chalcid wasp is drilling a hole into one gall; it will lay an egg within the larva of the inducer in the gall centre, or within an inquiline larva nearer the outside if one is encountered.

Galled buds on an English Oak. One marble gall (with an exit hole) and two cola-nut galls; the latter are induced by the wasp *Andricus lignicola.* Cola-nut galls arrived in England only in 1972.

Gall on stem of Cat's Ear, *Hypochaeris radicata*, induced by the wasp *Phanacis hypochaeridis.*







Proceedings of the Bristol Naturalists' Society **55**: 63–70

THE MAMMALS OF MENDIP

by M. J. WOODS

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INTRODUCTION

The Mendip Hills are probably most dramatic when viewed from the south where the massif rears steeply from the edge of the Somerset Levels. Further west the steepness becomes vertical and the sea takes the place of the land as the hills peter out in the dramatic cliffs of the finger of Brean Down and the island of Steep Holm in the Bristol Channel. From the north the ridges and valleys south of Bristol take away much of the impact of the escarpment while to the east the plateau becomes a narrow hog's-back before breaking up into a series of smaller hills to the north of Shepton Mallet.

There is a wide array of habitats on the slopes and plateau of Mendip. The hills have a number of deciduous woodlands of high wildlife value, especially on the southern slopes, where small-leaved lime woods and large stands of hazel coppice, now mixed with many other native tree and shrub species, provide habitats for a variety of mammal species. While the agriculture is mainly pastoral, there are some large areas of open common which support heather, bracken and herb-rich grassland and a number of forestry plantations to bring additional variety.

The information used here has been drawn from a number of sources but the primary ones are Somerset Environmental Records Centre (SERC) and the *Proceedings* of the Bristol Naturalists' Society between 1989 and 1994. Both organisations, in turn, have gathered their information from a range of sources.

SMALL MAMMALS

Britain's small mammal fauna is well represented on Mendip. The **wood mouse** *Apodemus sylvaticus* flourishes both in the woodlands and hedgerows, although long-term trapping studies have shown that its population fluctuates considerably, mainly in response to the autumn crop of tree seeds. The **yellow-necked mouse** *Apodemus flavicollis* is sufficiently closely related to the wood mouse to interbreed with it on the continent, although not in Britain. It is larger than the wood mouse, weighing half as much again, but in spite of this greater size it is only patchily distributed in a much more restricted range. It is a Red Data Book species (Morris 1993) which is limited to the south and south-east of England and the Welsh borders while being only intermittently recorded in the south-west. There are several records of yellow-necked mice in woods in the Cheddar area, notably in Black Rock Drove and Black Rock Reserves, Long Wood, The Perch SSSI, Cheddar Wood and Roundhouse Hill, but, as with so many mammal records, this clumping probably relates more to the location of recorders than to the populations of yellow-necked mice.

Apart from captures in live traps and records of cat kills, yellow-necked mice are occasionally noted in dormouse boxes and our knowledge of their distribution on Mendip reflects the location of the majority of these boxes. Like that of the wood mouse, the yellow-necked mouse population appears to fluctuate. A long-term trapping study in Long Wood Nature Reserve revealed a peak of seven captures in 1986 and then none until 1991, peaking again in 1993 with twelve captures and none since. (D. Woods, personal communication).

One of the mammals considered to be so common as not to be worth recording is the **house mouse** *Mus domesticus*. It lives in the whole of the Mendip area, generally in buildings rather than woodlands, from which it is probably excluded by other small mammals, for it is quite capable of withstanding cold temperatures and inhospitable conditions. Mendip farms are probably a stronghold for this species, especially those with deep-litter hen houses.

The last and smallest member of the mouse family to be found on Mendip is the **harvest mouse** *Micromys minutus*. It is the smallest British rodent, weighing only 6 g, and is a competent climber with a prehensile tail. As with other rodents its populations fluctuate markedly; it may become abundant, but it seems that this is only locally the case and the records for this mammal on Mendip are sparse, with the only known population at Priddy Mineries Nature Reserve. The lack of corn crops and of large areas of reed beds, both favoured by harvest mice, might be one of the reasons for their scarcity here.

The **bank vole** *Clethrionomys glareolus* tends to share the same habitats as the wood mouse but is less omnivorous than the latter and less arboreal (Montgomery 1980) as well as being more diurnal. It is almost as common on Mendip as the wood mouse. While bank voles are found in more woodland habitats, the **field vole** *Microtus agrestis* prefers more open ground, particularly rough, ungrazed grassland and can survive in low numbers in dunes, bogs, scree and moorland. Populations can be dense where conditions are right, but suitable areas of rough grassland are diminishing on Mendip, particularly in the face of agricultural reclamation. New areas of tree planting also provide suitable habitat for a number of years until the growing trees shade out the grassland, when the field voles largely disappear. Consequently their numbers will fluctuate in time with the cycle of forestry operations.

A third vole species occurring on the Mendip fringes, almost at the bottom of the hills, is the **water vole** *Arvicola terrestris*. There are recent records of this mammal using the River Yeo in Cheddar shortly after its emergence from the caves here, and also the River Mells at Edford Wood. Water voles are becoming increasingly scarce nationwide and the largely dry limestone plateau of Mendip is certainly not ideal for this semi-aquatic species.

One rare species for which the Mendips appear to be something of a stronghold is the **common** or **hazel dormouse** *Muscardinus avellanarius*. This mammal is patchily distributed in southern England and parts of south and mid Wales but it appears to be locally abundant in several of the hazel woodlands on the southern scarp of the Mendip massif, notably in Cheddar Wood, Long Wood, Black Rock and Black Rock Drove, the Perch, Round-house Hill and Axbridge Hill as well as living in more marginal areas on the plateau itself. Here their use of nest boxes (Morris *et al.* 1990) has enabled a long-term population monitoring study to be carried out. At the same time, much of the recent research into the ecology and lifestyle these elusive creatures has taken place in the Cheddar area.

There is one intriguing record for the Mendip area of the other member of the gliridae family to occur in England, the introduced **fat dormouse** *Glis glis.* This mammal is generally assumed to be slowly expanding its range from a single population released in 1902 at Tring Park in the Chiltern Hills, although, in its westward movement, it has barely passed High Wycombe. Signs of bark stripping by the fat dormouse noted in Edford Wood appear to be very much an isolated event, possibly from a single released individual (R. Corns, personal communication). The animal itself has not been seen.

Somewhat similar in appearance to the fat dormouse, but larger in size, is the **grey squirrel** *Sciurus carolinensis.* It, too, was introduced around the turn of the century. It spread rapidly and has colonised most of England and Wales. It is the only member of the squirrel family to occur on Mendip, where it is widespread. While it is found in every woodland of suitable size, it particularly favours hazel coppice containing a good mixture of other shrub and tree species.

The **brown** or **common rat** *Rattus norvegicus* is also locally abundant in this area and, although there are few arable fields where they can find food, Mendip farms supply welcome shelter and provisions, often along with doses of poison. Rats thrive in the company of man and regularly raid bird tables and compost heaps.

Five species of insectivorous, terrestrial small mammal can be found on Mendip. Three are shrews and of these the **common shrew** *Sorex araneus* occurs most frequently. Like others of its family it is a voracious feeder on invertebrates and lives in the leaf litter of the woodland floor and in the base layer of ground vegetation in grasslands. Shrews suffer from a low ratio of body volume to surface area, and have to feed frequently in order to survive. Common shrews have been recorded in the woodlands in the Cheddar and Rodney Stoke areas as well as in the grasslands of Draycott Sleights, Priddy Mineries and Shipham Gorge.

Smaller than the common shrew is the **pygmy shrew** *Sorex minutus,* which weighs between 5 and 6 g. It is generally less abundant than the common shrew and, while it shares the same habitats, Dutch research shows that it spends relatively less time underground than the common shrew (Michielsen, 1966). It has been recorded at all of the sites on Mendip for which records of the common shrew exist as well as at Chancellors Farm. The third member of the shrew family commonly found in Britain is the **water shrew** *Neomys fodiens.* Less frequently encountered than the previous two species, it is, nevertheless, often recorded away from water. Both records for Mendip, at the Perch and on Roundhouse Hill, are for animals trapped some distance from a suitable aquatic habitat.

The widespread presence of **moles** *Talpa europaea* on Mendip is obvious from the numerous molehills which show up most clearly in pasture fields. Often, when tunneling in the shallow soils of the more rocky areas, moles force the turf upwards to create a ridge which is also very apparent. Moles were originally inhabitants of deciduous woodland (Corbet & Harris, 1991) where the lack of soil disturbance means that there is less need for digging and consequently very few signs of their presence.

Although by tradition the **hedgehog** *Erinaceus europaeus* is most frequently noticed as a corpse squashed in the road, in fact there have been surprisingly few road casualties on Mendip in recent years, and hedgehogs are not as common in this area as one might expect. Some suggest that this is because of the number of badgers in the area, some of which are hedgehog specialists which have learned the art of unrolling a curled-up hedgehog using their long claws and powerful front legs. There is, however, no scientific evidence that this is depleting their numbers. Nevertheless, because they are considered to be common, they are under-recorded and only two records exist, one at Rodney Stoke Wood and the other on Round-house Hill.

RABBITS AND HARES

Rabbits *Oryctolagus cuniculus* are particularly common on the Mendips. They frequent any piece of rough ground, seeking cover among gorse and bracken as well as using underground burrows. Their numbers fluctuate widely in response to repeated outbreaks of myxomatosis, although the virulence of the disease appears to be in decline and there is growing genetic resistance in rabbits. The most recently recorded mortality rate is between 40% and 60% (Ross & Sanders, 1984).

Brown hares *Lepus capensis* are less frequently encountered, and nationally numbers have declined considerably in the past twenty years (Tapper & Parsons, 1984). The Mendips are not ideal hare country because of the lack of arable land, and some records are for woodlands, which hares often use for shelter during the day. Their decline in pastoral areas is partly due to the making of silage rather than hay, and to increased numbers of stock, which hares avoid (Hutchings & Harris 1995). They have been noted in Long Wood and the Perch as well as on Black Down and Draycott Sleights, at Chancellors Farm and Cheddar Gorge North.

DEER

Roe deer *Capreolus capreolus* are by far the most common deer on Mendip. While they are spreading nationally, they also appear to be increasing in numbers locally and there can hardly be a patch of woodland on Mendip without resident roe, which emerge at night to feed on the adjacent fields. They leave readily recognisable signs and they are well recorded throughout the area.

Chinese or **Reeves' muntjac** *Muntiacus reevesi* were introduced to eastern England at the beginning of this century and have slowly spread into southern England and the midlands. Wandering individuals turn up from time to time and have been noted at

Bleadon, Burrington and Draycott in the 1980s and in Cheddar Wood, King's Wood, Mascall's Wood and the Rodney Stoke area in the 1990s. A small population appears to be establishing itself in the north Mendips where these deer are seen regularly. Four muntjac (three males and a female) were released on Steep Holm Island in January 1977. Around 20 animals survive in a stable population, with cliff falls being the main cause of mortality. (Chapman *et al.,* 1994; N. Chapman, personal communication).

Individuals of two other British deer species are seen on the Mendips from time to time. A solitary **red deer** *Cervus elaphus* was repeatedly noted at Draycott Sleights in 1989 but has not been seen since. This may have made its way here from the Quantocks or possibly escaped from a deer park. Another probable escapee was a **fallow deer** *Dama dama* reported in Cheddar Wood on a single occasion in 1992.

SHEEP

In December 1992 six **Soay sheep** *Ovis aries* were released in Cheddar Gorge. They have prospered, increasing to 40 in 1995, and it is suggested that this is one of the largest 'wild' flocks of Soays in Britain (D. Bullock, personal comunication). They clearly thrive in this precipitous habitat, where they can escape from the unwelcome attentions of visitors' dogs, from which they will scatter if threatened rather than flocking as domestic sheep do.

CARNIVORES

The **red fox** *Vulpes vulpes* is widespread on the Mendips, where areas of unfarmed land give plenty of cover. Here they can find food in the form of small mammals, for these animals are skilled mousers, while they also forage for invertebrates in pasture land. Their population is said to have increased because of the large numbers of pigs kept outside in arks which provide them with a food supply all the year round, but there is no scientific evidence for this.

Another very common Mendip carnivore is the **badger** *Meles meles,* for the dry limestone hills with their patchwork of habitats appear to provide it with ideal living conditions. The often sloping, well drained soils are good for excavating extensive setts and there are food sources available throughout the year. As a result badgers thrive here and are a local speciality. The facts that they leave such conspicuous signs (Woods 1995) and that they are a Red Data Book species because of their legal protection, means that their presence is frequently noted.

Besides the badger, two other members of the weasel family live on the Mendips - the **stoat** *Mustela erminea* and the **weasel** *M. nivalis.* Both species are secretive and are particularly wary of aerial predators. Weasels, in particular, often spend long periods underground or under matted grass (Pounds, 1981). They do not leave obvious field signs and, although often active during the day, are rarely seen. Nevertheless neither species appears to be particularly common on Mendip and sightings are infrequent.

One member of the weasel family you would not expect to encounter on the largely dry Mendip Hills is the **otter** *Lutra lutra*. This mammal is making a slow recovery on the Somerset Levels, where it has hung on in the past in spite of disappearing from most of the rest of England and Wales. A single adult road casualty was noted at Downside in 1995.

BATS

The Mendip area seems to be particularly popular with bats - twelve species have been recorded here. As all bat species are Red Data Book, legally protected and notable, they are regularly recorded in Somerset even if individual species are not identified.

The **greater horseshoe bat** *Rhinolophus ferrumequinum* is very limited in its distribution nationally and is one of Britain's rarest bats. Numbers are greatest in sites with steep south facing slopes, mixed deciduous woodland and permanent pasture grazed by cattle with a series of caves or mines available for roosting and hibernation (Corbet & Harris, 1991). The southern slopes of the Mendip Hills appear to be ideal and are something of a stronghold for them. While not abundant, greater horseshoe bats have been recorded at more than 35 sites (Symes & Trump, 1989) including Picken's Hole on Crook Peak, at Shute Shelve, Ebbor Gorge, Wookey Hole and other Mendip caves.

The requirements of the **lesser horseshoe bat** *Rhinolophus hipposideros* are largely the same as the greater, although it is probably more widespread. It, too, has been recorded in a range of sites along the Mendip slopes in Burrington (Read's Cavern) and Ubley and from Compton Bishop to Ebbor Gorge and beyond (Jones & Jayne, 1988).

There are a small number of records for the **whiskered bat** *Myotis mystacinus* mainly around the Cheddar area. It is very similar in appearance to **Brandt's bat** *Myotis brandtii*, for which there are only two records on Mendip, at Blagdon (Jones & Jayne, 1988) and at Priddy in 1993 (E. & H. Wells, personal communication).

The **Natterer's bat** *Myotis nattereri* is larger than the two previous species and more widespread, being found throughout the United Kingdom. Once again there are few records for Mendip except in the Cheddar area.

Although comparatively common throughout most of the United Kingdom, the **Daubenton's bat** *Myotis daubentonii* is mainly a water bat and the largely dry Mendip plateau is not a very suitable habitat. It does occur on the lower slopes, however, and has been recorded over water in Cheddar and Wells as well as in hibernacula in Banwell and East Harptree Combe (Jones & Jayne, 1988).

The distribution of the **serotine bat** *Eptesicus serotinus* is limited to southern England and south Wales, although it is believed to be expanding its range both further east and north. As its preferred habitat is lowland pasture with hedgerows and woodland edges, it is well recorded over much of Somerset but little noted on Mendip, with records in Wells, Banwell and Blagdon and two records on the plateau, one of which is a roost in a nineteenth century stone house with high gable ends, a typical choice for this species.

There are a number of records of the large, high-flying **noctule bat** *Nyctalus noctula* around the Mendips, notably at Rickford, West Harptree, the Perch and Rodney Stoke. As it is mainly tree-roosting, the lack of large mature trees on Mendip may limit the number of suitable sites for this species.

There are no recent records of **Leisler's bat** *Nyctalus leisleri,* although a 1915 record notes one at Winscombe (*Tucker,* 1925).

The most common British bat, the **pipistrelle** *Pipistrellus pipistrellus* is well recorded on the Mendips. Pipistrelles have recently been divided into two sibling types having calls of different pitches, a 45 kHz type and a 55 kHz type (Jones & Van Parijs, 1993). The characteristic differences have not long been known, so past records do not differentiate between them. Recent information indicated 620 individuals of the 55 kHz type at a roost at Ubley (Trump, 1994).

The **brown long-eared bat** *Plecotus auritus* is mainly a woodland species which likes sheltered wooded valleys. It appears to favour the hazel coppice woodland found on Mendip and the records also reflect the fact that it occasionally roosts in dormouse boxes. Not only has it been found in the woods on both the northern and southern slopes but it also roosts in houses, and has been recorded in Hutton, Blagdon, Wells and on the Mendip plateau.

ACKNOWLEDGEMENTS

It would not have been possible to write this account without considerable help from others, notably Bill Butcher, Liz Byron and other members of the Somerset Environmental Records Centre; Norma Chapman; Kate Lawrence, Mendip Hills Warden of the Somerset Wildlife Trust; Edward, Helen and David Wells of Somerset Bat Group; Dr David Bullock and Adrian Woodhall of the National Trust; Doug Woods; Dr Robert Corns of English Nature and David Trump of Bristol Naturalists' Society.

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NOTES ON MENDIP BIRDLIFE

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INTRODUCTION

Palmer & Ballance (1968) gave a general account up to 1965 of the birds of the old county of Somerset, and so covered the whole of the Mendip Hills. The successor volume (Somerset Ornithological Society, 1988, cited below as SOS, 1988)) dealt only with the 'new' or post-1974 county, and therefore excluded the northern Mendip slopes and the outlying Bleadon Hill, which had then become part of Avon and are now part of the new District of North Somerset. The intention here is to bring the story up to date in respect of selected species. Most of the raw material is contained in the annual *Somerset Birds*, the bird report for Somerset and (for the northern slopes) in the annual *Avon Bird Report*, also in the detailed results of fieldwork done for the national bird atlas projects of the British Trust for Ornithology (BTO), viz., Sharrock (1976), Lack (1986) and Gibbons *et al.* (1993). For two small areas recent results based on another BTO enquiry, the Breeding Bird Survey, make it possible to give a comparison of two very different bird communities in the breeding season. Other sources are given in the references. We have not space to deal with all species and we make no reference to rarities or vagrants. Also, our concern is mostly with the breeding season; many of the commoner Mendip birds leave the plateau in winter.

GENERAL CHANGES

The most important general ornithological change recently is surely the decline that has come about in the numbers of many common birds (Marchant *et al.*, 1990; Wilson & Marchant, 1997). Much of this decline has been laid at the door of changes in farming methods, such as autumn sowing, decreasing the available amount of winter stubble; and increased use of pesticides, decreasing available invertebrates. Since the major influences are connected with arable practice, Mendip should largely have escaped them. However, arable practice cannot be the whole cause. For example, Skylarks and Song Thrushes have both decreased in numbers by about 60% in the last 25 years (Gregory, Crick & Baillie, 1996) and the declines seem about the same on arable and on pasture farms. It is not easy to detect even a large drop in the numbers of a common species by casual observation – the declines were brought to light only by the specialised monitoring surveys of the BTO. The moral is that even in a pastoral or heath environment it must not be taken for granted that all is well just because familiar birds continue to be seen.

The designation in recent times of areas of arable land as 'set-aside', to be left fallow for several years, has created wildlife havens which have done much for birds, in particular for birds of prey and especially owls. In the nature of things, the offspring of birds reared in 'set-aside' areas disperse elsewhere, so that other areas benefit too. Here again, with little arable land, Mendip must have little 'set-aside', though in the west there is a near equivalent in the abandoned strawberry fields on the southern slopes, described in this volume by Janet Boyd in her account of galls (Boyd, 1997), where the crop of seed-bearing weeds and the invertebrates they encourage must be of advantage to small common birds.

There have been changes for other reasons. A few species have declined or even disappeared because in Britain they are at the north-western fringes of their breeding range, and for whatever reason that range is contracting southwards or south-eastwards – in some cases the contraction has been in progress for many years. An early example was the Red-backed Shrike or Butcher-bird *Lanius collurio,* a summer migrant which has been declining in Britain and much of north-west Europe since the nineteenth century. In Somerset it was widespread up to the 1920s and was still common on the south-facing Mendip slopes up to 1930 (Palmer & Ballance, 1968), but decreased over the next decade. The last Mendip record was of a pair seen at Westbury-sub-Mendip in 1962, and the last pair known to have bred in Britain did so in Thetford Chase, Norfolk in 1988 (Gibbons *et al.*, 1993).

Another case in point is the Turtle Dove *Streptopelia turtur.* This summer visitor, the only migrant dove to breed in Europe, has been declining throughout its northern European range since the early 1970s and is now very scarce in Wales and the South-west. It needs open ground for feeding and woodland for nesting. Although birds were still present on Mendip in the breeding season up to the late 1980s, by the mid-1990s the Somerset breeding population was down to perhaps two or three pairs in a good year, none of them on Mendip. 'The voice of the turtle is heard in the land' no more, except perhaps from an occasional migrant pausing on spring passage.

On the other hand, some species have arrived to breed in Britain as a result of a general expansion of their breeding range. Usually these range expansions have come from the south, but there are instances of range expansions southwards and westwards. Where these arrivals settle when they reach us depends of course on whether they have special habitat requirements. The Collared Dove *Streptopelia decaocto* is the classic example of an expanding species, having moved from Asia Minor to Scotland in the course of forty years. Always associated with human settlements, it has therefore a limited distribution on Mendip (see below). Cetti's Warblers *Cettia cetti* are a recent southern European recruit to the British (and Somerset) breeding bird list, having first bred in the county in 1982, but being creatures of wetland and reedbed, they will not be found on Mendip.

Some expansion of range has taken place within Britain. For example, Redpolls *Carduelis flammea* have spread as a breeding species westward and southward into Wales and South-west England in the 1970s and 1980s. They are regularly recorded on Exmoor, the Quantocks and the Blackdown Hills, and on Mendip were present at Rowberrow Warren in 1988 and on Black Down in 1995. In spite of this spread, their numbers have greatly declined nationally in the last twenty years.

DISTRIBUTION AND ABUNDANCE

Bird distribution is nowadays mapped in terms of the ten-kilometre squares of the National Grid. For more detailed work, and in particular for the local organisation of national enquiries, each 10-km square is divided into 25 squares of 2 km side, so-called **tetrads**. These are customarily labelled by the letters A to Z (omitting O), according to the scheme below. Since a 10-km square is named by the grid reference of its south-west corner, for example ST35, it is easy to find any given tetrad on an Ordnance Survey map. Thus ST35X and ST35Y are the tetrads containing Crook Peak, and ST45T contains Black Down. We shall refer to a few specific tetrads later, but for the present they serve another purpose. The local organisation of national BTO projects is based on counties 'squared up' to contain whole 10-km squares, and we had available

E	J	P	U	Z
D	I	N	T	Y
C	H	M	S	X
B	G	L	R	W
A	F	K	Q	V

(in Bland, 1985 and Bland & Tully, 1992) the details from the Atlas projects for all tetrads in three 10-km squares, ST35, ST45 and ST55, including 34 tetrads ranging from ST35Y to ST55V, which contain most of the Mendip plateau area. To give an idea of the **spread** of a species on Mendip, we have used the number of tetrads out of these 34 in which it was seen during the Atlas fieldwork. Hard information about bird **numbers** is available only for certain species.

SPECIAL FEATURES OF MENDIP

Some features of the Mendip Hills have a marked effect on its birdlife. These are the almost complete absence of surface water; the presence of the conifer plantations on the plateau and of the mixed broadleaved woods; the abundance of open grassland and heath; and the large area of plateau devoid of either trees or buildings. We now consider some birds affected by these features.

SURFACE WATER

The shortage of surface water means of course that species relying on it are excluded from most of Mendip. For the 34 tetrads, the average number of species present was 46, compared with an average of 54 for the whole of 'squared up' Avon county, and it seems that the Mendip shortfall is due to the lack of water. However, some water birds have a small presence. Mallard *Anas platyrhynchos* were recorded in five areas during the fieldwork in 1988-1991 for the New Breeding Bird Atlas (Gibbons *et al.*, 1993); four were in the vicinity of pools although one record, from Black Down, remains a puzzle. Moorhen *Gallinula chloropus* and Coot *Fulica atra* have been recorded at

Sidcot, Charterhouse Pond and Priddy Pools, and the former species also at Sidcot and Rickford and on a small pond near Priddy.

WOODLAND

The woodlands on the scarp slopes and the conifer plantations on the plateau are home to Tawny Owls *Strix aluco.* The conifers provide a breeding site also for a small number of Long-eared Owls *Asio otus*; a pair reared two young in 1973, and others have bred annually since 1993. At the other end of the range of body size, and vastly more numerous, Goldcrests *Regulus regulus* find a favourite home in the plantations, which are a preferred habitat too for Coal Tits *Parus ater,* more widespread on Mendip than in the surrounding areas.

Buzzards *Buteo buteo* have become increasingly common on Mendip; SOS (1988) refers to 'a few scattered pairs' but the Atlas fieldwork found them in 27 out of 34 tetrads. They have recovered remarkably in Wales and the South-west from their 1950s decline, when myxomatosis almost wiped out the rabbits that were their principal food. Here is open ground in which to hunt rabbits and woodland in which to breed.

The summer migrant Nightjar *Caprimulgus europaeus* has suffered a dramatic decline over the last century and a quarter. Unusually the decline, at least in recent times, has been a thinning-out rather than a contraction of range. Kemp (1983) chronicled the decline in Avon and the Mendips since 1923. SOS (1988) reported only 14 males in the county in 1985, concentrated around the Quantocks and Exmoor, with none in the former stronghold of Shapwick Heath. A national survey in 1992 (cited in Gibbons *et al.*, 1993) suggested that the decline had halted, and that over half the population was using forestry plantations. In that year birds were churring again on Shapwick Heath, and in 1993 one was heard on Mendip, at Stock Hill. They have been present on Mendip annually since, and in 1997 at least ten birds, including juveniles, were seen at one woodland location (W. G. Bigger, personal communication). Nightjars nest on bare ground amongst dead litter; with no living vegetation cover – circumstances in which their plumage is strikingly effective as camouflage, and which are found in the débris of clear-felled woodland or amongst dead bracken. They prefer to feed amongst broad-leaved woodland.

Nuthatches *Sitta europaea* have increased by some 150% since the early 1970s, aided in particular by good autumn food crops in some years, allowing increased winter survival. Thus, after three years with slight falls, their numbers increased by a third between the breeding seasons of 1995 and 1996, following an excellent beech mast and acorn crop in the autumn of 1995 (Wilson & Marchant, 1997, p. 19).

OPEN GRASSLAND AND HEATH

The early-arriving summer migrant Tree Pipit *Anthus trivialis* is thought to have been in decline in southern England since at least the 1960s (Gibbons *et al.*, 1993). The birds prefer to feed on the ground, amongst sparse vegetation but without dense shrubs or trees, though with some trees or tall shrubs available as song posts. Woodland rides and the early stages of coppice and of conifer plantations are suitable. On Mendip they breed at sites from Stock Hill north to Black Down and Burrington

Ham in the east, across to Compton Hill and Crook Peak in the west. Two of these, on the northern flank, are now the only two breeding sites remaining in the area that was Avon county. Hall (1983) found them breeding on the slopes of Velvet Bottom.

Dartford Warblers *Sylvia undata* breed in dry heath with gorse. The small British population of this, our only resident warbler, has its stronghold in the heathlands of the New Forest and Dorset. Dartford Warblers are liable to suffer heavy losses in hard winters, but can recover rapidly – they may have two or three broods in a season. Following a run of good years they have spread to Cornwall and Devon, where small populations have built up. They reached Mendip in 1993, when a pair bred at Shute Shelve Hill. By 1996, there were at least 13 pairs breeding in five areas, including one across the old Avon boundary.

One of the commonest birds in areas of gorse is the Linnet *Carduelis cannabina*, present in 25 of 34 tetrads in the breeding season, but in only three in winter, when it joins other finch species in flocks on lowland farms and along the coast. Meadow Pipits *Anthus pratensis* were also found in 25 tetrads in summer, though in only 16 in winter.

THE 'BARREN' AREAS

An area without trees will have no breeding by Rooks *Corvus frugilegus.* In ten tetrads making up the treeless central area of the plateau they were found only when feeding in winter. Likewise the absence of buildings means no breeding Swifts, Swallows or House Martins - though all of these might be seen on long-range feeding flights; and the absence of human settlements means no Collared Doves (absent from 14 tetrads), as mentioned earlier. However, treeless open areas provide the very conditions that suit Skylarks and Meadow Pipits. Skylarks *Alauda arvensis,* in origin a steppe species, are present in summer throughout the large amount of open land, though many leave the area in winter (in the Atlas surveys they were located in 33 of 34 tetrads in summer, but in only eight in winter). Meadow Pipits *Anthus pratensis* , which prefer heathy areas, are also widespread – in summer they were found in 25 tetrads, though only in 16 in winter. For both species, those that leave probably winter along the coast. Meadow Pipits form a popular host for Cuckoos *Cuculus canorus*, which were found in 16 of 34 tetrads.

Good examples of open, bird-poor areas are in tetrads ST45W, from Cheddar Head Farm to Gorscliff Farm, which produced only 15 species in the Atlas fieldwork, and ST55Q, from Green Ore to Red Quar Farm, which produced only 23.

ROOKS AND ROOKERIES

Rooks *Corvus frugilegus* are regularly censused, either nationally or regionally, for two reasons. Firstly, their rookeries can be seen easily from afar (though accurate nest-counts are in fact quite difficult to make); and secondly, feeding as they do on ground invertebrates (in the breeding season, largely on grass areas, but the rest of the time on a mixture of field types), their health is an indicator of the health of farmland in general.

On Mendip, Rooks have been the subject of a study that must be unique in ornithology: the complete survey of an area, by the same observer, at two dates fifty years apart (Boyd, H., 1996). The study area, covering 186.5 square km, involved most of 10-km squares ST45 and ST55 and a small part of ST46, and was surveyed in 1945, when Boyd found 1,215 nests in 30 rookeries, and again in 1993-1996, when he found 1,156 nests in 36 rookeries. It is known that between these dates there had been a large fall in the numbers of rooks breeding on Mendip, followed by a marked recovery. As far as is known, the 1945 total is by a small margin the peak figure to date, as it represented an increase of about 20% over the 1933 total, when the same area was counted as part of the late Bernard Tucker's famous study of Somerset rookeries. (Tucker, 1935).

The reasons for this variation in Rook breeding numbers are still matters for debate. It is likely that the use of organophosphate insecticides has played a role, and so may have breeding-season drought. It is worth noting that there are two very stressful weeks in the breeding season, immediately after the young have hatched, when the male has to feed himself, his mate and typically four hungry young, the latter entirely on earthworms. Not until the young are older does the female leave the nest to join in the feeding task.

BLACK DOWN AND CHARTERHOUSE

We end with a snapshot of the birds of two small areas on the plateau. It so happens that two of the one-km squares making up Mendip have been studied by the methods of the BTO's new Breeding Birds Survey. ST4757, part of tetrad ST45T, is moorland on Black Down and includes the East Twin and West Twin Brooks; while ST5056, which is part of tetrad ST55D, includes part of Charterhouse minery, with the farmland of Mendip Farm and Paywell Farm and most of Nether Wood. The Survey involves an observer (always the same person for a given square) making two parallel walks, separated by 500 m, across the square on a day in May, and two more on a day in June, recording all bird sightings. The speed of walking is such that each visit takes about an hour and a half, so the May and June walks together cover 4 km and take nearly three hours. The total number of birds seen is expressed as a rate per hour, so that different localities can be compared, and the list of species seen gives an idea of the richness of the bird community. Here the 1996 results from the two Mendip squares are used for illustration; other years are similar. They show clearly that the bird communities of the two plateau habitats are very different yet both are impoverished in species and in birds.

Numbers of species In all, 27 species were seen on Black Down and 33 at Charterhouse. This may be compared with 90 for the whole Avon sample of some 102 one-km squares, which, of course, covered a much more diverse set of habitats. Both areas are "species-poor", Black Down being the poorer. Charterhouse had one sighting of Buzzard and Black Down one of Kestrel. Both have large hunting ranges, perhaps breeding some way off.

The commonest species Here we use actual numbers of sightings for simplicity, rather than rates per hour, as for both squares the time was very close to three hours (182 and 179 minutes respectively). On Black Down, by far the commonest species were Meadow Pipit (87 sightings) and Linnet (54), followed by Whitethroat (18) and Willow Warbler (17). These four accounted for just three-quarters of the birds seen. There were also six sightings of Cuckoo, five each of Pheasant, Skylark, Whinchat and Wheatear, four of Woodpigeon and three each of Tree Pipit, Grasshopper Warbler and Rook. This is a community of relatively low diversity. Of the usually universally common birds, there was one sighting each of Swallow, Blackbird and Great Tit, and none of House Martin, Dunnock, Robin, Song Thrush, Blue Tit, Starling or House Sparrow.

At Charterhouse, the commonest species were Swallow (21 sightings), Carrion Crow (15), House Sparrow (14), Jackdaw (13), Chaffinch (11), Whitethroat and Willow Warbler (six each), Woodpigeon, Coot, Meadow Pipit, Wren, Blue Tit and Greenfinch (four each) and Stock Dove, Chiffchaff, Magpie, Blackbird and Song Thrush (three each). Here it took thirteen species to account for three-quarters of the total records. There were two sightings each of House Martin, Dunnock and Robin, and one of Starling, so that all the "common" birds were present at a low level. The presence of the Coot (a single pair) and the Swallows was related to the pool, the Cuckoo to Meadow Pipit nests, and the House Sparrows to the presence of the farm buildings. The farmland species list is longer and more diverse than the heathland list – more of its species are moderately well represented and none is overwhelmingly abundant.

Total bird population The average sighting rate was 77 per hour at Black Down, and 55.5 per hour at Charterhouse (65 on the May visit but only 46 on the June visit, rather late in the month). In comparison the whole Avon County sample (102 squares) yielded an average of 134 sightings per hour, based on 278 hours of fieldwork. Both Mendip areas are therefore relatively "bird-poor"; but Black Down has the larger population of the two. Fewer species are involved there, but they include four heathland specialists.

ACKNOWLEDGEMENTS

We acknowledge with gratitude the advice of Brian Gibbs, Ornithological Recorder for Somerset, in connection with some rare species; the role of John Tully in providing data from the BTO's Breeding Birds Survey; the work of the army of observers who took part locally in the BTO's great Atlas projects and those who are now carrying out the Breeding Bird Survey and Common Birds Census; and the efforts of the many observers who provide the material for the annual Somerset and Avon Bird Reports.

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Proceedings of the Bristol Naturalists' Society, **55**:79–86

AGRICULTURE ON THE MENDIPS

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ABSTRACT

Many who live in the country no longer have a connection with farming. Since the discovery of agriculture, farmers have been a major influence on the countryside and they in turn have been affected by external factors. Support programmes have been in place to assist farmers in food production and emphasis should now be more on environmental management. Practical knowledge accumulated over the centuries among farmers and a great deal of scientific research has been done. Much information is available to farmers on the various aspects of their businesses. The Farming and Wildlife Advisory Group is a partnership body with a mission to unite farming and conservation. Farm Conservation Advisors are available to help farmers in the Mendip area. Farmers need well-honed skills in these various aspects of management. Modern methods enable work to be done in a timely manner, so reducing possibilities of damage to soils. The effects of past mining activities can still influence management practice. Major farming changes were not possible on Mendip until mains water supplies became available. The climate favours grass which occupies much of the area; there are many cattle and sheep farms and some quite large dairy farms, some of which are part of organisations off the hill. Despite some destruction of natural grassland and some hedge removal, many hedges, walls and trees remain. Many farmers, especially those in the Area of Outstanding Natural Beauty (AONB), feel they are on view but, in general, they welcome their visitors, who are asked to remember that they are enjoying themselves in the farmer's workshop.

INTRODUCTION

Developments in machinery and other techniques have removed the age-old drudgery from farm work. This is of great benefit to individuals but means that fewer people are needed to undertake the various tasks. In earlier times, the majority of people living in the country were employed on or connected with farms but now the majority, if indeed they have a job, are employed in other activities, often away from the countryside. Many people have more leisure time than previously and large numbers enjoy informal recreation in the country. Farmers and and foresters manage over 80% of the countryside and so visitors are usually enjoying their recreation in the farmer's workshop. There is potential for conflict here and designations such as 'Area of Outstanding Natural Beauty' (AONB) can be seen as potentially devaluing the worth of a farm. A confrontational approach on this will help no one and benefits neither farm businesses nor environmental conservation. The way forward is an educational one, with with quiet discussion of the various viewpoints, to increase understanding and facilitate orderly development in the countryside.

FARMING BACKGROUND

There is no true wilderness in Britain today as virtually all the land surface has been influenced by humans, in one way or the other, ever since the the retreat of the glaciers. The practice of agriculture has had a major effect because natural cycles are broken. Farmers grow crops to feed themselves or their animals, crops for fibre with various uses and timber for construction and heating. These activities mean that plants and the nutrients that they contain are removed elsewhere and not recycled on the spot. Weeds, sometimes defined as plants in the wrong place, have been a problem since the beginning of agriculture. A seedbed prepared for a particular crop is a good place for other seeds to germinate. Growing a single species as a crop facilitates the spread of pests and diseases. Many references can be found to attempts to deal with these problems.

Over the millenia, farmers have been a major influence, whether a bronze age man with a digging stick, a medieval ploughman with an eight-ox team or a modern farmer with a large tractor and complex equipment. The countryside, which we enjoy and delight in, is a result of the activities of many generations of people going about the business of making their living. Mostly within the last couple of hundred years or so, there have been deliberate planting and landscape works.

External influences have always affected farming activities. In Tudor times, the increasing trade in wool and cloth was a major factor in the decisions to enclose large areas and sow them to grass to feed sheep. Two or three shepherds and their dogs could replace perhaps twenty ploughmen, leading to the phrase, "Sheep eat men". Historians would claim that the wool trade was important in England's development but there must have been misery in the countryside. A Board of Agriculture was set up about 200 years ago to encourage food production during the Napoleonic Wars, and reports were commissioned on the situation in the various counties. John Billingsley (1798) wrote one on Somerset which contains information about the Mendips. This Board of Agriculture ceased in the 1820s because Treasury support ceased.

There was increasing concern and controversy over the Corn Laws, which maintained farmers' prices.These laws were repealed in 1846 amid great political upheaval. The rapidly increasing population needed food, and farmers remained prosperous for about another thirty years, until a run of bad weather and poor harvests in the 1870s. Also, about that time, cereals and cheese began to be imported from North America, and a little later the development of refrigerated ships meant that meat and butter could also be imported from Australia, Argentina, New Zealand and other places. Farmers in the United Kingdom could not compete and the industry went into a serious decline until 1939, except for a small upward "blip" from 1916 to 1922. A second Board of Agriculture had been established in 1889 and its first secretary is on record as saying to

Sir Daniel Hall, Director of Rothamsted Experimental Station, "British agriculture is dead and it is the duty of the Board to provide a seemly burial" (Dale, 1956). This second Board became a Ministry in 1919 and, following amalgamation with the Ministry of Food in 1955, it became the Ministry for Agriculture, Fisheries and Food (MAFF).

SUPPORT PROGRAMMES

By the late 1930s, it was clear that more food would have to be produced in this country, and measures were introduced to support agriculture. At the end of the Second World War there was a serious food shortage in Europe while this country was short of foreign currency, so the support was continued. Grants were made towards the cost of certain activities, and some commodities were brought within a deficiency payments scheme – put simply, a fair price was agreed and financial support was provided to bring the price realised in the marketplace up to this. This system was effective and pretty fair value for the taxpayer. Farmers responded in an admirably professional way to ensure an adequate food suply.

From 1973, when the United Kingdom joined the European Union (or European Economic Community, as it then was) support came from the Common European Agricultural Policy (CAP). This is a very complex system; on mainland Europe it is concerned not only with supporting food production but also with maintaining rural life and the social fabric of the countryside, and this means high support costs. There is a consensus that the CAP must be reformed and that, though farmers do merit some support, this should be directed in future much more towards environmental objectives. Section 17 of the Agriculture Act (1986) placed on MAFF "the duty to balance the interests of promoting an efficient agricultural industry with the socio-economic interest of rural areas, the care of the countryside and its enjoyment by the public". This requirement is incorporated into all Statutary Contracts of the Agricultural Develop- ment and Advisory Service (ADAS).

Following agreement a few years ago between members of the General Agreement on Tariffs and Trade (GATT), it is likely that, in the long term, farmers will be subject to severe competition from outside Europe. The purchasing managers of the multiple retailers set high standards for the quality and conditions of goods. To meet these standards, farmers are driven to specialise and have less scope for traditional mixed farming. The multiples encourage farmers to practise integrated crop management and one or two also encourage the calling in of the Farming and Wildlife Advisory Group for a Landwise Assessment (see below). There is increasing concern about the long-term sustainability of current life styles, including methods of food production. Some appear to think that sustainable agricultural practices will be facilitated by deregulation and exposure to the rigours of the market, but others consider that this would be likely to increase the trend towards specialisation and intensification. This is clearly a topic requiring careful consideration by agricultural policy makers.

SOLUTIONS FOR PROBLEMS

In earlier times, it was a hard struggle to grow enough food to last through the year and sometimes there would be hunger and even deaths, but there have been no major famines for over 400 years in Britain. In recent times, historians have discovered more about the diet of ordinary people in earlier ages; it was monotonous, inadequate nutritionally and often short in quantity. Over the years, knowledge has accumulated on how to deal with the various problems and this process has accelerated over the last 150 years, with a virtual explosion of information during the last half century. ADAS, other consultants and representatives of suppliers are well aware of the information and thus much knowledge is available to farmers about soil management, plant nutrition, animal feeding and pests and diseases.

There are numerous products on the market which a farmer can use to ensure a good harvest and to greatly reduce the risk of crop failure. Many are toxic in themselves but with good advice, careful attention to the approved conditions and thoughtful and responsible use, there should be few environmental problems. Fertilisers are used to make good any shortage of nutrients. Much more information has become available in the last few years about the management of nitrogen: some nitrates will always escape from any sort of farming system, but advice is available to minimise this. Careful use of nitrogen fertiliser will ensure high yields without raising serious environmental problems. Good reliable methods of soil analysis are available for substances such as phosphorus, which can escape from the soil to cause problems in water.

There are those who would wish to withdraw from modern methods, but this is not a realistic possibility. The great advantage we have over our medieval and earlier predecessors is that materials are available to deal with day-to-day work on the farm. Chemicals are widely used in areas other than agriculture: in cleaning materials, paints, hair sprays, petrol refining, detergents, man-made fibres and many, many more. They make a significant contribution to the quality of life and standard of living. Such materials must be rigorously tested and kept under review, and used wisely and carefully in agriculture and elsewhere. The people at Long Ashton Research Station and associated centres, working on the Low Input Farming Experiment (LIFE), have shown that good yields of various crops can be obtained when inputs have been considerably reduced. Managerial skills must be high. Each crop is frequently assessed and if a chemical spray is needed, it is used.

THE FARMING & WLIDLIFE ADVISORY GROUP

The Farming and Wildlife Advisory Group (FWAG) was established in 1969 to unite commercial farming and forestry with wildlife and landscape conservation. It is a partnership in which the major partners are the Country Landowners Association, the Countryside Commission, English Nature, the Environment Agency, the Forestry Authority, the National Farmer's Union, MAFF, the Royal Agricultural Society of England, the Royal Society for the Protection of Birds and the Wildlife Trusts. It is strongly supported by the Department of the Environment. Over 70 Farm Conservation Advisors (FCAs) are now in post in many counties and Local Authority areas in the UK. They can give confidential advice to farmers on specific items and draw up a plan for the whole farm. For the area of the Mendips in Somerset, the FCA is Ben Thorne, based at the Department for the Environment at County Hall, Taunton. For the areas in Bath and North East Somerset and in North Somerset, the FCA is Edward Gallia, based at MAFF's Wessex Regional Centre, Burghill Road, Westbury-on-Trym, Bristol. The FWAG has produced numerous publications about environmentally responsible farming.

The FWAG Landwise options are designed to make conservation mean business and to give an opportunity for farmers to develop their own programmes at their own pace. The *Landwise Report* is free to new farmer customers and takes little time. The *Landwise Review* carries a modest charge and is for farmers wishing to update their plans and develop a programme of environmental improvement. The *Landwise Plan* costs more but provides a highly detailed analysis and a comprehensive plan of action. It includes "Cabcards". These are small, portable and weather-proof diagrams relating to specific parts of the farm and/or individual fields. Items covered include pesticides, fertilisers, grazing, silage and so on, and include recommendations for best practice in the particular area. They are useful guides for farm staff and contractors and encourage feedback and involvement in conservation work.

WHAT A PRESENT-DAY FARMER NEEDS

The modern farmer needs highly developed managerial skills to keep his business viable and obtain a reasonable return on his investment. He must make the best use of his own physical work and also that of employed workers and hired contractors. He needs to be technically alert and competent to make effective decisions on inputs of materials and on management of animals and crops, and he must continually develop his sense of stewardship to manage his farm in an environmentally responsible way and develop habitat in suitable areas of the farm – in all a very demanding programme.

A major problem is the provision of winter feed for animals, especially dairy cows. They eat grass during the growing season and some of this must be conserved for the winter. The traditional way was hay-making – cutting and drying it in the wind and sun, a process very much dependent on the weather. The herbage is quite mature when cut for hay and so the feeding quality has been reduced. Nowadays a high proportion of feed is conserved as silage, which in effect is pickled grass (organisms in the leaves produce lactic acid). The techniques are now well understood. As the grass is cut younger, the food quality is much better and there is less risk from the weather. Professor Webster, of Langford Research Station, has remarked that a modern dairy cow producing 6,000 litres of milk each year is working as hard as a human jogging six or eight hours a day. Therefore it is right and proper that she should be fed on good quality food. Unfortunately, the earlier cutting does not permit flowers to set seed, and ground-breeding birds run the risk of losing their nests or newly-fledged young.

THE PRACTICE OF AGRICULTURE ON THE MENDIPS

Soils vary in the area; some are clayey and some shallow but many are silty or loamy in texture. Soils of the Nordrach Association occupy a considerable area; these are deep fine silty soils, formed from loess deposited during glacial times. From the soils angle, therefore, there is potentially high fertility but rainfall, altitude and exposure militate against crop farming. Soils that are cultivated when too wet can be damaged by compaction, causing pan and clod formation. A pan is a horizontal hard layer in the soil through which roots cannot penetrate and through which water movement is slow.

Clods are hard lumps which cannot be penetrated by roots. So a soil with pan is artificially shallow and one with clods is, in effect, a stony one. The great advantage of larger and more powerful tractors is that work can be done in good time when soil conditions are good. For maximum benefit, field sizes must be reasonable and some hedges and walls have been removed. The larger machines can be troublesome in the narrow lanes but, as one farmer remarked when asked why he didn't pull into a layby to let cars pass, "once you pull off, you can never get on again".

My grandfather farmed at Dundry, near Bristol and he was also a busy dealer in cattle and sheep. About 90 years ago, he was in the habit of purchasing cattle at the Bristol market held on Thursdays at the back of Temple Meads. Most of these animals were walked over the Mendips to the Wells market, held on a Saturday. Fields were rented on the Mendips for them to be held overnight. No doubt the herbage would have delighted a botanist but perhaps dismayed an animal nutritionist. The roads would have been dusty in summer and muddy in winter. The Minutes of the Somerset NFU around 1920 often contain items about the Highway Authority tarring roads and making them slippery for horses. In 1940 there was a call to plough grass and grow cereals, but few on the Mendips had the necessary equipment. The Somerset War Agricultural Executive Committee (the "War Ag") sent a man to the Priddy area to plough a field. He put out his markers and began to plough the opening furrow. On glancing round, he was surprised to see no furrow. The turf was so thick that it sprang back as soon as the plough had passed.

PRESENT-DAY FARMING ON THE MENDIPS

The growing season on the Mendip Hills is shorter than elsewhere. There are many moist days and harvesting is difficult, even with modern equipment. Not many cereals are grown on the plateau, and wheat is probably the most important, though some barley is grown. There are a few fields of rape and potatoes, and maize is grown for silage. There is a miniscule area of horticulture. The climate is excellent for grass, which occupies over 85% of the area and is utilised by sheep and cattle. The sheep population has been increased by half to about 30,000 during the last ten years and beef cattle have gone up four-fold. Dairy cows have decreased by one fifth - possibly because of the imposition of milk quotas. Both cattle and sheep are needed for grazing management in the interests of conservation. At the time of writing, it is not possible to see the ultimate effect of the Bovine Spongiform Encephalopathy (BSE) crisis. About one quarter of the farms are between 5 hectares (12 acres) and 12 ha (49 acres) in size while 10% are over 100 ha (240 acres).

Mining has influenced, and still does affect, farming processes in parts of Mendip (see the contribution by Martin and Fawcett in this publication). Zinc can be absorbed by plant roots and translocated to the shoot, where it interferes with the metabolism of iron, so that crops, grass and even natural vegetation affected by zinc toxicity look very yellow. Zinc is leached down through the soil, and problems are sometimes seen following earth-moving activities or changes in cultivation techniques which cause slightly deeper penetration. Lead is not much absorbed by plant roots and it is not very toxic to plants. It can be eaten by animals in the form of dust on leaves. Farmers in affected areas are aware of the problem and are careful with grazing practices. Animals are not allowed to graze down so that they ingest the soil, but are removed from the field when herbage is still relatively long. Molehills can cause problems, especially in fields laid up for hay or silage. The presence of soil upsets the silage fermentation in any case, and the presence of soil in feed has, on occasion, caused lead poisoning in animals housed for the winter.

Cobalt is not an essential element for plants but is a vital micronutrient for ruminant animals. Affected animals will literally waste away. Some cases of cobalt deficiency have been seen on Mendip but good information is available about curative measures.

The Mendips are well known as an aquifer but little of the water is available on the surface. Availablity of water formerly controlled the number of animals that could be kept and so the type of farming that was possible. Farmers frequently arranged to send their animals off the hill in summer and in turn the lowland host farmer would send some of his own animals up onto Mendip in the winter, a mutually beneficial arrangement. The Mendip farmer could keep more animals and increase the viability of his business; the extra animals in winter facilitated good sward management by allowing tight grazing, while the lowland farmer's fields, which could well be wet and liable to damage by treading in winter, would have fewer hooves walking in them. The Bristol Water Company provided a supply to one or two farms in the mid 1930s as part of a scheme to tap a major spring for the Axbridge reservoir, and a few more farms were connected in 1939 as part of the military development at Yoxter. The major provision of piped water to the Mendip area came in the 1950s. Mains electricity was laid on in the early 1960s. The availability of power, as well as water, facilitated farming operations and materially improved living conditions for farmers, workers and wives.

DEVELOPMENTS IN RECENT YEARS

In recent years, many fields have been ploughed and reseeded with nutritious herbage, boring for botanists and a poor habitat for butterflies and other creatures. Sadly, some precious and irreplaceable natural grassland has been lost in this process. About twenty years ago, an attempt was made on one farm to grow cereals intensively on a monoculture basis, but this did not last. Some farms have become parts of larger enterprises with headquarters off the hill. These are dairy farms which produce milk for yoghurt; another group produces cheese, the whey being fed to pigs. When holdings have changed hands, new buildings have sometimes been necessary. In general these have been well fitted into the landscape, but there have been one or two notorious problems.

Some pigs have always been kept out of doors on Mendip but the development of a large-scale enterprise has stimulated some comment. This is an outdoor multiplying unit for a national organisation. The breeding sows live in huts in fields which have been reseeded with grasses providing a strong supporting turf. When the piglets are weaned, they go into sheds to be reared to a weight of 30kg. The males then go to another unit to be reared for bacon and the females go off to other farmers. The sheds have been designed for good natural ventilation. In Holland problems have been caused when ammonia released from manure combined with sulphur dioxide in the atmosphere to produce acid rain, but no problems like this have been seen on the Mendips. The intensification of some dairy farms and the development of the pig enterprise does provide employment in the locality. At the beginning of the development of the pig enterprise, there were problems of soil erosion. Pigs will not be grazed in future in the fields concerned .

CONCLUSIONS

Some fences and walls have been removed, but overall, there is an impression of hedges and trees remaining. One senses that farmers, especially in the AONB, feel themselves to be on view. The majority welcome their visitors and request them to follow the **Country Code**. To a sheep a dog, even a well-behaved domestic one, means 'predator' and the reaction is 'run!'. Little Johnnie will be sad if he loses his ball, but if a calf swallows it, an unpleasant death may result. Plastic bags can also be a menace and the horrors of metal cans and broken glass are very well known. Lorries from the stone quarries have been diverted away from certain areas onto the narrow lanes where they cause damage to dry-stone walls when passing each other. The overall message is: please help the farmers to keep the Mendips an attractive and productive place.

Dick Russell would like readers to know that this contribution was produced at very short notice, with little time for checking, Any figures mentioned are correct in a broad brush sense. He is grateful to farmers, friends and colleagues who gave up their time to talk to him. The views expressed are his own and not necessarily those of any person or organisation with whom he has been in consultation.

The Editor acknowledges with gratitude the author's help in stepping in to fill what would otherwise have been a regrettable gap in the subjects covered in this issue.

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Proceedings of the Bristol Naturalists' Society, **55**: 87–94

RECENT VEGETATION HISTORY OF BLACK DOWN, MENDIP

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INTRODUCTION

The East and West Twin Brooks flow down the northern flank of Black Down, Mendip, above Burrington Combe (Fig. 1). In 1980 the profile of the peat, from the surface down to bedrock, a depth of 135 cm (4 ft 5 in.) was sampled by Dr B. Finlayson at the site of a former spring head in the catchment of the East Twin. He also took samples for radiocarbon dating, a procedure that involves irradiation of the samples at Harwell. These indicated that the peat had accumulated over a relatively short time period of around 300 to 400 years. Dr Finlayson had slides for pollen examination prepared from points every 5 cm down the peat profile; the pollen counts were made later by the author. The findings give an opportunity to look at the continuity of the present vegetation communities of Black Down. They also give a measure of the period of infill of spring head sites in moorland gullies.

THE PRESENT-DAY VEGETATION

Figure 1 shows the area, and the main land uses. The summit plateau and north-facing slopes of Blackdown carry a mixture of open heath communities. There is a Forestry Commission plantation of young conifers about 1 km to the west, while mixed ash woods occupy the north-facing slopes within the main part of Burrington Combe. The heath communities can be related to the topography and to the soils, as follows.

(a) The **flatter summit areas**, with their peaty, podzolic soils of the Ashen Soil Series (Findlay 1965) carry a Callunetum, a plant community dominated by Ling *Calluna vulgaris,* with Cross-leaved Heather *Erica tetralix,* occasional Bell Heather *E.cinerea*, Bilberry *Vaccinium myrtillus*, Purple Moor-grass *Molinia caerulea*, Wavy Hair-grass *Deschampsia flexuosa* and Sheep's Fescue *Festuca ovina.*

(b) On **water flow lines** and **water receiving sites,** Purple Moor-grass is dominant, with Cottongrass *Eriophorum angustifolium*, Deergrass *Trichophorum cespitosum*, Soft Rush *Juncus effusus*, Heath Rush *J. squarrosus*, Tormentil *Potentilla erecta*, Bedstraw *Galium saxatile*, Hair Moss *Polytrichum commune* and Bog Moss *Sphagnum* spp.

(c) There are occasional **spring head** and **valley bog** sites, in which the Bog Moss becomes dominant.

(d) The **better drained** and usually **steeper sites** with acid brown earth of the Maesbury Soil Series (Findlay, 1965) support a Pteridetum, a community dominated by Bracken *Pteridium aquilinum,* with Sheep's Fescue, Common Bent *Agrostis capillaris,* Bilberry, Bluebell *Hyacinthoides non-scripta* and Blackberry *Rubus* spp.

The head of the East Twin catchment is within the Callunetum while the actual peat samples were derived from a former spring-head site dominated by Bog Moss and Purple Moor-grass.

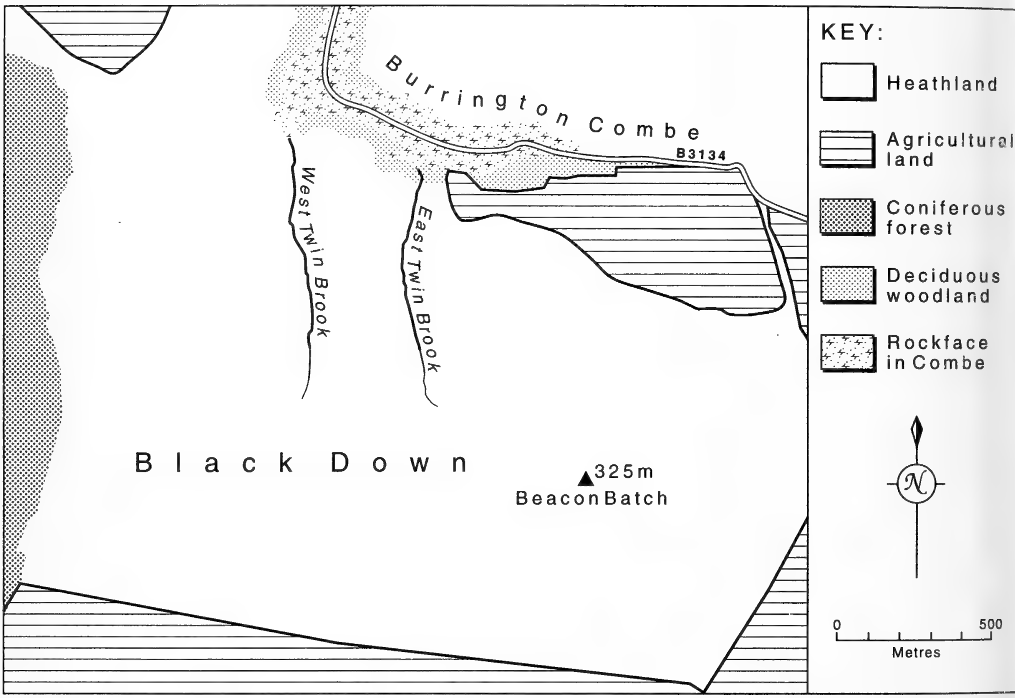


Figure 1. Blackdown, showing main land uses.

The plant communities of the heaths were originally described by Heath, Luckwill and Pullen (1937) and the sub-divisions they arrived at can still be recognized, in spite of changes in burning regime, recreational pressure and direct human interference. The severe fires of 1976 greatly damaged large areas of heather, and had the effect of encouraging the development of a flush of Purple Moor-grass and Wavy Hair-grass in the areas where the heather had previously been dominant. It took some twelve years before the heather began to overtop the grasses. At present (1996), the heather communities on the northern slopes are regaining dominance.

VEGETATION HISTORY

THE PEAT PROFILE

STRATIGRAPHY

The stratigraphy of the peat column was as follows:

Depth	*Nature*
0 - 14 cm	Moor-grass peat
14 - 82 cm	Moss peat with Moor-grass and Cottongrass.
82 -100 cm	Gravel band
100 -135 cm	Organo-mineral horizon with occasional gravel.
135 cm	Bed rock

The loss-on-ignition totals (a measure of the amount of organic material present) varied from 55% to 85% in the upper moor grass and moss peats, falling to 12-20% in the lower minerogenic horizon. The gravel band was not analysed. Relative proportions of sand and gravel are given on a subjective five-point scale in Figure 2, which summarises the results of the investigation.

RADIOCARBON DATES

Dr. Finlayson's samples were taken from the base of the peat column and from just above the gravel layer.They give a date of 370±90 BP (before the present) at the base of the peat column (sample ref. HAR 2685) and 210 ±70 BP immediately above the gravel layer (sample HAR 2415).

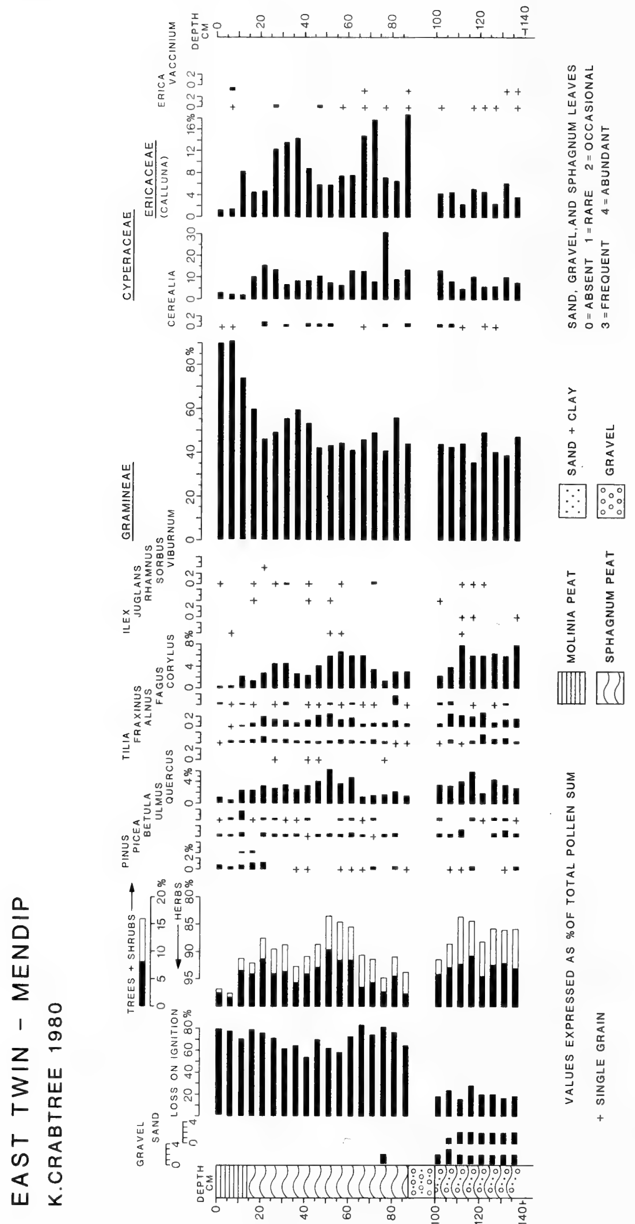
POLLEN ANALYSIS

Samples for pollen analysis were taken at 50 mm intervals of depth. Treatment was by standard procedures; with the upper peat samples not requiring treatment with hydrofluoric acid. Pollen was reasonably well preserved and fairly abundant throughout. The results are summarised in Figure 2.

Counts were made at each sample level, attempting to achieve counts in excess of 500 grains excluding spores. Actual numbers are recorded on the extreme right of the diagram (Figure 2b). The pollen data are expressed in terms of the total pollen sum excluding Pteridophyte (bracken) spores. No pollen from water plants was present.

The pollen flora is dominated by grasses (Gramineae); which rise to 90% of the total pollen sum in the upper two samples. This is in keeping with the present vegetation at the site, which is dominated by Moor-grass. In the lower organo-mineral horizons the grass falls to around 40-50% and sedges (Cyperaceae) make up around 15%.

The tree pollen values are generally low, being only 2% in the uppermost samples and usually 3-10% in the remainder of the section. Herb (non-tree) pollen values are never less than 84% and so it would appear that the record only covers the period during which vegetation has been very open. Within the individual tree pollen curves the main contribution is from Oak *Quercus* with from 1-6% of total pollen. The rise in pine *Pinus* at 20 cm and the record of spruce *Picea* at 15 cm and 10 cm all suggest the post–18th Century plantings of conifers on and around Mendip, while the continuous


EAST TWIN – MENDIP
K.CRABTREE 1980
DEPTH CM
GRAVEL
SAND
LOSS ON IGNITION
TREES + SHRUBS
HERBS
PINUS
PICEA
BETULA
ULMUS
QUERCUS
TILIA
FRAXINUS
ALNUS
FAGUS
CORYLUS
ILEX
JUGLANS
RHAMNUS
SORBUS
VIBURNUM
GRAMINEAE
CYPERACEAE
CEREALIA
ERICACEAE
(CALLUNA)
ERICA
VACCINIUM
VALUES EXPRESSED AS % OF TOTAL POLLEN SUM
+ SINGLE GRAIN
MOLINIA PEAT
SPHAGNUM PEAT
SAND + CLAY
GRAVEL
SAND, GRAVEL, AND SPHAGNUM LEAVES
0 = ABSENT 1 = RARE 2 = OCCASIONAL
3 = FREQUENT 4 = ABUNDANT

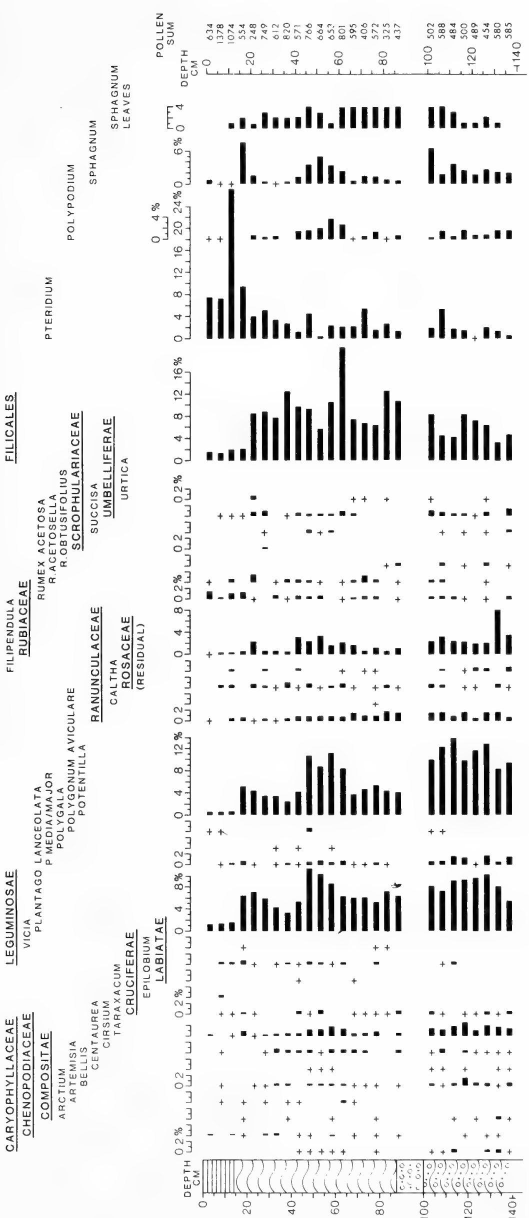


FIGURE 2. Pollen diagram from East Twin site. Pollen data expressed as a percentage of total pollen sum. Gravel, sand and sphagnum recorded on a subjective 0 – 5 scale. The percentage loss on ignition values indicate the organic nature of the peats and the dominant mineral component of the lower 50 cm. Herbaceous pollen represents 82 – 97% of the total pollen, and is dominated by grass (Graminae) pollen.

record of beech *Fagus* gives an indication that the whole section is later than the beginning of Godwin pollen zone VIII (Godwin, 1975), that is, the last 3,000 years. Ash *Fraxinus* is under-represented as usual, but the continuous trace of it is probably derived from the Burrington Combe ash woods. Amongst the shrubs, the presence of walnut *Juglans* pollen in the organo-mineral horizon suggests a date well within the historic period, as the first traces of walnut in Britain are usually Roman or later. Walnut is only rarely recorded and usually from the south, as it is a warmth-demanding species.

The fact that the pollen spectrum is dominated by pollen from the local, on-site vegetation may rather mask any changes of a more regional character; and in this case it is difficult to see much significance in some of the herbaceous pollen curves. Occasional grains of cereal (Cerealia) type plus a wide range of herbs associated with agriculture or at least with disturbed ground, such as Wormwood *Artemisia*, Fat Hen *Chenopodium*, cabbage family (Cruciferae), plantains *Plantago* spp., sorrel *Rumex* spp., and Nettle *Urtica*, may indicate continued agriculture on the adjacent limestone or limestone shale areas, with their better soils and lower elevation.

The profile can be divided into three sections.

(i) The uppermost 15 cm, with very high grass pollen values, high bracken spores, low sedge, low heather, low plantain, low Tormentil, low Bog Moss spores and low fern (Filicales) spores, would appear to relate to the present local Moor-grass vegetation with adjacent bracken–covered slopes. The peat is dominated by the remains of Moor-grass, with no Bog Moss leaves. The period includes the rise in pine and occasional spruce, so it probably covers the last 200 years at the most. The land has been common land, with occasional burning to control heather, certainly for the past 60 years and probably throughout the period since the enclosure of Mendip between 1770 and 1811.

(ii) From 20 cm depth down to the gravel band the peats show relatively high proportions of heather pollen, high sedge, higher plantain, Tormentil and fern, and fluctuating Bog Moss spore values (though high presence of Bog Moss leaf fragments), lower grass (*c.*50%) and Bracken spore values. Although the site was still dominated by Moor-grass, the Bog Moss and sedge pollen and the character of the peat suggest a bog condition, with Bog Moss and Cottongrass as well as the Purple Moor-grass. In the regional context the agricultural indicators are greater, suggesting either more intensive agriculture or agriculture closer to the site.

(iii) The lower samples below the gravel band have a somewhat intermediate pollen character, resembling that at *c.* 50 cm but generally with low heather values, and high Tormentil and Bedstraw values, almost certainly of local origin.

DISCUSSION

Comparable studies covering the last 400 years and tied by absolute or by radiocarbon dates are relatively rare in the literature. None are known from the Mendips. Curtis (1977) reported on buried soils in a similar topographic position on the North York

Moors. Periods of moorland instability were related to heather burning during the last 200 years. Areas of excessively burnt heather were prone to erosion, with subsequent deposition in the valley head sites and then renewed peat accumulation. These Yorkshire sites were dated by pollen and more particularly by archaeological evidence in the form of Victorian crockery buried by one such episode.

Tinsley (1976), working in the North Pennines, recorded a partly dated profile covering the last 1,000 years. The area was one of grouse moors but previously had been monastic land, and major vegetational changes could be related to major social and agricultural changes in the area. In sites such as North Gill Wood, Tinsley noted how tree pollen increased in the upper 20 cm, corresponding to late 19th and early 20th century plantings or to regeneration following the mid 19th century agricultural depression.

In parts of central Wales, Walker & Taylor (1976) also recorded a post–19th century rise in pine pollen, related to Forestry Commission plantings following the pushing of agricultural practices to their altitudinal limits during the Napoleonic Wars and their subsequent abandonment. Maltby & Crabtree (1977) saw similar pine and spruce pollen rises on Exmoor in the upper 4 cm as indicators of late 19th centuy plantings.

The radiocarbon dates allow a tentative calculation of accumulation rates as being approximately 2.5 mm per year below the gravel layer and 3.3 mm above. The rise of the pine and spruce would thus be dated to the 20th century plantings and the change to a grass–dominated community at 10 cm would be related to changes in management since 1950. However radiocarbon dates covering the last few hundred years are very difficult to calibrate with calendrical dates (Stuiver & Pearson, 1986) and such estimates of accumulation rates and of actual dates must be treated with caution.

The depositional event which produced the gravel layer is dated between 370 and 210 radiocarbon years ago. One-off major events have occurred on the Mendips; e.g. the July 1968 storm and floods (Hanwell & Newson, 1970) reactivated the lower courses of the Twin Brooks into Burrington Combe and produced gravel spreads. This was a precipitation–induced erosional and depositional event and seems to have left the section examined here unaffected.

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THE BIOLOGICAL IMPLICATIONS OF HEAVY METALS IN THE MENDIPS

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INTRODUCTION

The Mendips are well known for deposits of ores of certain heavy metals, particularly lead and zinc, and the history of the mines of Mendip has been extensively documented by Gough (1930 and subsequent editions). The Mendip Hills are thought to be the first area of Britain developed by the Romans for lead mining (Shepherd, 1993), although the rapidity of development – within six years of the Roman Conquest – suggests the take-over of an existing industry, dating back perhaps to the third century BC (Mason, 1954; Neale, 1971; Gilson, 1970). Roman culture made considerable use of lead, and production in Europe and Asia Minor during that time has been put at 80,000 tons per year. Shirahata *et al.* (1980) estimated that as much as 5% of the mined lead was lost to the atmosphere. This atmospheric output, due to inefficiencies in smelting technique, has been detected as Roman-age peaks of lead deposition in cores from Swedish lake sediments (Renberg *et al.*, 1994) and in peat from the Gordano Valley near Bristol (Martin, Coughtrey *et al.*, 1979). Metal mining activity, including the processing of earlier mine waste, continued on Mendip until 1908 and led to considerable contamination of the mining areas by heavy metals. We consider below the biological implications of this contamination with special reference to the effects on local plant communities.

GEOLOGY OF THE MENDIP HILLS

The Mendip Hills were formed during the Hercynian (or Variscan) Orogeny – a period of folding of the earth's crust that began in the Upper Carboniferous period (approximately 300 million years ago) and continued through the Permo-Triassic, also leading to the emplacement of the Lizard Complex in Cornwall and the Cornish granites. During the Triassic period (205-250 million years ago), debris derived from the folding of Carboniferous limestones was mixed with finer alluvium transported by flood waters, and consolidated to form the Dolomitic Conglomerate, the most important ore-bearing rock-type of the Mendips. Faulting – the fracture of rock bodies due to tectonic movement – followed the folding, forming the cracks and fissures within which the metal-bearing ore of the Central Mendip lead-zinc orefield now occurs.

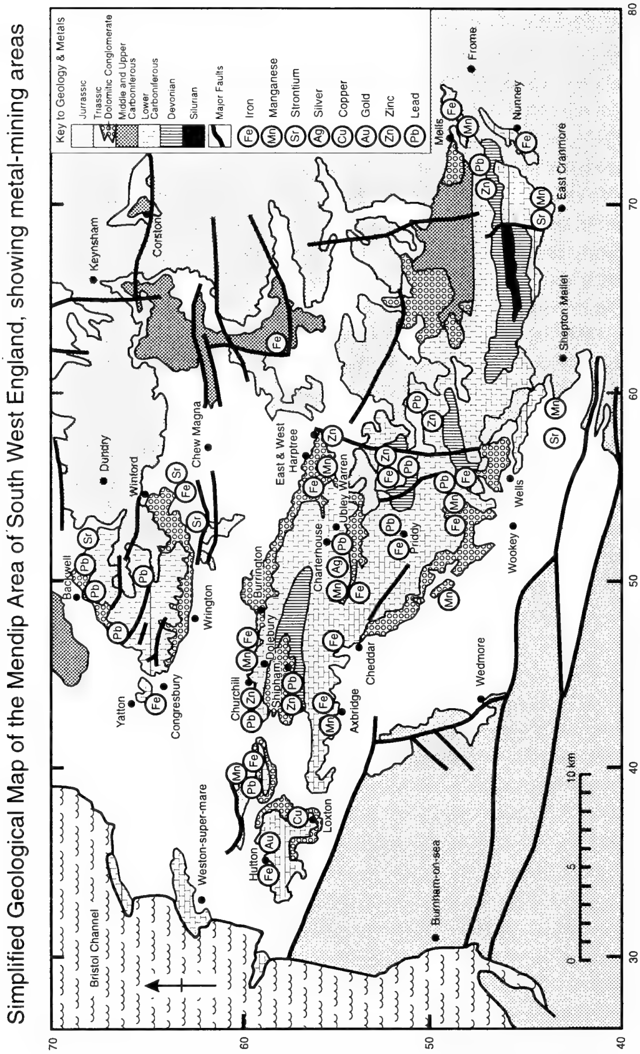

FIGURE 1. SIMPLIFIED GEOLOGICAL MAP OF THE MENDIPS

Metal-bearing ores resulted from the permeation of the Mendip fault system by water rich in dissolved metals, occurring at intervals over an estimated 100 million years (UpperTriassic to Upper Cretaceous period). The Mendip region was bordered at that time by deep-water basins, in which the burial, compaction and slow heating of earlier Carboniferous sediments had generated hot brines. As these moved toward the basin margins they became enriched in dissolved heavy metals which had been concentrated in the sediment by marine organisms and by deep-water precipitation (Alabaster, 1982). On reaching Mendip these metals were deposited in the fracture spaces as veins of ore, originally mainly as sulphides but now found as a variety of carbonates, sulphides and other compounds.

Mendip was mined for a wide range of metals (see Fig.1) with varying intensities up to 1908 (Gough 1930); although latterly the industry was oriented more toward the re-smelting of mine waste still rich in metals. The two major sites of lead mining activity have been Priddy and Charterhouse whilst smaller scale activities appear to have been widespread across the Mendips. At Shipham and Rowberrow smithsonite ($ZnCO_3$), a zinc ore also known as 'calamine', was extensively mined until 1859 (McQueen-Foord, 1986; Gough, 1930) for use in the ordnance industry. Other metals associated with lead and zinc have also been commercially important such as silver associated with lead at Charterhouse. The heavy metal cadmium is commonly present as a 'guest' element in zinc and lead ores and makes up approximately 3% of Mendip deposits of the mineral sphalerite (ZnS), although it was never commercially exploited there. Its industrial value as a rust-proofer, anti-friction agent, paint pigment, stabiliser in plastics manufacture and in alkaline storage batteries was not realised until 1939, after mining had ceased on Mendip, and it was viewed only as a contaminant and waste product of zinc bullion (Cocks & Walters, 1968). However, its persistence in the soil at Shipham where zinc mining was most intensive has later become important from a human health perspective.

SOILS AND SEDIMENTS

Soils are substantially derived from mineral material, often reflecting the chemical and physical properties of their parent rock. They represent an interface between living and non-living systems, form the basis of ecosystem nutrient cycling and are the rooting media for most terrestrial plants. Local interactions of climate, topography, geology, biota and land use lead to distinctive geographic variations in soil character, and thereby in their associated flora and fauna.

Figure 2. Last remaining lead-works chimney, at the Harptree works (from a photograph by Gilson, 1980)

This effect can be clearly seen in Mendip. The slow weathering of slag produced over a long history of mining and smelting has left a legacy of extensive areas of highly metal-contaminated soils overlying severely disturbed ground known locally as 'gruffy ground' (possibly derived from the Old English *'grafa'*, meaning ditch). This slag, seen particularly well at Priddy and Charterhouse, consists of two main types, of which the most abundant has a 'glassy' nature and is shiny black when broken, while the other is a softer and more porous type and appears more easily weathered (Brown, 1973). Both types contain considerable concentrations of metals, which can be up to 5% in the case of lead (see Table 1).

Water from the mining and smelting areas at Priddy drains into St Cuthbert's Swallet, and Stenner (1978a, b) has shown that sediments in St Cuthbert's stream, St Cuthbert's Pool and St Cuthbert's Swallet all contain high concentrations of lead and zinc. Sediments in the Wookey Hole cave system are similarly contaminated, a problem evident as long ago as 1861 when paper makers at Wookey obtained an injunction prohibiting the disposal into waterways of water used for washing ore at the St. Cuthbert's smelting works (Gilson, 1980).

TABLE 1. Concentrations of metals (µg/g dry weight) in soils from Mendip.

Data are also included for mine slag, and for 'clean' soils at Corston and the Avon Gorge. References: 1, Wigham *et al* (1980); 2, Hopkin *et al* (1986); 3, Brown (1973); 4, original, unpublished data. Note: 1 µg/g = 1 part per million (ppm); 10,000 ppm = 1%

Site	*Cadmium*	*Zinc*	*Lead*	*Copper*	*Ref.*
Shipham (zinc mining area)	563	71,400	6,860	80·1	1
Shipham (zinc mining area)	375	32,750	9,300	28·5	1
Shipham	406	24,900	6,480	75·2	2
Shipham	6 9	8,457	1,655	37	2
Burrington (non-mine site)	4·4	236	280	13·6	1
Charterhouse		1,800	4,350		3
Charterhouse		4,500	15,000		3
Charterhouse	14	15,000	62,150	78	4
Charterhouse	34	2,104	31,933	42	4
Charterhouse slag		1,900	14,000		3
Dolebury Warren (inside fort)	8	682	379	27	4
Dolebury Warren (hill base)	1	216	51	19	4
Ubley Warren (range of 93 values)		202 - 30,577	2,865 - 62,526		4
Clifton Down, Avon Gorge	16	2,223	1,668	44	4
Corston, near Bath	<0..2	124	54	15.4	4

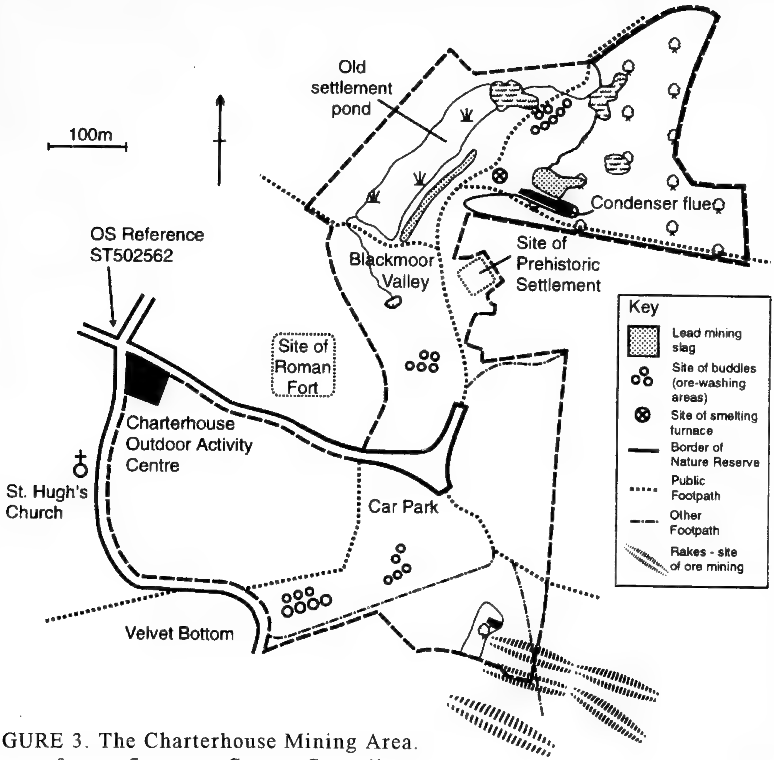

FIGURE 3. The Charterhouse Mining Area.
Redrawn from a Somerset County Council map.

Table 1 illustrates the range of concentrations of metals in soil associated with mining activites in the Mendips. For comparison, values from nominally uncontaminated, 'clean' sites at Corston near Bath and in the Avon Gorge in Bristol are also included. The figures show the local variation both in the level of metal contamination and in the particular metal assemblage at any one site: Charterhouse and Ubley Warren are very highly contaminated by lead and usually also by zinc, whereas the soils at Shipham are most highly contaminated by zinc and cadmium and to a lesser degree by lead. Burrington, a non-mining area, shows very much lower concentrations, although cadmium, zinc and lead levels are still higher than in soils regarded as uncontaminated.

THE IMPLICATIONS FOR PLANT GROWTH

High concentrations of heavy metals in the soil can seriously inhibit plant growth. For example, conifers planted by the Forestry Commission on Mendip after mining ceased showed signs of chlorosis (yellowing) indicative of lead toxicity (Foster, 1970). As well as having very high concentrations of heavy metals, the soils of the abandoned Mendip mine sites show poor water retention due to rapid drainage, and low amounts of major nutrients such as nitrates and phosphates. Together, the physiological demands of drought conditions (caused by poor soil water retention), low nutrients and very high soil metal content create an environment hostile to many plant species which might otherwise have colonised such a newly available open space. As a result some areas remain only sparsely populated by higher plants, and in turn this lack of growth has impeded soil development, which is consequently exceedingly slow.

However, the Mendip mine sites are far from being barren wastelands! The intervening years since the start of mining have produced sites with a flora so specialized and unique that at Charterhouse it merits the status of a Site of Special Scientific Interest. What has occurred here is a rapid process of Darwinian Natural Selection. Where the inability to tolerate high metal concentrations in the soil means death, the selection process is rapid, and so the plant communities found on metal-rich sites on Mendip contain a high proportion of metal-tolerant species. Species sensitive to the high metal levels will suffer impaired growth and will eventually disappear from the site, leaving those able to withstand the stress to exploit their competitive advantage in a relatively unpopulated area.

Species showing tolerance to heavy metals in the soil occur in all plant groups, from lichens and mosses to flowering plants. Higher plant species showing metal tolerance fall into two groups - **metal tolerant ecotypes**, in which only some individuals of a species are tolerant, and **metallophytes**, in which all individuals are tolerant.

METAL-TOLERANT ECOTYPES

These are generally species characteristic of the region, and can be found growing both on and off metalliferous soils. What marks them out from most plant species is that the 'normal' population includes *some* individuals able to survive on high-metal soils.

If seeds from this population are distributed over a newly exposed mine site, those which have inherited a capacity for metal-tolerance will be selected, and may flourish to produce a local metal-tolerant 'race' or *ecotype.* Common species which have produced tolerant ecotypes on Mendip include *Holcus lanatus* (Yorkshire Fog) and *Plantago lanceolata* (Ribwort Plantain). Elsewhere in Britain, the grasses *Festuca*

ovina (Sheep's-fescue) and *Agrostis capillaris* (Common Bent) have developed high tolerance to metals on mining sites over a wide geographical range.

METALLOPHYTE SPECIES

Unlike most species, metallophytes are naturally or *constitutively* tolerant to high soil metal levels, and so they can colonize metalliferous mine spoil without the need for selection from a wider, largely non-tolerant, population. It has been suggested that these species were once more widely distributed, but that through competition from more vigorous species they are now largely confined to more open communities where this unusual quality gives them a competitive advantage.

In Britain, the metallophyte species of higher plants are *Thlaspi caerulescens* (Alpine Penny-cress); *Minuartia verna* (Spring Sandwort); *Silene uniflora* (Sea Campion) and in some areas but not apparently on Mendip, *Armeria maritima* (Thrift). The most abundant and widespread metallophyte on Mendip appears to be *T. caerulescens* (formerly *T. alpestre*). *Minuartia verna* is surprisingly scarce except at Priddy, although in the lead mining areas of Derbyshire and Yorkshire it is the most abundant metallophyte.

Although known from inland mine sites, *A. maritima* and *S. uniflora* (formerly *S. maritima*) occur mainly in maritime habitats, whereas *M. verna* and *T. caerulescens* always occur on metal-rich sites. The reliable association of certain metallophytes with particular metals in the soil has enabled them on occasion to be successfully used as indicators in geobotanical and biogeochemical prospecting. It is interesting to note that although White (1912) associated the occurrence of *M. verna* with old spoil heaps of lead mines, he considered its association with lead mines in other parts of the country as "a little curious". He goes on to say:

> "I do not find any reason suggested for this preference other than the rather shallow supposition that the plant has a peculiar power of resisting metal poisons, and so can flourish on the refuse of mines where other vegetation is unable to subsist. Should the idea have an actual foundation it seems that another Carophyll might take honours as a poison resister."

The other member of the plant family Caryophyllaceae referred to is *Cerastium triviale* (*C. fontanum*, or Common Mouse-ear) which he notes occurs in special abundance on the debris from lead mines.

SPECIES NOT METAL-TOLERANT

Metals are distributed very unevenly within the soil of a mine site, so it is usually also possible to find species not known for their ability to develop tolerance, which are exploiting pockets of low-metal soil or spreading their roots in a surface layer rich in moss or humus of low metal content. These species may be thought of as adopting a strategy of *avoidance* of heavy metals.

LICHENS AND MOSSES

The lichen flora of the lead mining area of Charterhouse has been described by Brown (1973); an assemblage of species found on the lead slag at Charterhouse that is repeated on lead slag at Priddy and East Harptree, and has similarities to those recorded on old zinc mines in Belgium. Moss species too have been selected on the basis of their tolerance of metals. In 1970 Appleyard noted that:

> "Abandoned lead workings are common on Mendip, the most noticeable being at Charterhouse and to the east of Priddy. In both these localities *Grimmia doniana* grows on the slag from the lead workings. It is not known elsewhere in North Somerset."

Table 2 gives concentrations of metals found in a variety of lichen and moss species from Mendip.

TABLE 2. Concentrations (µg/g dry weight) of zinc and lead in species of mosses and lichens from Mendip sites. References: 1, original, unpublished data; 2, Brown (1973).

Species	*Site*	*Zinc*	*Lead*	*Reference*
Hypnum cupressiforme (Moss)	Ubley Warren	84-113	121-757	1
Pleurozium schreberi (Moss)	Ubley Warren	35-187	18-372	1
Rhytidiadelphus triquetrus (Moss)	Ubley Warren	75	140	1
Grimmia doniana (Moss)	Charterhouse	4,735		2
Ceratodon purpureus (Moss)	Charterhouse	960	4,340	2
Stereocaulon pileatum (Lichen)	Charterhouse	816	4,610	2
Cladonia subulata (Lichen)	Charterhouse	298	1,310	2

MECHANISMS OF METAL TOLERANCE IN HIGHER PLANTS

Table 3 shows the levels of cadmium, zinc and lead found in plants growing on polluted Mendip sites. Detailed studies of plants and their associated soils at Shipham have been published by Matthews and Thornton (1980). Whilst the species listed share a manifest ability to survive on metalliferous soils, they clearly do not show the same degree of metal uptake (compare, for example, the tissue metal content of *T. caerulescens* and *P. pratensis* in the table). Research has shown that species vary considerably in the extent to which their roots take up metal ions from the soil solution and to which that metal is then distributed between different plant parts. Some maintain a tissue concentration below that of the soil in which they are rooted, whilst in others metal uptake appears unrestricted and can considerably exceed soil concentrations.

TABLE 3. Concentrations of metals (μg/g dry weight) in a range of plant species from mining areas of Mendip. Source: original, unpublished data. The two species shown in bold type are referred to in the text.

Species	*Site*	*Cadmium*	*Zinc*	*Lead*
Pteridophytes:				
Dryopteris filix-mas (Male Fern)	Charterhouse	5	100	68
Equisetum fluviatile (Water Horsetail)	Charterhouse	6·8	209	24
Dicotyledons:				
Thlaspi caerulescens (Alpine Penny-cress)	Shipham	70	2,400	740
***Thlaspi caerulescens* (Alpine Penny-cress)**	**Charterhouse**	**10**	7,233	**200**
Silene uniflora (Sea Campion)	Charterhouse	<5	344	61
Calluna vulgaris (Heather)	Ubley Warren		22-53	3-27
Sedum acre (Biting Stonecrop)	Charterhouse	<5	313	358
Monocotyledons:				
Typha latifolia (Bulrush)	Charterhouse	<5	81	45
***Poa pratensis* (Smooth Meadow-grass)**	**Charterhouse**	**<0.2**	**106**	**56**
Alopecurus pratensis (Meadow Foxtail)	Charterhouse	0.4	284	51
Festuca ovina (Sheep's Fescue)	Ubley Warren		14-113	1-182
Agrostis capillaris (Common Bent)	Ubley Warren		5 -139	2-98
Holcus lanatus (Yorkshire Fog)	Ubley Warren		30-86	16-127
Holcus lanatus (Yorkshire fog)	Charterhouse	5	156	93
Cynosurus cristatus (Dog's Tails)	Ubley Warren		49-97	41-77
Dactylis glomerata (Cock's Foot)	Ubley Warren		29-59	30-40

Even within the Mendip metallophytes, *M. verna* and *T. caerulescens* accumulate high concentrations of lead, zinc and cadmium, whilst *S. uniflora* contains relatively low concentrations similar to those in species not noted for their association with metal mining areas. *T.caerulescens* has been reported containing a staggering 33,000 μg/g (3.3%) of cadmium (Brown *et al.,* 1995) and is one amongst a small and extraordinary group of plant species known as *hyperaccumulators.*

There is currently much interest in species that have the ability to accumulate high concentrations of metals, as harvesting crops of such species could remove substantial amounts of metals from contaminated soils, rendering them less toxic. At present most hyperaccumulator plants in the temperate world are also rather small in size and so the amount of metal removed from the soil is limited. Attempts to induce species of larger plants to become hyperaccumulating, by chemical or genetic manipulation, are currently underway.

No single physiological mechanism by which plants achieve their metal tolerance has been found; instead it appears that a variety of effective strategies exist. However, three processes seem to be fundamental: the uptake of metal from the soil; its transport and distribution within the plant; and the resistance of plant tissues to damage from metal toxicity (their internal tolerance). Many non-tolerant plants show unrestricted metal uptake, but are unable to de-toxify the metal ions once incorporated into their tissues and are killed as a consequence. In contrast, tolerant ecotypes often show a considerable capacity to restrict both the uptake of metal and then its transport from root to shoot tissue. The particular mechanisms and level of tolerance employed by a plant are determined not only by the adaptive limitations of the species concerned, but also by the metal or metals present in the soil, and the amount that is dissolved in the soil solution. This second factor, which is referred to as a metal's *availability*, is determined by chemical and physical characteristics of the soil, such as pH. It is towards a greater understanding of these biological, physical and chemical interactions that much of the work on plant metal tolerance at Bristol University, and elsewhere, has been directed.

QUANTIFYING METAL TOLERANCE IN PLANTS

Various experimental techniques exist for quantifying the level of tolerance a plant or population may have to a particular metal. These involve measuring growth responses when the plant is grown in substrates having a known concentration of the metal in question, where tolerant individuals will grow better than non-tolerant plants. One of the simplest ways to compare the tolerance of populations from, for instance, a contaminated mine-site and a non-contaminated site, is to measure the increase in root length over a given period of time when grown in nutrient solution. Plants from each population are grown in two solutions: - one *with* and one *without* the metal of interest. Comparison of the increase in root length in the two solutions provides a ratio which can be used as a simple and reliable measure of tolerance termed the *Tolerance Index* (TI), defined as the ratio

$$\frac{\text{Increase in root length in solution of known metal concentration}}{\text{Increase in root length in control solution with no metal}}$$

The greater the value of the TI, the better the performance of the plant in the metal solution. The technique can also be used for other measurable growth characteristics, such as plant weight.

The grass *Holcus lanatus* has been much used by workers in Bristol to study such effects. Plants collected from sites with a high soil cadmium concentration, such as Shipham on Mendip, were found to be better adapted to cadmium in the test solution (Wigham *et al.*, 1980). For metal-tolerant ecotypes such as *H. lanatus*, the particular metals to which an individual is tolerant and the range of concentrations over which that tolerance operates before a toxic dose is reached, usually reflect the metal content of the soil in which the plant had been growing. For metallophyte species however, their tolerance is less determined by local soil characteristics but instead tends to cover a greater range of metals and concentrations.

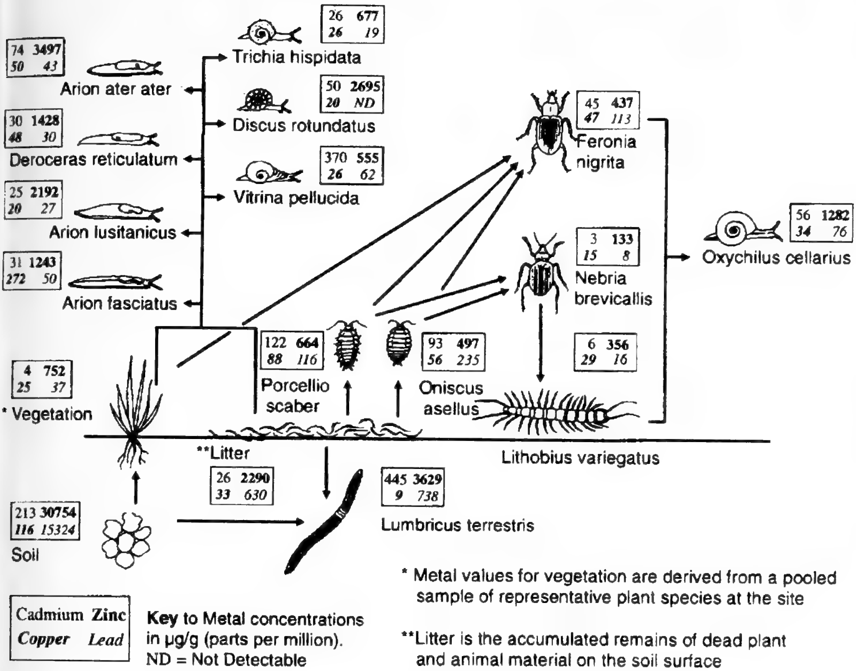

FIGURE 5. Metal content for some samples of soil, vegetation and invertebrates at Shipham, and their proposed food-web relationships

FOOD WEB RELATIONSHIPS

In addition to plants and animals, microbial populations are crucial to the functioning of an ecosystem. They are responsible for a diverse range of activities, such as nitrogen fixation and the breaking down of organic matter. Perturbations to these communities could well have profound consequences for the local cycling of essential nutrients. Microbes (bacteria and fungi) sampled from soils and plants in metal-contaminated environments have often been shown to have evolved metal-tolerance (Olson & Thornton, 1982).

Neither cadmium nor lead has any known biological function, and both can accumulate in living systems to levels where they become poisons. Copper and zinc are **micronutrients** – they are essential in small amounts for the healthy growth of plants and animals. However, for any micronutrient element the difference between its nutritive function and its toxicity to both plants and animals is only a matter of concentration

(Shacklette *et al.*, 1978), and indeed zinc and often copper are present in the soils of Mendip mine sites in toxic concentrations. Animals that feed on the plants or animals of such areas are in turn susceptible to the potentially harmful effects of a metal-enriched diet. Fig. 5 is a simplified food web, based on data collected from Shipham, which shows how raised metal concentrations can be passed on through a food chain.

INVERTEBRATES

In woodland at Avonmouth near Bristol which has suffered pollution by air-borne zinc, cadmium, lead and copper from a local smelting works, studies suggested that the structure of the invertebrate community had altered in response to the soil metal load. The large reduction in the numbers of woodlice, millipedes and earthworms compared with a similar but unpolluted woodland 25km away was consistent with high soil metals levels acting to exclude more metal-sensitive species (Martin & Bullock, 1984).

TABLE 4. Concentrations of metals (μg/g dry weight) in two species of woodlice (*Oniscus asellus* and *Porcellio scaber*) collected from the Mendips.

Data show mean values for hepatopancreas and for whole animal. '%' = total amount of metal as a percentage of the weight of the organ or body (10,000 μg/g = 1.0%). References: 1 - data from Hopkin & Martin (1984); 2 - data from Hopkin & Martin (1982a); 3 - original, unpublished data; (a), (b), (c), (d) & (e) indicate data from same animals

Species	*Site*	*Cadmium*	*Zinc*	*Lead*	*Copper*	%	*Ref*
Hepatopancreas:							
O. asellus	Shipham	7,735	1,724	8,032	2,219	4·58	1
O. asellus	Shipham	3,411	756	7,703	2,434	2.41	1
O.asellus	Charterhouse	2,530	3,008	1,597	6,368	2.62	1
O. asellus	Shipham (a)	1,617	4,665	2,877	397	0·96	2
O. asellus	Charterhouse (b)	904	1,531	1,474	1,857	1·18	2
O. asellus	DoleburyWarren(c)	1,544	2,476	2,266	1,077	0·74	2
P. scaber	Tyning's Farm (d)	59	4,289	9,699	2,650	1·67	3
P. scaber	Corston (clean) (e)	37	2,649	2	1,224	0·39	3
Whole animal:							
O. asellus	Shipham (a)	139	29.11	266	4.7	0·10	2
O. asellus	Charterhouse (b)	40·3	131	464	7.54	0·08	2
O. asellus	Dolebury Warren(c)	80	178	116	6.57	0·05	3
P. scaber	Tyning's Farm (d)	6	111	64·5	16.95	0·07	3
P. scaber	Corston (clean) (e)	3·4	255	0	9.3	< 0·04	3

Woodlice, snails and slugs all accumulate high concentrations of metals within their soft tissues. Woodlice from the Mendips have been analysed as part of wider studies of how woodlice cope with high concentrations of metals, and of the use of various organisms as biological monitors of environmental contamination (Hopkin *et al*, 1986).

Woodlice, in particular, accumulate lead, zinc, copper and cadmium in one relatively small organ, known as the hepatopancreas (Hopkin & Martin, 1982a). This organ forms only about 5% of the animal's total weight but it contains more than 75% of the zinc, 95% of the cadmium, 80% of the lead and 85% of the copper in the body (Hopkin & Martin, 1984).

Table 4 shows data for concentrations of metals in the hepatopancreas and in the whole animal of the two commonest woodlice collected from four sites on Mendip and also from one 'clean' site. For animals collected from mining areas, several percent (up to 4.6%) of the weight of the hepatopancreas is made up of the four metals. It has been postulated that storage of metals in the hepatopancreas represents a detoxifying mechanism. Hopkin & Martin (1982b and 1984) found that when the concentrations of zinc and cadmium exceeded 1.5% and 0.5% respectively the animals became moribund and were unable to move rapidly when stimulated. In these cases it was assumed that the detoxification mechanism had been overloaded.

VERTEBRATES AND THE IMPLICATIONS FOR HUMAN HEALTH

As far as the authors are aware comparatively little has been published on the effect of heavy metals on the vertebrate animals of Mendip. However, a study by Avery *et al.* (1983) of the concentrations of lead, zinc, cadmium and copper in lizards (*Lacerta vivipara*) at Charterhouse (see also Avery in this volume), showed that despite concentrations of lead and zinc being high in soils and moderately high in potential food materials, the concentrations in lizards were unexceptional apart from cadmium - for which concentrations were higher than at control sites.

THE SHIPHAM CADMIUM SCARE

Cadmium, lead, copper and zinc are all trace elements known to have caused major human health problems in several parts of the world (Hutton, 1987). Cadmium, in particular, is a highly toxic metal which accumulates throughout life in the kidneys and liver of mammals exposed to it (Hutton 1987; Kobayashi, 1978). So when, in 1977, a nationwide geochemical survey of stream sediments undertaken by Imperial College, London, revealed uniquely high concentrations of cadmium and zinc in the soils in and around Shipham, concern was understandably focussed on the health of the local residents (Litten 1986; Inskip *et al*, 1982; Thomas, 1980).

There followed an extensive study of the village, including sampling and analysis of soil, air, water, house-dust, vegetables, milk, blood, urine and hair; plus detailed questionnaires concerning the health and dietary habits of most of the 1,092 residents of Shipham and its neighbouring villages Rowberrow and Star (Marples & Thornton, 1977; Matthews & Thornton, 1980, 1982; Thornton *et al.*, 1980; Inskip *et al.*,1982; Olson & Thornton, 1982). Despite local soil cadmium levels being the highest recorded in Britain and possibly in the world (Thornton *et al*, 1980), this comprehensive studyd no significant health effects on the local population. The Shipham Survey Commitee's final report in December 1980 (Thomas, 1980) recommended only that the villagers limit their consumption of home-grown vegetables, minimize dust by grassing over redundant flowerbeds and exercise vigilance over the ingestion of soil by children.

The mining in Shipham had been mainly for zinc ores in the form of 'calamine' or smithsonite, and the abnormally high soil concentrations of cadmium (20-800 ppm) and zinc (50,000 ppm) were associated with these old workings. It was the far greater diversity of their diet that saved the residents of Shipham from cadmium poisoning like that seen in villages downstream of Japan's largest zinc mine in the 1960s. The subsistence farmers living on the banks of the Jinzu river in Japan drank, and irrigated their crops exclusively with, mine-polluted water (Kobayashi, 1978). In Shipham, however, the very mining activity that so enriched the soil in cadmium also disturbed the ground so much that it was left unsuitable for cultivation. Also, as elsewhere in the UK, most of the local population's food originates outside the area, so that the cadmium intake in the diet remains well below recommended levels. Inskip *et al.* (1982) assessed the causes of death of Shipham residents over a 40-year period and concluded that "...if cadmium contamination has any effect on the mortality pattern in Shipham it is slight and does not present a serious health hazard to residents".

It seems likely however, considering historical mining and smelting practices, that the residents of Mendip at one time suffered considerable occupational and environmental exposure to high doses of heavy metals and the associated symptoms of cadmium and lead poisoning. The Reverend Joseph Glanvil, vicar of Frome, recorded in 1668 that smoke from the fires used to fracture ore-bearing rock was known to kill miners returning too soon to the mines. He also noted that 'flight' (fine airborne particles given off during smelting) was used in homes to kill mice and rats; that where it settled on grazing land it poisoned the cattle, and that where it fell into streams also carrying ore-washing water, cattle were killed up to three miles away (Coysh, 1962). Many Mendip villages lie close to mining areas, and in Shipham houses were even built directly over mine shafts to safeguard the family's claim to mining rights. The effect on the health of the local human population can have been no less profound than for their livestock.

SUMMARY

Heavy metal pollution generally occurs as a result of human activity concentrating and redistributing naturally occurring elements within the land, air or water. On Mendip, the long period of mining which produced a severely polluted environment and left a metal-rich soil, has ultimately yielded a fascinating and unusual flora, and an illustration of evolution on an observeable timescale. Studies aimed at unravelling the complex processes involved in metal tolerance help us towards a greater understanding of the biological activity and environmental impact of these potentially toxic metals, and ultimately to predict, restore and limit future damage both to the environment and to human health.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the use of unpublished data collected by a number of undergraduates during project work supervised by the first author, also Tim Colborn for his invaluable help in computerising the maps and food web diagram, and Chris Alabaster for his kind permission to reproduce the location of mining sites in Figure 1.

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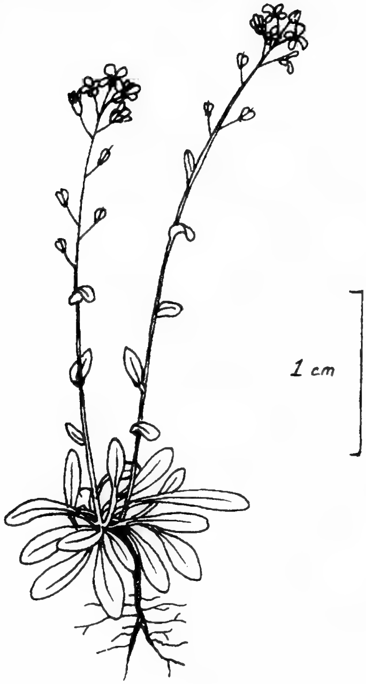

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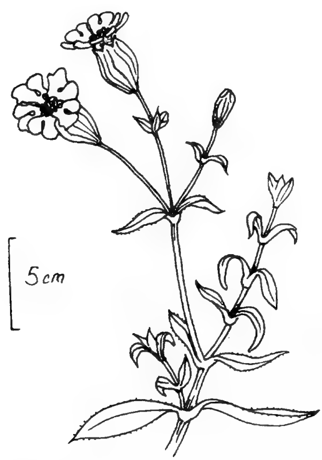

Silene uniflora (Sea Campion)

Proceedings of the Bristol Naturalists' Society (1995), **55**:113–134

THE GEOLOGICAL HISTORY OF THE MENDIP HILLS AND THEIR MARGINS

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ABSTRACT

The Mendip Hills form a well-defined upland massif in which rocks of various lithologies and ages, from Silurian to Recent, are exposed. At least three distinct episodes of marine deposition are represented, in the Silurian, early Carboniferous and Jurassic, punctuated by periods of non-marine deposition during the Devonian, late Carboniferous and Triassic, and of intense erosion during the Permian and Tertiary. The earliest earth movements to have left evidence in the Mendip Hills were the later stages of the Caledonian orogeny, though this affected only the oldest, Silurian, rocks of Mendip. The familiar 'whaleback' structure of the Mendip Hills, comprising four en-echelon periclines overthrust to the ENE, developed during the Hercynian earth movements in Permian times. Finally, regional extension during Triassic and Jurassic times affected deposition of these strata and was associated with several phases of mineralisation and fracturing of earlier rocks. The general form of the Mendip Hills developed by erosion during Permian and Triassic times before being submerged beneath a considerable thickness of Jurassic and later sediment. Exhumation of this ancient landscape commenced during Tertiary times but the Mendip massif in its present form has been exposed for only one or two million years.

INTRODUCTION

The Mendip Hills form a discrete geological entity, an elongate upland inlier of predominantly Palaeozoic rocks projecting above the Mesozoic lowlands to north and south and bounded to the west by the Bristol Channel and to the east by the southern end of the Cotswold Hills. Although the present boundaries are clearly defined, this has not always been so. Earlier in their geological history what is now the Mendip Hills comprised only part of a much larger area subject to particular environmental conditions or geological processes. Consequently the geological history of the Mendip Hills cannot be understood in isolation but must take into account the wider regional setting.

Description of the geology of the Mendip Hills can be approached from two main angles. The first considers the major rock units and the environments in which they were deposited. The second considers how these various rocks have responded to subsequent events, such as large scale earth movements or erosion, to produce the Mendip Hills as we see them today. These two aspects are, of course, closely interlinked. Sediment deposition is often determined by large-scale earth movements in the form of regional subsidence or uplift. Conversely, the distribution of different rock types through the stratigraphic succession has profoundly influenced both the way in which these rocks have deformed during subsequent earth movements and how they have eroded subsequently.

The geological map of Figure 1 is intended merely to provide an overview of the major geological features of the Mendip Hills. For more detailed information on locations and geological features reference should be made to the appropriate Ordnance Survey maps: 1:25,000 Explorer Series 4 and 5, Mendip Hills West and East, and to British Geological Survey maps (Sheets 280 and 281, Wells and Frome, and Bristol District Special Sheet).

STRATIGRAPHY AND PALAEOENVIRONMENTS IN THE MENDIPS

The strata preserved in the Mendip Hills record about 425 million years of Earth history, rather less than 10% of the total time that the Earth has existed. Even within this period the record is far from complete; major gaps exist which represent millions of years while other, equally substantial, parts of the succession are represented only by relatively tiny volumes of sediment. Even for those parts of the geological column which are well represented the extent of exposure of any rock unit is related very much to lithology. Harder units, such as limestones, form steep slopes which weather to produce only thin soils while softer rocks, such as clays and shales, form lower ground blanketed by thicker, well-vegetated soils. Furthermore, the numerous quarries which dot the surface of the Mendips all exploit the harder lithologies. Hence the geologist has here a very patchy record from which to interpret past environments and processes.

THE SILURIAN SYSTEM

The oldest rocks exposed in the Mendips are of mid-Silurian age, attributable to the Wenlock Series (428–421 million years ago). They outcrop only in a single elongated inlier in the eastern Mendips, extending from Beacon Hill eastwards for more than 5 km to Downhead but never more than 600m wide (Fig. 1). There are few natural exposures but the succession has been well documented from quarries and smaller temporary excavations (Hancock 1982). The best and most extensive sections can be seen in the actively working Moon's Hill Quarry, but permission must be sought from the quarry management to enter this site.

The lowest part of the Silurian succession comprises more than 95m of mudstones and siltstones, with brachiopods and other shelly fossils present at several levels. Further fossiliferous mudstones and tuffs (volcanic ash falls) occur about 100m

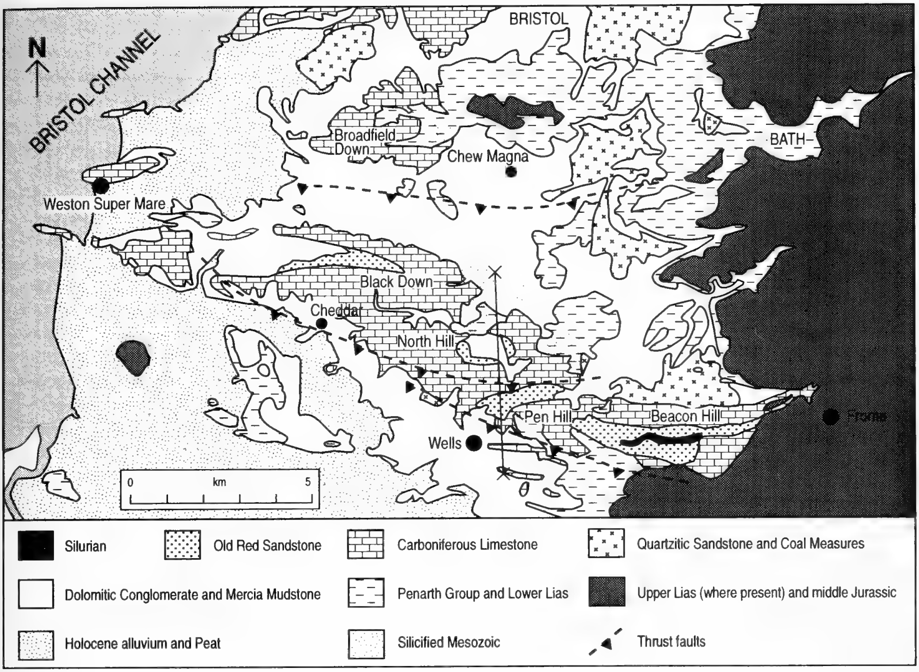

FIGURE 1. Simplified geological map of the Mendip Hills and surrounding area.
X-X marks the line of the section shown in Figure 4.

higher, but otherwise the succession, some 650m thick in total, is dominated by extrusive volcanic and volcaniclastic rocks (Fig. 2). The sequence of fossils in the lower part of the succession indicates deposition in a progressively shallowing sea, with higher faunas suggesting a more restricted inshore environment. Above are units with cross-bedding and grading of some of the tuffs, indicating deposition in water, but there are no fossils to indicate marine conditions. A reddened, oxidised top to one of the higher lava flows suggests subaerial exposure at times. Overall, the Silurian succession shows clear evidence of shallowing marine conditions leading to emergence in which the volcanic rocks were perhaps deposited in a landscape of shallow pools and flowing streams. This episode of shallowing appears unrelated to sea-level changes documented on a wider scale but has been attributed to local uplift associated directly with the volcanism.

THE OLD RED SANDSTONE

The Devonian System is represented here by the Old Red Sandstone. Where the base is seen in the eastern Mendips it overlies the Silurian succession with an angular unconformity representing a gap of at least 57 million years. To what extent this gap was due to non-deposition or to post-Wenlock erosion cannot be ascertained. Inland the Old Red Sandstone is very poorly exposed, so understandably most work has concentrated on the superb coastal sections of the Portishead region to the north (Pick 1964; Williams & Hancock, 1977). At Portishead three distinct stratigraphic units can be recognized (Fig. 2).

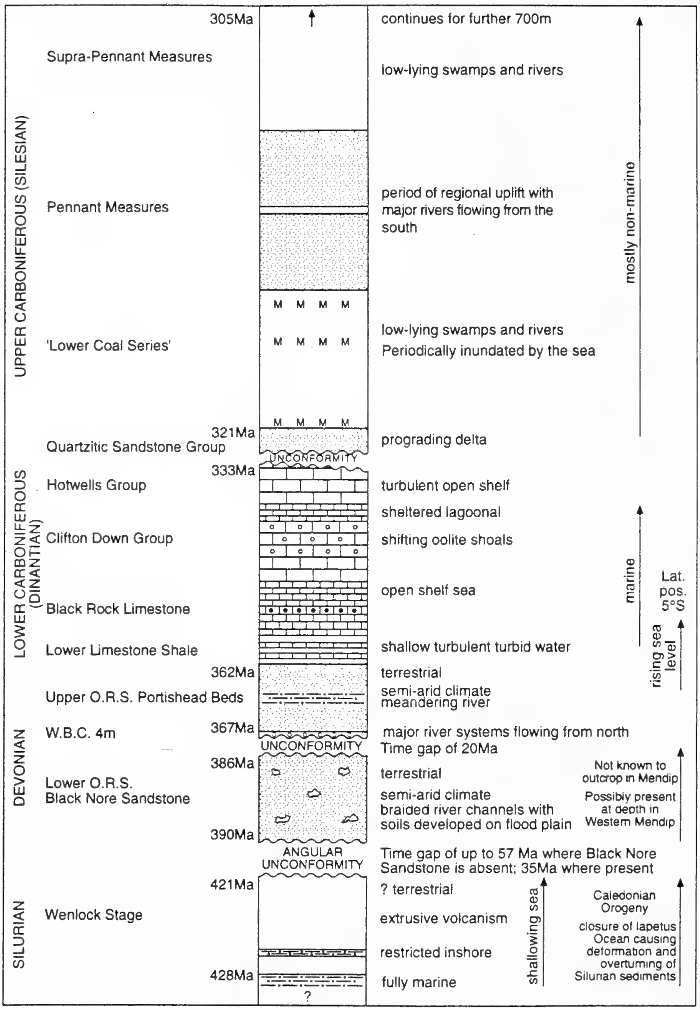

FIGURE 2. Summary geological column of the Palaeozoic succession in the Mendip Hills. For key to symbols see fig 3, opposite.

At the base the Black Nore Sandstone comprises red, often cross-bedded, sandstones with abundant nodules of calcrete, a type of limestone which forms in semi-arid soils.

It has been assigned tentatively to the Lower Old Red Sandstone (Lower Devonian, Emsian Stage; 390 - 386 Ma), although no fossils have been found to confirm this. A marked unconformity, representing perhaps 20 million years, separates it from the four metres thickness of the Woodhill Bay Conglomerate, containing pebbles of a wide range of lithologies, which in turn is overlain by the Portishead Beds of the Upper Old Red Sandstone (Upper Devonian, Famennian Stage; 367-362 Ma). These comprise red

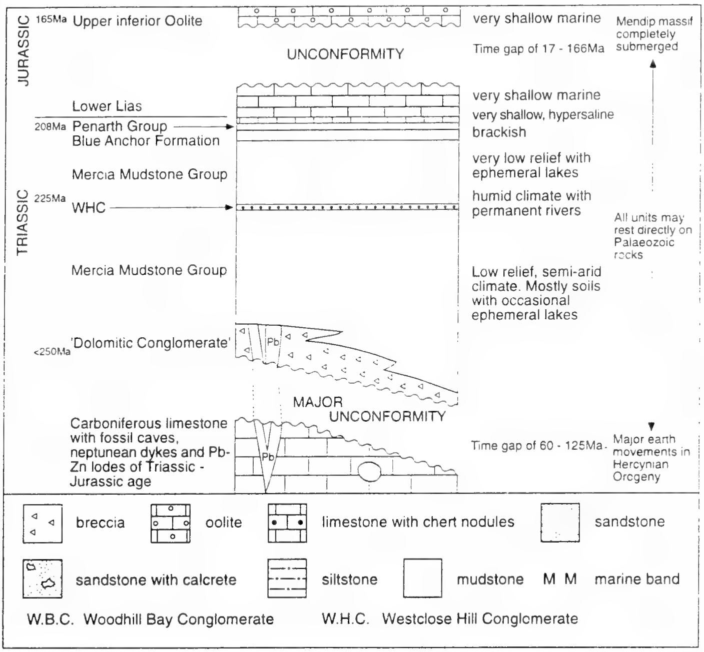

FIGURE 3. Summary geological column of the Mesozoic succession in the Mendip Hills.

and green sandstones, often pebbly or cross-bedded, with numerous siltstone units, though lacking the calcrete nodules typical of the Black Nore Sandstone. Some of the siltstone units contain fish remains.

Within the Mendip Hills only the Portishead Beds outcrop, where they occur in the cores of all four periclines: Black Down, North Hill, Pen Hill and Beacon Hill. It has been suggested that Lower Old Red Sandstone may exist in the western Mendips where the Portishead Beds are at least 500 m thick on Black Down without the base being seen (Kellaway and Welch 1993). However, on Beacon Hill to the east the Portishead Beds are only about 400 m thick and rest directly upon Silurian volcanics (Green and Welch 1965). Poor exposures of the upper part of the Portishead Beds in Burrington Combe have yielded fish remains from one horizon and also plant microfossils which indicate that the uppermost beds are, in fact, of early Carboniferous age.

The entire Old Red Sandstone succession shows clear evidence for deposition in a non-marine environment, with the red coloration of many of the units indicating frequent subaerial exposure. The Black Nore Sandstone was deposited in an alluvial environment, as indicated by the cross-bedding and channel fills. The calcrete nodules formed in soils away from the main active river channels and indicate that the climate was semi-arid. The Woodhill Bay Conglomerate was deposited in a much more swiftly-flowing river able to transport quite large pebbles over a considerable distance, with some of the clasts having originated in North Wales (Wallis 1927). The Portishead Beds were also deposited in an alluvial environment but the greater lithological variation, compared with the Black Nore Sandstone, suggests a more sinuous or meandering river system with pebbly and cross-bedded sandstones channel fills and the finer siltstone overbank or floodplain deposits.

THE CARBONIFEROUS LIMESTONE

Of all of the geological column it is the Carboniferous Limestone, deposited between 362 and 330 million years ago, which dominates the Mendip landscape. This has been true not only for the last two million years but for a significant proportion of the total time which has elapsed since the end of the Carboniferous. In simple terms the Carboniferous Limestone can be said to have been deposited in a warm, shallow sea. However, to understand fully the environments in which the Mendip succession was deposited, it is necessary to consider it in a broader context. In early Carboniferous times, what are now the Mendip Hills lay in a northward-shallowing sea to the south of a central Welsh landmass known to geologists as St. George's Land. This sea was continuous across South Wales, the Forest of Dean and the Bristol – Mendip region, and hence the character of the Mendip succession reflects its position within this depositional basin.

The transition from the non-marine Old Red Sandstone to typical marine limestones above is gradual and was caused by rising sea level in early Carboniferous time, drowning the low alluvial plains on which the Old Red Sandstone had been deposited. The Devonian–Carboniferous boundary, as indicated by plant spores, actually lies within the upper part of the Old Red Sandstone on Mendip, showing that the rise in sea level did not affect this area immediately. The subsequent rise was not continuous but was interrupted by minor falls and local or regional episodes of uplift. All of these factors have left their imprint upon the Carboniferous Limestone succession.

During the early Carboniferous this area lay only a few degrees south of the equator. The climate was fairly arid and so, with the limited runoff from St. George's Land, little sediment was washed in to dilute the thick succession of fairly pure limestones being deposited within the basin. These limestones were formed largely as a result of biological and chemical precipitation directly from seawater. In this area there is a general increase in thickness of the Carboniferous Limestone eastwards, from about 800m around Burrington Combe to more than 1100m in the eastern Mendips. The succession has been divided into four major units (Figure 4), with little evidence for

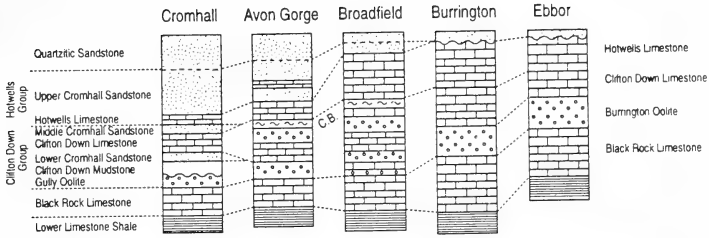

FIGURE 4. Comparative sections of the Carboniferous Limestone succession from south Gloucestershire to the Mendip Hills, showing the great reduction in clastics from North to South.
C. B. = Concretionary Beds.

any substantial breaks in deposition. The lowest of these is the Lower Limestone Shale, up to 150m thick, which represent a transition from the non-marine environments of the Old Red Sandstone to the clear seas of the succeeding limestones. As the name suggests, it is dominated by grey mudstones with thin limestone bands, often rich in shell and crinoid debris. They were deposited in shallow, turbulent water where the amount of suspended sediment prevented the establishment of the coral faunas found in later parts of the limestone succession.

Above lies a sequence of much purer limestones in which clastic sediment is virtually absent. The Black Rock Limestone comprises more than 300m of dark grey shelly and crinoidal limestones with a rich fauna of corals and brachiopods. Chert bands and nodules are abundant in the middle part of the Black Rock Limestone and are developed locally at other horizons. The silica which forms the chert is thought to be derived from sponge spicules, dissolved and reprecipitated during diagenesis, the process which turns sediment into rock. In places the Black Rock Limestone has been altered after burial into dolomite.

The Black Rock Limestone is succeeded by the Clifton Down Group, comprising some 450m of oolites, crinoidal limestones and fine-grained calcite mudstones or 'chinastones'. The Clifton Down Group shows greater lateral variation than the other limestone units. In the eastern Mendips coarse crinoidal limestones, the Vallis Limestone, predominate while to the west is a more variable succession dominated by oolites and 'chinastones'. Fossils are abundant at only a few horizons. Most notable are masses of the coral *Lithostrotion* which occur at several levels in the Clifton Down Limestone. The fauna is not very diverse reflecting the environments of depos- ition in the Clifton Down Group. The oolites accumulated on shifting oolite 'sand- banks', akin to those forming in the shallow, current-swept seas off the Bahamas today. Few organisms could survive on such a constantly shifting sea floor. The 'chinastones' were deposited in quiet lagoon environments where minor salinity fluctuations and restricted circulation may have prevented many organisms from becoming established.

At the top of the Carboniferous Limestone succession lies the Hotwells Group which here consists almost entirely of the Hotwells Limestone up to 220m thick. This is the most richly fossiliferous part of the entire limestone succession, with abundant corals, brachiopods and other fossils. On the northeastern flanks of the Mendip Hills the top 25m of the Hotwells Group contains thin mudstones, palaeosols and coals. This is virtually the only incursion of clastics into the Mendip region since the Lower Limestone Shale more than 900m below and is the southernmost extension of a major clastic unit, the Upper Cromhall Sandstone (Fig. 4).

The virtually unbroken clastic-free limestone succession of the Mendip Hills arose from its optimum position on the shallow shelf sea to the south of St. George's Land. The depth of water was such that falls in sea level caused only changes in the style of deposition rather than a break in sedimentation, while the area was sufficiently distant from land that it was rarely reached by clastic sediment. Passing to the north the proportion of clastics increases dramatically, with the Lower, Middle and Upper Cromhall Sandstones accounting for more than half of the total Carboniferous Limestone succession at Cromhall, to the north of Bristol (Fig. 4). Similarly, the proportion of early Carboniferous time represented by breaks in the succession also increases significantly to the north. Some 20km to the south-west lies the Carboniferous Limestone inlier at Cannington Park where the succession is essentially similar to, although somewhat thicker than, that of the Mendip Hills. When considered together with the substantial north-south tectonic shortening which the region has experienced, this gives an indication of the huge area which this early Carboniferous carbonate platform, of which the Mendips are but a part, once covered.

QUARTZITIC SANDSTONE GROUP AND COAL MEASURES

The Carboniferous strata which succeed the limestones of the region form much more subdued scenery and are very poorly exposed. Nonetheless, they have played a significant role in the development of the Mendip Hills as we see them today and in the past have been of major economic significance. Erosion has long since removed any trace of these strata from the main upland massif and where they are preserved in the lowlands to north and south they largely are blanketed by Mesozoic strata.

The Quartzitic Sandstone Group is nowhere more than 50m thick (Figs 2 & 4). It comprises sandstones, palaeosols and very thin coals deposited in a non-marine environment, very different from the environment in which the Hotwells Limestone beneath was deposited. The age of the Quartzitic Sandstone Group is uncertain although it may encompass the Pendleian to Marsdenian Stages (333-321 Ma). There may well be a stratigraphic break between the Hotwells Group and the Quartzitic Sandstone Group, following which deltas prograded out southwards across the carbonate platform.

The overlying Coal Measures are more than 2500m thick in the Somerset Coalfield, to the north-east of the main Mendip massif and range in age from 321 to about 305 Ma. A small area of Coal Measures also occurs at Ebbor, on the south side of the Mendip

Hills, and indicates that the basin in which these various patches of Coal Measure strata were deposited was once continuous across the area.

The Coal Measures of this region have long been divided into three distinct units, each of about equal thickness, although the original terminology has now been superseded by a more standardised scheme. The 'Lower Coal Series' at the base, now assigned to the Lower and Middle Coal Measures, and the 'Upper Coal Series', now the Supra-Pennant Measures of the Upper Coal Measures, are both dominated by dark, non-marine mudstones with coal seams. These were deposited in low-lying swampy environments where plant material could accumulate faster than it decayed. At least four marine incursions affected the area during deposition of the 'Lower Coal Series' (Fig. 2). These marine bands contain characteristic fossils which can be correlated across north-west Europe. True marine bands are unknown above the Middle Coal Measures but it is thought that many coal seams may reflect enhanced preservation of vegetable matter as a result of raised water tables associated with higher sea level.

The 'Lower' and 'Upper' Coal Series are separated by a thick succession of sandstones, the Pennant 'Series' or Measures, containing few workable coals and with only minor mudstone developments. The Pennant sandstones were deposited by large, fast-flowing rivers bringing sediment from a mountain belt rising to the south during an episode of earth movements that came before the main Hercynian Orogeny.

THE CALEDONIAN AND HERCYNIAN EARTH MOVEMENTS

The Earth's crust is far from static and it is clear from the presence of folded marine limestones at altitudes of more than 250m O.D. that the Mendip region has experienced considerable uplift. These earth movements, caused by the collision and separation of continental plates as they drifted across the Earth's surface, were far from continuous. Long periods of relative quiescence were interrupted by much shorter periods of intense tectonic activity. This area preserves evidence for two of these major orogenies. Both occurred during the Palaeozoic and so the later Mesozoic strata which blanket much of the Palaeozoic geology are relatively little deformed.

The earlier of these was the Caledonian orogeny and was related to the closure of a 'proto-Atlantic' ocean, known as Iapetus, during the early Palaeozoic. It culminated in continental collision during the Silurian and was over by mid-Devonian times. Its effects are seen particularly clearly in the early Palaeozoic rocks of Wales, the Lake District and Scotland, most notably in the prevailing NNE-SSW structural grain of the southern half of Scotland. The Silurian rocks of East Mendip show clear evidence for late Caledonian deformation. They are overturned and steeply dipping, with the Old Red Sandstone above resting upon them with marked unconformity and a stratigraphic gap between them representing an interval of at least ten million years. However, most strata in this area post-date the Caledonian orogeny. Instead, these later Palaeozoic rocks, as well as the earlier ones which had been deformed once already, were affected by a much more intense episode of deformation in the late Palaeozoic, culminating about 290 million years ago in the Hercynian, sometimes also called the Variscan, orogeny. This was caused by the coalescence of the two supercontinents of Gondwanaland and Pangaea, eventually to form a single Pangaean supercontinent in mid-Triassic times (Veevers, 1989). The main late Permian episode of deformation was preceded by several lesser episodes of folding and uplift, usually recognisable only by changes or gaps in deposition.

The unbroken Carboniferous Limestone succession of the Mendip Hills reflects a long period of quiescence, but the break at the base of the Quartzitic Sandstone Group (Figure 2) may represent the first ripples of orogenic unrest. A stronger signal is seen in the Coal Measures, most notably in the Pennant Sandstone (Figure 2). These sands were carried northwards by major rivers draining from a rising mountain chain to the south, formed by continental collision. As the Hercynian orogeny gathered momentum so the depositional regimes of the late Carboniferous were replaced by erosional regimes in the Permian as the late Palaeozoic strata were uplifted. Because of this intense erosion no Permian rocks are known from the Mendip Hills but the evidence for this final phase of deformation is spectacularly displayed in the structure of the Mendip Hills as seen today.

In broad terms, the structure of the Mendip Hills consists of four en-echelon periclines, or 'whaleback folds', extending in a roughly WNW–ESE orientation. This produces the characteristic elongated elliptical outcrop pattern of the Carboniferous Limestone as seen on the geological map (Fig. 1). Each of these periclines is much steeper, indeed sometimes overturned, on its northern limb than its southern one (Fig. 5). Similar asymmetric folding is known to occur at depth beneath the Mesozoic cover to the south (Chadwick 1983) while a more complex region of folded Upper Palaeozoic strata extends northwards to Bristol and beyond. The detailed structure of this area is extremely complex and has been a rich source of debate among geologists for more than a century. The most recent interpretation of the area has been made by Williams & Chapman (1986), whose conclusions are broadly in agreement with earlier work.

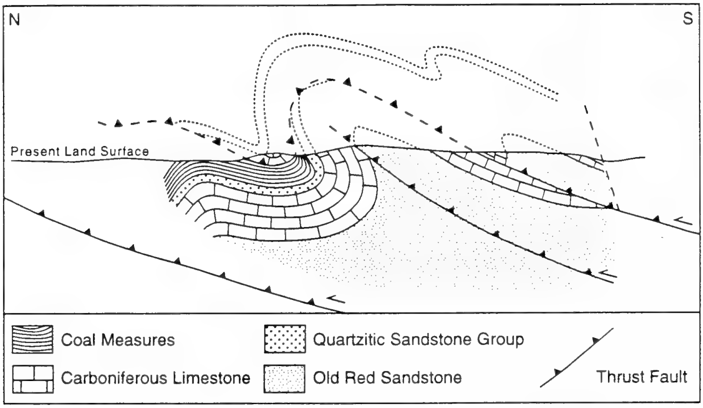

FIGURE 5. Simplified structural cross-section across the Pen Hill and North Hill periclines (along the line X-X on Figure 1).

Essentially, the structure of the Mendip Hills reflects their position very close to a major orogenic feature, the so-called Hercynian (or Variscan) Front, and the heterogeneous nature of the Upper Palaeozoic succession, with strong contrasts between competant and incompetant lithologies, which was being deformed. The dominant compressive stresses were from south to north and this caused the development of the strongly asymmetric folds and several extensive low-angle thrust planes over which the Upper Palaeozoic rocks were pushed northwards. In several instances these relatively thin thrust sheets were pushed up over Upper Palaeozoic rocks to the north, resulting in stratigraphic repetition (Fig. 5). Later removal of much of the leading edge of these thrust sheets has produced the small inliers, or klippen, of Carboniferous Limestone lying upon Coal Measures, as seen at Vobster and Churchill to the north of the main Mendip massif. Two of these thrusts have an oblique climb to the north-east rather than directly to the north in the direction of maximum compression, and it is perhaps this feature which has produced the en-echelon arrangement of the Mendip periclines. The Carboniferous Limestone is the most structurally competent lithological unit in the Mendip Hills. During compression it experienced some fracturing but relatively little deformation other than the open asymmetric folds which characterise the Mendip Hills. Instead the limestone moved northwards as very large, but relatively thin, blocks. In contrast, the overlying Coal Measures comprise a thick, highly competant sandstone, the Pennant Sandstone, sandwiched between two highly incompetant mudstone units, the 'Lower' and "Upper Coal Series'. Immediately to the north of the Mendip Hills much of the compressive stress generated during the Hercynian orogeny was accommodated by intense deformation within the 'Lower Coal Series' while the Pennant Sandstone and 'Upper Coal Series' experienced relatively little disturbance. This tectonic disruption of the 'Lower Coal Series' was a major hindrance to mining in the Radstock Coalfield and others in the Bristol-Mendip region.

Although no trace of any Permian sediment remains in the Mendip Hills it is clear that as a landscape the region was at its most spectacular during this time. The highest point in the Mendip Hills today lies at 325m O.D. on the Old Red Sandstone exposed in the core of the Blackdown Pericline. However, prior to the onset of Permian erosion this would have lain at a depth of more than 3km beneath the Carboniferous Limestone and Coal Measures. Almost certainly the most intense period of uplift must have been accompanied by equally intense erosion but, notwithstanding this, differential relief must have been much greater during Permian and early Triassic times than today. Simply projecting the unconformity beneath the Triassic cover suggests an altitude at least twice that of the present day, while the pre-Triassic basement immediately to north and south extends down to at least -200m O.D. An average relief of perhaps 1500m for the proto-Mendips in Permian to early Triassic times would seem a reasonable approximation.

TRIASSIC

The Triassic period (250-208 million years ago) is arguably the most fascinating period during the entire history of this area. It saw the emergence of the upland limestone massif in something approaching its present form before it was submerged once again beneath a blanket of Mesozoic rocks, not to be exhumed for more than 200 million years.

Following uplift during the Hercynian orogeny, the relatively soft Coal Measure sediments were stripped away from the uplands in Permian times to reveal the core of Carboniferous Limestone and Old Red Sandstone beneath. In humid climates, such as prevail at the present day, the solubility of limestone in water causes the Carboniferous Limestone to be eroded more rapidly than the Old Red Sandstone. However, in semi-arid environments, such as predominated in Permian and Triassic times, sandstones weather and erode faster than do limestones. The effect of these differing climates on the erosion of the Old Red Sandstone and the Carboniferous Limestone is strikingly seen in the Black Down pericline, at the western end of the Mendip range. The Carboniferous Limestone cover was breached first at its western end in Permian orTriassic times, allowing more rapid erosion of the underlying Old Red Sandstone. This produced a broad valley, originally floored by Old Red Sandstone but now blanketed by Triassic sediment, flanked by steep limestone ridges traversed by narrow gorges. This feature persists today as the Lox Yeo valley, the present river having excavated the soft Triassic sediments. However to the east, on Black Down itself, the limestone cover persisted until comparatively recently, perhaps no more than one or two million years ago. Having exposed the Old Red Sandstone core, erosion has lowered the surface of the flanking Carboniferous Limestone outcrop more rapidly than the central Old Red Sandstone ridge, which now rises more than 65 metres above the limestone plateau.

As well as the precursor of the Lox Yeo valley, many other smaller valleys were incised into the limestone uplands during Triassic times. Most were short steep gullies draining directly to the lowlands but a few were more substantial, such as that draining the structural low between the Black Down and North Hill periclines. Drainage across the limesone outcrop today is largely underground, via caves. Only in extreme floods, such as those of July 1968 (Hanwell & Newson, 1970), do any of the surface valleys transmit any significant flow. Indeed, most of the present minor valleys occupy almost identical positions to their Triassic precursors, and owe their presence to the relative ease with which the Triassic sediments are eroded.

The much higher incidence of surface drainage across the limestone outcrop in the Triassic landscape highlights another difference between the climates then and now. Present-day rainfall is sufficiently constant to allow the development of an integrated karst drainage system able to transmit all but the highest flow rates through the limestone. However, in the semi-arid, sub-tropical climate of Triassic times (when the Mendip Hills lay some 20° north cf the Equator) rainfall tended to be concentrated at a particular time of the year, perhaps during monsoons (Dubiel *et al.*, 1991), or in occasional heavy downpours. Such a climatic regime would tend to produce flash floods, overwhelming any underground drainage conduits to sweep down the flanks of the limestone uplands, carving steep gullies or wadis into them. Nonetheless, despite the obvious surface drainage features of the Triassic Mendips, cave systems did develop within the limestone, transmitting much of the background flow. These ancient cave passages, now choked with red and green mudstones and siltstones, have been encountered in many Mendip quarries. They are of interest not only as evidence for the nature of the Triassic landscape but also on account of the rich faunas of late Triassic and early Jurassic fossil vertebrates which some of them have yielded (Simms, 1990; Savage, 1993).

The Permian in this area was marked by an overwhelmingly erosive regime. Although many cubic kilometres of Coal Measure sediments must have been stripped from the Mendip periclines during this time, little of this eroded rock is preserved in the sediments which subsequently reburied Mendip. The oldest sediments which lie unconformably over the Palaeozoic rocks are assumed to be Triassic in age, although there is no definite evidence for this other than that they are overlain by late Triassic strata. The Triassic rocks in this area can be grouped broadly into three main units: the 'Dolomitic Conglomerate', the Mercia Mudstone Group and the Penarth Group (Fig. 3).

The Dolomitic Conglomerate does not represent a single stratigraphic unit in the traditional sense but is a complex diachronous unit whose age probably shows considerable lateral variation. It can perhaps best be considered as a Triassic regolith, a mantle of debris over the solid bedrock beneath. Often it has been dismissed as nothing more than a fossil scree, but this is only part of the story. Although often dolomitised, probably the effect of Triassic hypersaline groundwater, it is not invariably so, while it is more often a breccia than a conglomerate. It is more or less confined to what was the outcrop of the Carboniferous Limestone and Old Red Sandstone during Triassic times, passing into brilliant red sandstones, the Redcliffe Sandstone, where underlain by Coal Measures.

At least three major types of Dolomitic Conglomerate can be recognised in the field, each representing a distinct environment of formation.

Fossil scree deposits are recognised by a chaotic jumble of highly angular and sometimes quite large blocks of locally derived rock. True screes contain relatively little matrix between clasts (clast-supported breccias), but where movement of the blocks has been lubricated by mud in a mud– or debris flow, the space between clasts may be filled with matrix or the blocks may even seem to 'float' in the finer matrix (matrix-supported breccias). Both screes and debris flows are common on the steeper slopes of the Triassic hills.

The second type of Dolomitic Conglomerate is found in many of the ancient valleys incised into the flanks of the limestone hills. This too is rather poorly sorted and chaotic but, unlike the scree, the clasts are rounded to a varying degree providing clear evidence of transport by water, probably during flash floods. Where these flash floods escaped the confines of the steep gullies on reaching the lowlands, they were able to spread out to deposit alluvial fans of coarse debris. Successive beds of this **clast-supported conglomerate** are often clearly separated by a thin zone of reddening, an incipient soil, on the top of the preceding unit; excellent examples can be sen in the car park of the Wellsway Inn at Compton Martin.

The third type is dominated by a reddish-brown muddy to sandy matrix in which 'float' numerous small angular fragments of limestone (**matrix-supported breccia**). It is characteristic of the more gentle Triassic slopes, although it often forms a component of the more matrix-rich debris flows, and represents a palaeosol, or fossil soil, akin to the thin rubbly Terra Rossa soils found in semi-arid limestone areas such as southern Spain or Greece.

The Dolomitic Conglomerate is both overlain by and passes laterally into the Mercia Mudstone Group, a sequence of predominantly red mudstones and siltstones which reaches more than 1,000m in thickness in the Somerset Basin to the south of the Mendips, but less than 300m in the Chew Valley to the north. The succession is very much thinner on Mendip itself, and is absent altogether where younger rocks lap directly onto the underlying Palaeozoic massif. The Mercia Mudstone Group was deposited in a predominantly terrestrial to shallow lacustrine environment; palaeosols formed in semi-arid environments dominate the Chew Valley succession. Fluvial incursions are represented by several minor sandstones, the most important and widespread of which is the Butcombe Sandstone. This sandstone, no more than a few metres thick, is of late Triassic age (Carnian stage; 225 million years ago) and can be correlated with similar sandstones in other parts of Britain and Europe, and with the Westclose Hill Conglomerate on the south side of the Mendip Hills (Fig. 3). It was deposited during an interval of only a few million years when the prevailing semi-arid climate of the Triassic was replaced by a significantly more humid one (Simms & Ruffell, 1990). With the greater frequency of flooding, debris washed from the Mendip uplands was carried much further out into the lowlands. In consequence the Butcombe Sandstone contains numerous small pebbles of Carboniferous Limestone and chert in addition to debris eroded from the Triassic sediments immediately beneath it.

Towards the end of the Triassic a rise in sea level flooded the extensive Triassic lowlands (Fig. 3). The first signal of this marine encroachment is seen in the grey-green blocky siltstones of the Blue Anchor Formation, containing marine dinoflagellates, at the top of the Mercia Mudstone Group. A minor erosional break is followed by the Penarth Group (the Rhaetic of earlier accounts), which comprises the Westbury Formation at the base and the Lilstock Formation above. The Westbury Formation typically comprises black shales with minor sandstones and contains a restricted, quasi-marine invertebrate fauna alongside a mixed marine and terrestrial vertebrate fauna (Storrs, 1994). Locally, however, it may pass into a shelly limestone or conglomerate with Carboniferous Limestone pebbles, as at Wedmore or Butcombe (Green & Welch, 1965). The overlying Lilstock Formation comprises pale mudstones with thin limestones, including the algal stromatolites of the Cotham Marble, deposited in very shallow water with fluctuating salinity. Unlike the Mercia Mudstone Group, whose thickness varies enormously as it blankets the uneven Permo-Triassic topography, the thickness of the Penarth Group is remarkably constant, though seldom exceeding ten metres, suggesting that it was deposited on a very even surface of the underlying Mercia Mudstone. On the Mendip Hills themselves the Penarth Group has largely been removed by erosion and persists only in the east of the region or, where silicified, in the Harptree area. Nonetheless, it is clear that the late Triassic marine transgression transformed the Mendip uplands into an archipelago with the Penarth Group lapping onto the shores of the islands.

LOWER AND MIDDLE JURASSIC

The history of the Mendip Hills from late Triassic times onwards is one of gradual submergence and burial beneath an increasing depth of marine sediments. Planation of the underlying Palaeozoic rocks by the sea prior to burial beneath sediment was commonplace, producing some spectacular unconformities in places. Jurassic

ERRATA and ADDENDA

NATURE IN AVON, the *PROCEEDINGS OF THE BRISTOL NATURALISTS' SOCIETY*, Vol. 55 for 1995 and **Special Issue No. 4,** ***'THE MENDIP HILLS'*** (reprinted from Vol. 55)

The geological history of the Mendip Hills and their margins, by M. J. Simms.

Figures 6 and 7, referred to respectively on page 127 and page 131, were inadvertently omitted. They are reproduced below.

FIGURE 6 Horizontal Upper Inferior Oolite (Middle Jurassic) limestones unconformably overlying steeply-dipping Vallis Limestone (Lower Carboniferous) in the classic quarry section at Vallis Vale, near Frome.

FIGURE 7. Pull-apart' Neptunean dyke in Carboniferous Limestone filled with Lower Lias silts. Offest of the dyke along a bedding plane can beseen clearly to the left of the hammer. Cloford Quarry, near Frome.

ERRATA and ADDENDA

NATURE IN AVON, the *PROCEEDINGS OF THE BRISTOL NATURALISTS' SOCIETY*, Vol. 55 for 1995 and **Special Issue No. 4**, ***'THE MENDIP HILLS'*** (reprinted from Vol. 55)

P. 1 The words 'economic pressure' should be added to the last line on the page.

Pp. 4-8 The author's name, K. C. Allen, should have appeared in the headers to the left-hand pages.

Pp. 42 & 45. In each case the end of the last line of the first paragraph was inadvertently detached and moved down.

P. 45 second paragraph: delete 'night' from second line.

P. 47 third paragraph. The last two lines should read '... the exotic Velvet Ant, *Mutilla europaea*, which parasitises bumblebees; the females are wingless and ... (Note: *M. europaea* is not an ant)'.

P. 52 End of third paragraph, after '...with Chinery's 1993 GUIDE', add 'Richmond Publishing maintain their high standard with **ANIMALS UNDER LOGS AND STONES** by C. P. Wheater and H. T. Read, 1996, Naturalists' Handbook No. 22, Slough: Richmond Publishing, a must for this branch of study'.

P. 62 Add to first line: 'All these species grow in the Priddy Mineries area - see Dr Allen's paper on Botanical Walks, especially pp 12-13'

P. 86 Bibliography to **'Agriculture on the Mendips' by R. D Russell**: add the following entries:

FINDLAY, D. C. (1965) *The soils of the Mendip District of Somerset*, Memoir of the Soil Survey of Great Britain, England and Wales. Harpenden: Agricultural Research Council.

TREVELYAN, G. M. (1979), British history in the nineteenth century and after (1782 – 1919), 2nd ed., London: Longmans.

P. 127 Figure 6 was omitted . It is reproduced overleaf.

P. 131 Figure 7 was omitted. It is reproduced overleaf.

Pp.136-158 The second author's name in the left-hand page headers should read ' **P. L. Smart**'.

NATURE IN AVON, the *PROCEEDINGS OF THE BRISTOL NATURALISTS' SOCIETY*, Vol. 55 for 1995

P. ii Past Presidents:- J. W. Tutcher took office in **1931.** The President who took office in 1945 was Sir Lewis L.**Fermor**.

Pp. xx-xxv The pages between pages xx and xxv were printed in the wrong sequence. They should be read in the order of the printed page numbers.

sequences tend to be highly attenuated and of atypical facies. It is probable that by mid-Jurassic times most, if not all, of the Palaeozoic massif was buried, but later erosion has removed virtually all traces of this thin cover except in the east.

The late Triassic Penarth Group is succeeded by the Lower Lias. In typical, basinal sequences this comprises several hundred metres of dark mudstones with many thin limestones in the lower part. In contrast, the succession around Shepton Mallet is a so-called 'littoral' facies of coarse shelly to conglomeratic limestones with many Carboniferous Limestone pebbles; while to the north, around Radstock, is developed a sequence of condensed limestones, with abundant phosphate and reworked fossils, separated by very thin mudstones. Neither sequence is much more than about 30 metres thick and in places is much less, with numerous stratigraphic gaps. The Middle Lias is entirely absent from the Mendip region and the Upper Lias almost so, probably a consequence both of limited deposition and of erosion prior to deposition of the Middle Jurassic sediments.

To the west of North Hill the Lower Jurassic is confined almost exclusively to Mesozoic fissure infills, discussed below. However, there is one other unusual occurrence which is of considerable significance in reconstructing the former extent of the Jurassic in western Mendip. At Callow Rock Quarry, north-west of Cheddar, a Pleistocene cave passage has been intercepted which is almost completely choked with limestone cobbles of early Jurassic age (Hettangian-lower Sinemurian). These are highly fossiliferous, suggesting a shallow-water, condensed sequence, and indicate the former existence of an extensive cover of early Jurassic sediments in the Lox Yeo valley or spreading across the limestone ridge itself.

In eastern Mendip, Middle Jurassic sediments rest unconformably on the Lower Jurassic or overstep directly onto the Palaeozoic rocks, as seen in the spectacular unconformity at Vallis Vale (Fig. 6), where a remarkably flat surface extends for many metres encrusted with oysters and bored by bivalves and other marine organisms. Only the Upper Inferior Oolite is preserved, attaining a thickness of up to twenty metres of coarse, bioclastic and often rubbly limestone. No rocks younger than these are seen to rest directly upon the Palaeozoic rocks and, furthermore, there is relatively little attenuation of later parts of the Mesozoic succession. This suggests that the Palaeozoic rocks, in the eastern Mendips at least, were entirely buried by Middle Jurassic times, some 165 million years ago.

Passing eastwards from Beacon Hill, the Palaeozoic ridge becomes submerged beneath a cover of Middle Jurassic and later rocks. The easternmost inlier of Carboniferous Limestone lies just to the north of Frome but the influence of the underlying ridge on subsequent tectonic activity in this area can be seen clearly in the northeast-southwest faults which traverse the Jurassic.

MINERALISATION AND NEPTUNEAN DYKES

One of the most significant features of Mendip geology, at least in terms of historical development of the landscape if not in terms of actual volume of material, is the occurrence of metallic ores. These ores have been mined for at least 2,000 years, since Roman times or earlier. In terms of the geological history of the region this ore mineralisation is but one manifestation of events which affected the region from late Triassic until at least mid-Jurassic times. The features which resulted may be grouped broadly under three headings: ore mineralisation, silicification and Neptunean dykes.

ORE MINERALISATION

The Mendip Hills have been the source of a diverse suite of metallic minerals, as well as non-metallic, or gangue, minerals such a quartz (SiO_2), calcite ($CaCO_3$) and barite ($BaSO_4$), which were described in some detail by Alabaster (1982). At various times in the past the region has been an important source of the ores of four metals: iron, manganese, zinc and particularly, lead (see Martin & Fawcett, this volume). The area is also the type locality for Mendipite, a lead oxychloride ($Pb_3O_2Cl_2$).

IRON AND MANGANESE

Compared with the rich iron orefields in the Coalpit Heath basin to the north of Bristol, and in the Forest of Dean, the Mendip Hills were never more than a minor producer of iron, although production was at least of the order of a few thousand tons. The main ores were haematite (Fe_2O_3) and goethite ($FeO.OH$), often in the form of soft red and yellow ochre deposits filling fissures or cavities in the Carboniferous Limestone or Dolomitic Conglomerate or even as a direct replacement of carbonate lithologies. Locally they also occur infilling joint or fault shatter-belts in non-carbonate lithologies.

There is strong evidence that most of the iron mineralisation in the Mendip Hills, as in other similar orefields, was emplaced in mid to late Triassic times (Alabaster 1982, Simms 1990). Firstly, iron deposits are restricted to Carboniferous and Triassic strata with none occurring in the overlying Jurassic rocks despite their favourable carbonate lithologies. Secondly, fissures filled with iron minerals are cut both by unmineralised Jurassic fissure fills and by the unconformity between the Carboniferous Limestone and the Upper Inferior Oolite.

The mechanism of emplacement of the iron minerals appears to be broadly similar to that of other iron deposits of comparable age, such as those of the Forest of Dean. Prolonged intense weathering of Carboniferous rocks, particularly the iron pyrite (FeS_2) or siderite ($FeCO_3$) – rich mudstones of the Coal Measures, released iron into solution or suspension whereupon it was transported into pene-contemporaneous fissures and cavities where it accumulated to form concentrated masses of iron oxide. Although weathering of the Carboniferous Limestone also releases small amounts of iron, this being the cause of the reddish colouration of soils on limestone hills, the Coal Measure mudstones represent a very much richer primary source of iron. The relatively minor importance of the Mendip iron orefields, compared with those of Coalpit Heath and the Forest of Dean, reflects the fundamentally different structure, and hence outcrop configuration, of Mendip. The rich orefields of Coalpit Heath and the Forest of Dean lie within or around the margins of synclinal basins in which a central core of Coal Measure mudstones lies within a limestone rim, thereby tending to concentrate iron emplacement within the basin, usually in karstic cavities in the limestone or, in the Coalpit Heath area, in joints and fissures within the Coal Measure sandstones. In contrast the Mendip Hills have a largely anticlinal structure so that the Coal Measure mudstones were stripped back from the underlying limestone by streams which tended to disperse any weathered iron compounds away from the area before significant karst cavities could form to provide sites for iron accumulation.

Manganese, where it occurs in the Mendip Hills, is invariably associated with the iron mineralisation. The principal ore is pyrolusite (MnO_2) but this is always associated with other minor manganese compounds. The richest deposits have been found at Merehead Quarry, in the eastern Mendips, which has produced several thousand tonnes. Elsewhere yields generally have been of the order of a few tens of tonnes. The manganese occurs in the form of 'pods' with iron-rich, often siliceous, margins. Alabaster (1982) considers the manganese to have been derived and emplaced by the same basic mechanism as the iron, with Coal Measure mudstones and perhaps also the Silurian volcanics as the primary source. Alabaster (1982) considers that segregation of iron and manganese following burial and drowning by the encroaching Jurassic sea may have led to secondary enrichment and the formation of the manganese 'pods'.

LEAD AND ZINC

By comparison with other lead-zinc orefields in Britain, such as those of Derbyshire or North Wales, Mendip was never a major producer. Nonetheless, the importance of the mines in Roman or even earlier times was considerable. It has been estimated that the area has yielded more than 200,000 tonnes of lead ore and perhaps a similar quantity of zinc ore throughout its entire mining history (Green & Welch, 1965). Silver was an economically significant impurity in the galena.

The lead occurs mostly as galena (PbS) in elongated, near-vertical veins trending for the most part WNW–ESE. These are rarely more than a metre wide but may be hundreds of metres long. Several distinct orefields have been identified (Alabaster, 1982; Stanton, 1981). The early miners knew that the richest concentrations of lead ore in these veins was near the surface and that the mineralisation died out at quite shallow depth, often less than 30m from the surface. Later mining ventures, with shafts and levels excavated to much greater depths, served only to confirm this and failed to find significant new reserves. Most of these veins are now completely worked out but excavations in Grebe Swallet, Charterhouse have revealed the original form of one such vein (Stanton, 1991). This has shown that much of the richness of these near-surface workings is due to secondary enrichment of the lead ore as a consequence of surface lowering of the limestone plateau. Although primary vein material may occur as thin crusts of galena and gangue minerals, most of the lead ore recovered by the miners occurred as abraded slabs and lumps, in some instances weighing several hundred kilograms, in a jumbled mass of clay and other insoluble rock fragments which had been concentrated by the dissolution of the surrounding limestone.

Lead is important in all of the Mendip orefields but zinc occurs in significant quantities only in the Shipham area. It is rarely found in its primary ore state as sphalerite or zinc blende (ZnS) but occurs largely as smithsonite or calamine ($ZnCO_3$), the product of prolonged weathering. Cadmium is a significant, and notorious, component of the zinc ores in Mendip (see Martin & Fawcett, this volume).

It was long considered that the lead-zinc mineralisation of the Mendip orefields was associated with the Hercynian earth movements in late Carboniferous and Permian times. However, there is now firm evidence that most, if not all, of this epsiode of mineralisation occurred during the Jurassic. Moorbath (1962) suggested a mid-Triassic age for Mendip galena emplacement, his lead isotope analysis giving an age of 230±30 million years. However, most field evidence points to at least a post-Triassic age. Alabaster (1982) considered that the lead-zinc sulphide mineralisation post-dated the iron-managanese mineralisation since not only do some of the sulphide veins cut across the iron and manganese deposits, but in some worked-out lead veins in central Mendip a crust of iron ore still remains on the walls. Late Triassic cave infills have also been observed to be cut or capped by very similar sulphide and gangue mineralisation in quarries to the north of Bristol, notably at Tytherington and Chipping Sodbury (Simms, 1990), part of the same structural province as the Mendip Hills. Curtis (1981) found evidence for at least a post-Penarth Group (=Rhaetic) age for lead mineralisation at Chipping Sodbury and suggested a post-Middle Jurassic age as probable. Moore (1867) noted lead-zinc mineralisation in the Inferior Oolite along the Nunney Valley near Frome, and this was confirmed by boreholes near Egford, in which Stanton (1981) observed significant lead-zinc-barite mineralisation in Upper Inferior Oolite limestones which had also experienced substantial silicification. In all, the evidence suggests only one significant episode of lead-zinc mineralisation in the Mendip Hills, this having occurred in Middle Jurassic times.

SILICIFICATION

A variety of types of silica mineralisation are found in the rocks of this area. The occurrence of discrete chert bands at several levels in the Carboniferous Limestone has already been mentioned. Siliceous nodules, known as 'potato stones', are found in the Triassic Mercia Mudstone close to the unconformity with the underlying Carboniferous Limestone, notably in the Dulcote area. These represent quartz replacements of gypsum or anhydrite ($CaSO_4$) nodules and are a consequence of the enhanced solubility of silica in hypersaline groundwater. This same basic mechanism may well account also for the frequent association of silica with the iron-manganese deposits emplaced during the late Triassic, a time of significant aridity in which hypersaline, silica-rich, groundwater may have been prevalent in this area.

However, the most extensive silicification is associated with Lower and Middle Jurassic limestones in the central and eastern part of the Mendips, where they are known collectively as Harptree Beds. Observations on unweathered Harptree Beds in the Egford borehole and at Whatley Quarry show that the host limestones were silicified only patchily (Stanton, 1981). The most intensely silicified areas survive at outcrop as massive cherts and have been mapped as Harptree Beds. Elsewhere, the less completely silicified areas are reduced, by dissolution of the host limestone, to a jumbled mass of chert fragments set in clay and, ultimately, to isolated chert blocks. Such weathering of partially silicified limestones may account for the presence of scattered blocks of Harptree Beds chert near Dolebury, some distance to the west of their main outcrop. Silicification was clearly selective for the purer limestones; at

Winford Manor, north of Mendip, silicified Dolomitic Conglomerate in Harptree Beds facies rests upon unaltered mudstones of the Blue Anchor Formation (=Tea Green Marls) and Penarth Group (=Rhaetic) (Donovan & Kellaway, 1984). The silicification of the Harptree Beds clearly postdates the Inferior Oolite but there is little to constrain the age more closely. Kellaway (1991) has suggested an Albian-Cenomanian (early Cretaceous) date for emplacement on the assumption that it is of diagenetic origin, though there is no substantial evidence to support this. The fairly close distributional relationship between the outcrop of the Harptree Beds and the location of the main lead-zinc orefields in Mendip suggest that the two may be related, a possibility already suggested by Stanton (1981), with both being the result of hydrothermal activity along fractures associated with Mesozoic flexuring of the Mendip periclines.

NEPTUNEAN DYKES

A prominent feature within the Carboniferous Limestone of the region are elongated fissures filled with younger sediment, typically clay or limestone, ranging in age from late Triassic to mid-Jurassic. Known as Neptunean Dykes, these fissures are seldom more than 2m wide and 20m deep but they may extend in a fairly straight line for hundreds of metres, typically orientated WNW-ESE. There are obvious similarities here with the lead-zinc lodes, and the relationship between the two is discussed later.

These sediment-filled Neptunean dykes have been known for well over a century (Moore, 1867). In some, the sediment filling may be chaotic; in others it may show laminations and evidence of slumping and disruption by blocks fallen from the walls. The stratigraphy within the fissures is often highly condensed, suggesting that they remained open for several million years but lacked any direct connection to the surface. Sediment and small fossils must instead have filtered down through a surface cover of debris or interlocking blocks. The importance of the fossil faunas contained within them is two-fold. Firstly, marine fossils provide evidence for the time of drowning of that part of the Mendip Hills and the former extent of the Jurassic cover. Secondly, they have yielded some of the earliest known mammal remains, described originally by Moore (1867) on the basis of isolated teeth (Savage, 1993).

The mode of formation of these structures has been much discussed. Copp (*in* Duff *et al.,* 1986) suggested that sea floor material might have been sucked into fissures as they opened suddenly beneath. Simms (1990) suggested instead that they might be solutional features, or 'giant grikes' since they are confined to carbonate lithologies. However, most evidence indicates that they are 'pull-apart' fissures associated with regional tectonic extension (Smart *et al.*, 1988; Jenkyns & Senior, 1991). They are not confined to the Mendip Hills but also occur in the Carboniferous Limestone of Broadfield Down, south Gloucestershire and South Wales. Most have parallel or sub-parallel sides and in the best examples projections on one wall can be correlated with hollows on the opposite wall (Figure 7). Most are developed parallel to the dominant joint set imposed during the Hercynian orogeny. Hence on the gentle southern limbs of the periclines the neptunean dykes are near vertical and sediment- filled while on the much steeper northern limbs they are sub-horizontal and may be filled entirely with calcite.

The infills of many of the dykes are complex and it is clear that there was more than one episode of dilation. Often a central mass of lithified sediment is bounded on either side by symmetrically-zoned calcite veins. In such cases lithification of the original sediment fill was followed by further dilation opening up cavities on either side. The fossil content of different dykes also indicates that extension occurred sporadically from late Triassic to mid-Jurassic times; this, as Jenkyns & Senior (1991) point out, correlates with the early rifting phase of the Central Atlantic.

Attention has already been drawn to the similar configurations of the Neptunean dykes and the lead–zinc lodes. Indeed, the two often occur in close association (Stanton, 1991). It seems quite possible that the Neptunean dykes (late Triassic to mid-Jurassic), the lead-zinc mineralisation (mid-Jurassic) and the silicification forming the Harptree Beds (post mid-Jurassic) represent different phases of the same regional tectonic event.

UPPER JURASSIC TO PLEISTOCENE

From Middle Jurassic times onwards the Palaeozoic ridge of the Mendip Hills exerted only a minor influence on sedimentation, although a south-easterly extension of it probably accounts for the extent of pre-Albian erosion in the Warminster area where Upper Greensand rests directly on Oxford Clay. By early Upper Jurassic times at the latest an unbroken cover of Mesozoic sediments extended acros the whole Mendip range and by the close of Cretaceous times the Palaeozoic ridge may have lain beneath perhaps a kilometre of sediment. There is virtually no direct evidence of these late Mesozoic deposits, although a small outlier of Upper Greensand and Gault Clay lies less than 3km to the south of Carboniferous Limestone outcrops at Nunney, near Frome. Stanton (1991) records fragments of possible Lower Cretaceous chert in the secondary ore deposits of Grebe Swallet, near Charterhouse, while Kellaway (1991) describes similar evidence, including fragments of Middle Chalk, in fissures in eastern Mendip.

We can only speculate on the subsequent history of the Mendip Hills through the Tertiary. As elsewhere in southern Britain, the close of Chalk deposition probably was followed by a period of emergence and erosion in Palaeocene times. Subsequent deposition of marine units, such as the Eocene London Clay, may have extended west-ward as far as this, but by Oligocene times the region almost certainly lay in a terrestrial environment, and the long slow process of stripping back the Mesozoic cover could resume. We can only conjecture on when the Palaeozoic ridge was first uncovered but there can be little doubt that the western Mendips were exposed first and the Mesozoic cover was then eroded slowly eastwards to its present position (see Farrant & Smart, this volume).

At the present stage in its history, much of the original Triassic topography has been exhumed and many of the modern valleys occupy their Triassic precursors, in which the softer Triassic sediments are more easily eroded than the surrounding limestone. In the prevailing humid climate of the Pleistocene, solution of the limestone has been more rapid than erosion of the Old Red Sandstone, producing level limestone plateaux surrounding central sandstone peaks. To the east the retreat of the Mesozoic scarp continues to expose more of the underlying Palaeozoic ridge, only for it to be consumed by the vast quarries nearby.

Although the Mendip Hills as we see them today might be considered a 'second-hand' topography inherited from the Triassic, this is a rather superficial interpretation of the modern landscape. Much has happened since the erosive period during Permian and Triassic times which originally shaped this Palaeozoic massif. The post-Triassic events, and sediments, have had a profound influence on the development of the present range of hills. Although scenically the Mendip Hills of today are far less spectacular than their Permo-Triassic precursors, subsequent events have greatly enriched the unique character of this area in many more subtle ways which have had a fundamental influence on the landscape, culture and industry of this area.

ACKNOWLEDGEMENT

I thank Kathryn Sharp for drafting the figures.

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THE GEOMORPHIC EVOLUTION OF THE MENDIP HILLS

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ABSTRACT

Detailed surface and underground studies of landscape formations over the last 30 years have advanced understanding of the geomorphic evolution of the Mendip Hills. Here we attempt to summarise this work and to describe the formation of the main geomorphological features. By combining this research with new dating evidence from many of the region's caves we have been able to make estimates of the rate of landscape evolution in the Mendip area, and to estimate when the distinctive Mendip landscape came about.

Note Technical terms printed in ***bold italics*** at their first appearance are explained in the Glossary following the references at the end of the text.

INTRODUCTION

The Mendip Hills form an elongated upland plateau extending some 40 km from the Bristol Channel coast east to Frome. They have long been noted for their outstanding scenery and geology. The distinctive Mendip landscape is the result of a complex interplay between the underlying geology, erosional processes, climate and time. Although much has been written about the geomorphology of the Mendips (Ford & Stanton, 1969; Donovan, 1969; Smith, 1975a, 1977; Waltham *et al.*, 1996), we attempt here to summarise the genesis and evolution of this fascinating landscape.

To gain an understanding of the evolution of the Mendip landscape it is necessary to examine both the surface and the underground geomorphology. The underground geomorphology is especially important, as cave deposits preserve evidence of the early stages of evolution which would otherwise be lost by later surface erosion. Furthermore, cave deposits can be dated, thus enabling a timescale to be constructed. A relative chronology has previously been elucidated, but new information obtained from dating cave deposits allows us for the first time to place limits on the age of many of the geomorphological features.

SURFACE GEOMORPHOLOGY

The geomorphic character of the Mendips is determined primarily by the underlying geology. The **Old Red Sandstone** forms the core of the Mendip periclines and develops prominent rounded hills, often covered in peat bog. In contrast, the **Carboniferous Limestone** which underlies much of the area gives rise to a distinctive rugged karst topography, characterised by dry valleys, deep gorges, rocky outcrops and sinking streams. The softer Triassic **Mercia mudstones** generally form the lowlands surrounding the hills, such as Wrington Vale, although remnants still occur on the Mendip Plateau. The harder **Dolomitic Conglomerate**, a diachronous marginal facies of the Mercia Mudstone Group, is also characterised by a karst topography.

Over much of the Mendips, any overlying Mesozoic rocks have been stripped from the Palaeozoic rocks to reveal the buried Triassic landscape underneath. In Triassic times the area was a very arid rugged environment with deep wadis and gorges, which were subsequently filled in with screes, conglomerates and sandstones to form the Dolomitic Conglomerate. Despite the aridity, there is some evidence that caves were formed and their remains can still be found (Stanton, 1977; Simms, 1990). In fact, much of the modern Mendip scenery is inherited from the exhumed remnants of this former landscape. The detail in which it has been uncovered is so good that W. M. Davies proposed the term 'Mendip' to describe such an exhumed topography.

PLATEAU SURFACE

Perhaps the most striking landscape feature of the Mendip Hills is the remarkably level plateau at an elevation of about 250 m. This extends over much of central Mendip, from Callow Hill in the west to Beacon Hill in the east, cutting across both the steeply dipping Carboniferous Limestone and the Mesozoic cover. The origin of this plateau has been a matter of some controversy for many years. As Donovan (1969) and others have noted it is neither an exhumed Triassic feature, nor is it wholly Jurassic, since the Jurassic cover is not horizontal. Green (Green & Welch, 1965) regarded it as having a late Tertiary origin, whilst Ford & Stanton (1969) advocated a Pliocene age. Donovan suggested that mid-Cretaceous erosion may have been partly responsible, while Stanton (1977), using solutional lowering estimates provided by Atkinson (1971), argued for an age of around a million years. Almost certainly it has a polygenetic origin, as the patches of Harptree beds (silicified cherts and mudstones of Lower-Middle Jurassic age) suggest initial Jurassic planation, but these rocks have also undergone folding and levelling, probably over the last few million years.

Several other erosion surfaces have been recognised in the Mendip area (Trueman, 1939), but many of these are probably stratimorphic in origin. Ford & Stanton (1969) recognised a series of erosional benches along the southern flank of the Mendips, which they argued were formed during still-stands in response to an intermittently falling sea-level. However, many of these supposed marine benches may be random erosional bevels or caused by structural or lithological factors. Many of them occur where softer Triassic and Jurassic clays and mudstones have been stripped off underlying harder rocks (Stanton, 1985). Only the Axe bench at an elevation of 40 m O.D. may be a true erosion surface. This feature and another level at 21 m O.D. form flat or gently sloping terraces between Cheddar and Wells, occupied for much of their length by the A 371 road. They probably mark a pause or change in the erosion of the Mercia Mudstone Group, rather than a true marine bench.

The plateau surface is pockmarked by many closed depressions and hollows of various origins. Although not recognised as such by Coleman & Balchin (1959), many of these are old mining pits and grooves. The latter can be easily distinguished by their irregular rough-hewn nature; some date back as far as Roman times, although most are later (Stanton & Clarke, 1984). However, many of them are natural features, ***dolines***, which can be divided into two categories according to their origin.

(a) Collapse dolines occur where subsidence and collapse take place following dissolution of the underlying strata at depth. Many of these develop in the impermeable Harptree Beds that overlie the Carboniferous Limestone, particularly in central Mendip. Wurt Pit, near Harptree is an excellent example, formed by the dissolution of deep Carboniferous Limestone, followed by collapse and subsidence of the overlying impermeable cover rocks (Smith, 1975b; Barrington & Stanton, 1977). This was almost certainly aided by the leakage through fractures of aggressive water from the silicified cherts and quartzites of the Harptree beds, dissolving the limestone and Dolomitic Conglomerate below. However, significant cave voids can develop within the Mercia mudstones, even where they are not underlain by Carboniferous Limestone. Many of these cave systems occur in calcareous bands or in interdigitated Dolomitic Conglomerate units within the Mercia Mudstone Group. This has been shown by recent discoveries of extensive cave systems with active streamways developed in the mudstones, such as at Wigmore Swallet (Jarratt, 1991) and Attborough Swallet. Enlargement of these voids by stream action, followed by collapse and piping in the mudstones above may lead to the formation of collapse dolines on the surface.

(b) Solutional dolines, such as Bishop's Lot, near the Hunters Lodge Inn, are formed solely by dissolution of the limestone, with no collapse into an underlying cavity. Ford & Stanton (1969) attributed the formation of these dolines to gradual solution working down from the surface along joints. These were later deepened by the breakdown and dissolution of the limestone at the top of the fissure.

However, many Mendip depressions may result from a combination of dissolution and partial collapse, and are often inherited from dolines developed on the Mesozoic cover which are left superimposed on the limestone after the cover has been eroded away. Excavations at Whitepit, a large closed depression near Priddy with no obvious collapse features, revealed a horizontal cave at no great depth with a large debris cone directly below the surface depression. In this case it appears that the presence of an earlier open cave not far below the surface, aided by leakage of water into the limestone overlying the cave, led to partial collapse to form the depression. Many, if not most of the closed depressions are probably compound in origin. Some, especially along the shale/ limestone boundary, are modified or abandoned stream sinks, such as Bos Swallet and Rod's Pot in Burrington. The densest concentration of depressions occurs where there is a thin Mesozoic cover, such as around the Castle of Comfort Inn in central Mendip. When the cover is eroded, most of the depressions are soon removed by solutional lowering of the surface. True solutional dolines wholly on the limestone are rare.

A belt of much larger closed depressions or basins occurs along the southern edge of the central Mendip Plateau between Cheddar and Wells (Fig. 1) and elsewhere. These were described in detail by Ford & Stanton (1969) and Stanton (1977). The best developed are the Brimble Pit–Cross Swallet depressions near Westbury-sub-Mendip. Brimble Pit itself, a small doline, lies at the lowest point of a shallow depression 10 m deep, over 1000 m long and 500 m wide. The floor of the basin is covered in a thick layer of horizontally stratified loessic silty clay, pitted with small sinkholes. The basin is bounded by very gently graded slopes, dividing it from neighbouring depressions and valleys. The south-eastern margin of the basin is marked by a low col that feeds into an overflow channel incised several metres into the flanks of the plateau.

The Cross Swallet basin is similar in depth, but is smaller in area being only 500 m in diameter. It also has a marginal col and overflow channel, but not as well defined as that at Brimble Pit. A fresh corrosion terrace exists at the level of the col, and extends all the way around the basin, sometimes extending up to 23 m in width. The centre of the basin is infilled with horizontally laminated yellow-brown silty clay over 7 m thick, 5 m below the edge of the terrace.

The origin of the basins was examined by Ford & Stanton (1969). They argued that the basins were formed by solutional activity during warm phases in the Pleistocene, and were sealed by permafrost during the ensuing cold periods. Meltwater became ponded during the brief summers until it spilled over the col, cutting the overflow channel. The loessic silty clay deposited in the lake helped seal the lake bed. In Cross Swallet, the presence of the terrace indicates a stable lake surface at the col level.

DRY VALLEYS AND GORGES

As well as the closed depressions, the plateau surface is incised by a series of impressive dry valleys which debouch onto the surrounding lowlands via deep and spectacular dry gorges. The largest of these, Cheddar Gorge, is entrenched up to 120 m deep and is fed by a network of dendritic feeder valleys (Trudgill, 1977). The origins of these dry valleys and gorges have been debated for over a century. The earliest ideas involved earthquake rifting and similar catastrophic phenomena. The first plausible hypothesis was put forward by Dawkins in 1862, who suggested that they were formed as a result of cavern collapse. This was also the view held by Winwood & Woodward (1891) in an account of a Geologists' Association field excursion to Mendip. In 1902, Callaway noted the joint-controlled nature of Cheddar Gorge and concluded that it must have been formed by a subterranean stream. Reynolds (1927) was one of the first to suggest that the Gorge was cut by a surface river. The last advocates of the collapsed cavern theory were Stride & Stride (1949), although this myth is still often perpetuated in many modern geological texts.

Clearly, as Ford & Stanton (1969) demonstrated, Cheddar Gorge is not a collapsed cavern, but was formed by an underground river. This is shown by the difference between the long profile of the Gorge and that found in the stream caves. Whereas the steepest section of the Gorge is near its mouth, most stream caves descend rapidly at first before levelling out at depth. Furthermore, there is an immense disparity between the volume of the Gorge and that of even the largest Mendip caves such as G. B. Cavern and Lamb Leer. Also, the Gorge has often cut though existing cave passages,

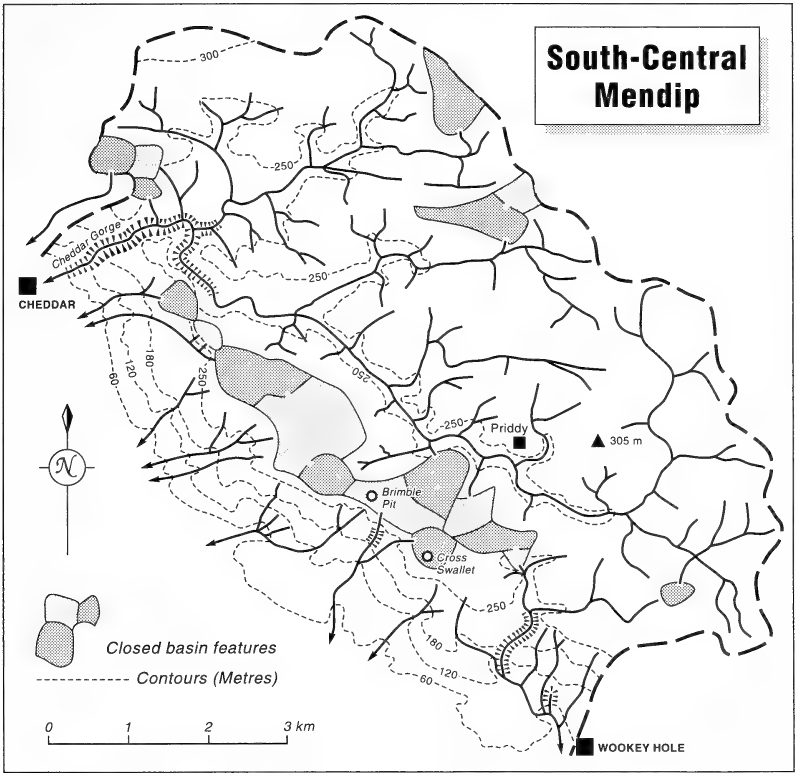


FIGURE 1. Location of the major closed depressions and dry valleys, central southern Mendip Adapted from Ford & Stanton (1969)

such as Sun Hole, without any significant modification to its form. Cavern collapse can only have played a minor, if not trivial, role in gorge formation.The commonly accepted view is that the dry valleys and gorges were incised over the last million years by underground meltwater rivers during periglacial periods, when underground drain- age was restricted (Smith, 1975c). Extensive mass movement and solifluction, coupled with development of permafrost during glacial periods led to the blocking of the swallet caves with gravel (as can be seen in G. B. Cave), ice and frozen mud and the establishment of surface drainage.

Due to the nature of the Mendip plateau, the steepest stretches of the dry valleys were at the mouth and it was here that incision was greatest. Cheddar Gorge is the largest of the gorges on the Mendips because it drained the bulk of the plateau and it had the greatest potential vertical range, maximising its erosive power. In contrast, Ebbor Gorge has only a small catchment area and so is much smaller. Each successive periglacial episode caused renewed incision, creating marked knick points, while during the interglacial periods, underground drainage was renewed and the dry valleys fossilised, except under conditions of major flood such as that of 1968 (Hanwell & Newson, 1970). Only one gorge, that immediately downstream of Wookey Hole, may be partially ascribed to cavern collapse.

The material eroded during these periods was deposited as large low-angle alluvial fans (marked as 'head' on most geological maps) extending out from the foot of the major valleys. An excellent example occurs at Burrington Combe, and forms a clear morphological feature (Clayden & Findlay, 1960; Findlay, 1965). The fresh form of the fans (former stream channels can still be seen on the Burrington fan) suggests they were last active during the Late Devensian. Active gravel emplacement at this time is confirmed by dating of stalagmites associated with gravels in G. B. Cave (Atkinson *et al.*, 1978).

As Bradshaw & Frey (1987) have noted, many modern valleys follow earlier filled-in Triassic valleys. Erosion has picked out the softer Mercia mudstones, which fill many of the fossil Triassic wadis, in preference to the harder, more resistant Carboniferous Limestone. Most of these features occur in the western portion of the Mendips, where exhumation is generally complete. Further east, many of these Triassic valleys are still infilled, awaiting exhumation, such as the network of Dolomitic Conglomerate filled valleys converging on East Harptree. However, not all the valleys follow existing Triassic lines. In central Mendip, many of the larger stream-cut valleys are incised into the hard limestone, such as Cheddar Gorge, Burrington Coombe and Ebbor Gorge. This may reflect the harder silicified nature of the Dolomitic Conglomerate in the Harptree area, which is not so easily eroded, but probably also reflects the rapid torrential nature of the incision. Apart from a few exceptions in the extreme east, all the valleys cut into the limestone are now dry. This is due to the development of underground drainage and extensive cave systems. These are discussed in the next section.

CAVE GEOMORPHOLOGY

Of equal importance in understanding the evolution of the Mendip landscape is cave geomorphology. The Mendips contain some of the best-studied caves in Britain, and much of the initial modern work on cave geomorphology, in particular the detailed pioneering studies of D. C. Ford in the 1960s, was undertaken here. The majority of the larger cave systems occur either where streams sink underground at discrete swallets, or where the water emerges as large springs around the flanks of the Mendips. This is well demonstrated in the Cheddar catchment (Fig. 2), where nearly all the major known caves are associated with sinks or springs. Almost all the major swallet caves occur where streams draining the impermeable Old Red Sandstone flow across the generally impermeable Lower Limestone Shale and sink into the Carboniferous Limestone. Also several cave systems, such as Wigmore Swallet, developed where streams flow off the impermeable Mesozoic cover and sink on reaching either the Dolomitic Conglomerate or the Carboniferous Limestone. Descriptions of all the known caves can be found in Barrington & Stanton (1977) and Irwin & Jarratt (1992).

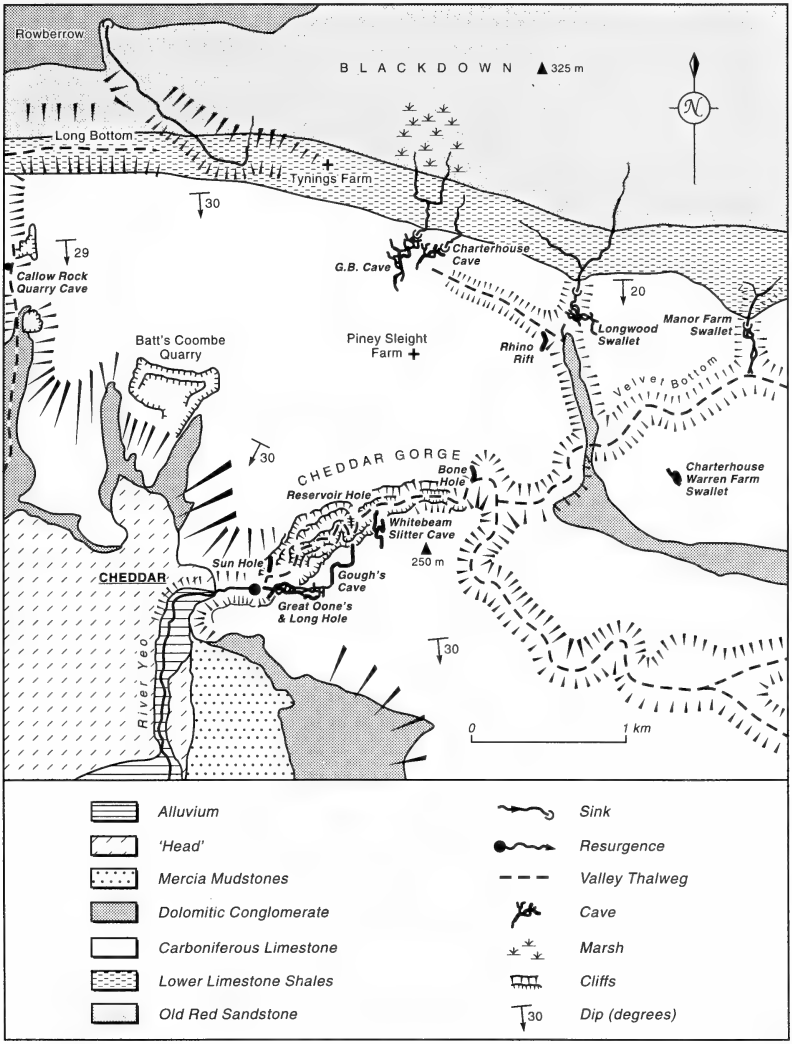


FIGURE 2. Location of the swallet and resurgence caves in the Charterhouse– Cheddar area

SWALLET CAVES

Most of the swallet caves developed at the base of the Black Rock Limestone at the contact with the Lower Limestone Shale. On entering the swallet, the water descends rapidly through generally open ***vadose*** passages which run downdip to the local saturation level, often more than 150 m below the surface, before flowing more gently through predominantly water-filled ***phreatic*** conduits below the water-table to the resurgence. Many of the caves provide excellent evidence that joints in the rock are the dominant factor in controlling passage orientation – up to 83% of the passages in Manor Farm Swallet are joint-controlled (Smart & Stanton, 1974). This control creates complex joint-controlled passage networks developed predominantly down dip, which have been extensively modified by vadose erosion, sedimentation and collapse. The influence of bedding planes is shown by the down dip orientation of many of the passages, while faulting is especially important in the formation of large chambers, notably in Longwood Swallet (Atkinson, 1967), and vadose shafts such as Rhino Rift (Stanton, 1972). The swallet caves commonly display a complex network of influent tributaries which unite into a larger streamway at depth. On reaching the water-table, these streamways become segmented by a series of sumps, often preventing further exploration. The streamways in Swildon's Hole provide an excellent example of this type of cave (Fig. 3).

Phreatic and vadose caves can be easily distinguished by their morphology. Vadose passages tend to be canyon-shaped with small irregular scallops (dissolutional flow markings), while phreatic passages have an elliptical or circular smooth, sculpted morphology, with large rounded scallops. Furthermore, flow in vadose passages is always downhill, whereas in a phreatic passage, in which the water flows under pressure, uphill segments can occur, but the passage always follows the hydraulic gradient. In phreatic conduits aligned down the dip, a looping profile develops as flow initially goes down dip before ascending up joint risers to regain a higher stratigraphic level, until it reaches the level of the resurgence. The crests of the loops can be used to define the level of the watertable. Where flow is along strike, the passage will generally be developed at or close to the watertable, occasionally meandering up and down the controlling bedding plane. This structural control can be seen admirably in the active river passage in Gough's Cave, Cheddar (Fig. 4).

CAVE FORMATION.

The majority of the Mendip caves were first seriously studied by D. C. Ford, who in a series of papers (Ford, 1964, 1965, 1968, 1971) proposed a series of models for cavern genesis and development based on detailed field observations. He suggested that there were three main cave types: **predominantly vadose caves** such as G. B. Cave; **caves developed at or close to the water-table** such as Swildon's Hole; and **deep phreatic systems** such as St. Cuthbert's Swallet, although it could be argued that G B. Cave has not yet been explored to a depth sufficient to display the water-table characteristics seen in the lower part of Swildon's Hole. Ford went on to link these three types of cave into a general model, whereby the main conduit is developed at the water table, which it defines, but also steps up and down in a series of phreatic loops. Furthermore, he proposed that the amplitude of the loops will decrease through time as continued dissolution develops alternative flow-routes. This latter suggestion, based on observations in Swildon's Hole, is not borne out by recent exploration by divers of the modern resurgence caves at Wookey and Cheddar, where phreatic loops in excess of 60 m in amplitude exist. He also defined a fourth type of cave, the 'vadose-invasion cave', characterised by predominantly vertical development. The best example of this type of cave is Rhino Rift, near Charterhouse, which comprises five vertical shafts.

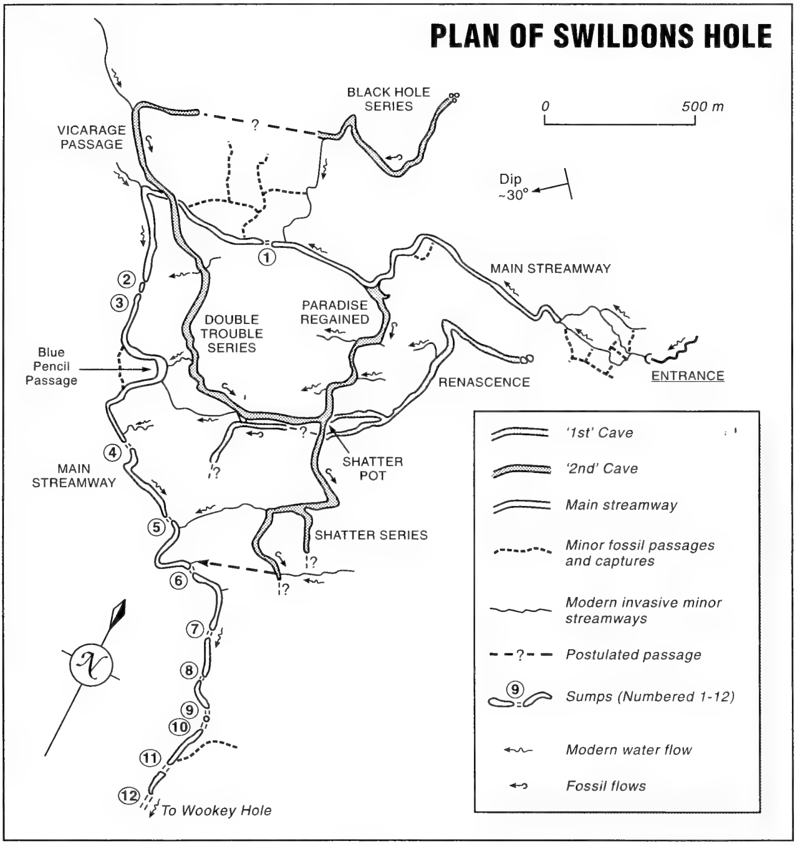


FIGURE 3. Plan of Swildon's Hole, showing successive stages of cave development. The Double Trouble and Paradise Regained passages are abandoned looping phreatic passages.

The caves in the Cheddar catchment, including G. B. Cave and the Gough's Cave complex (Farrant, 1991), are some of the most intensively studied in Britain. The geomorphology of G. B. Cave was first examined in detail by Ford (1964), who chose it as his type example of a vadose drawdown swallet cave (Fig. 5). He envisaged an initial period of phreatic erosion forming a complete passage network, which was followed by alternating phases of vadose drawdown, erosion, clastic sedimentation and

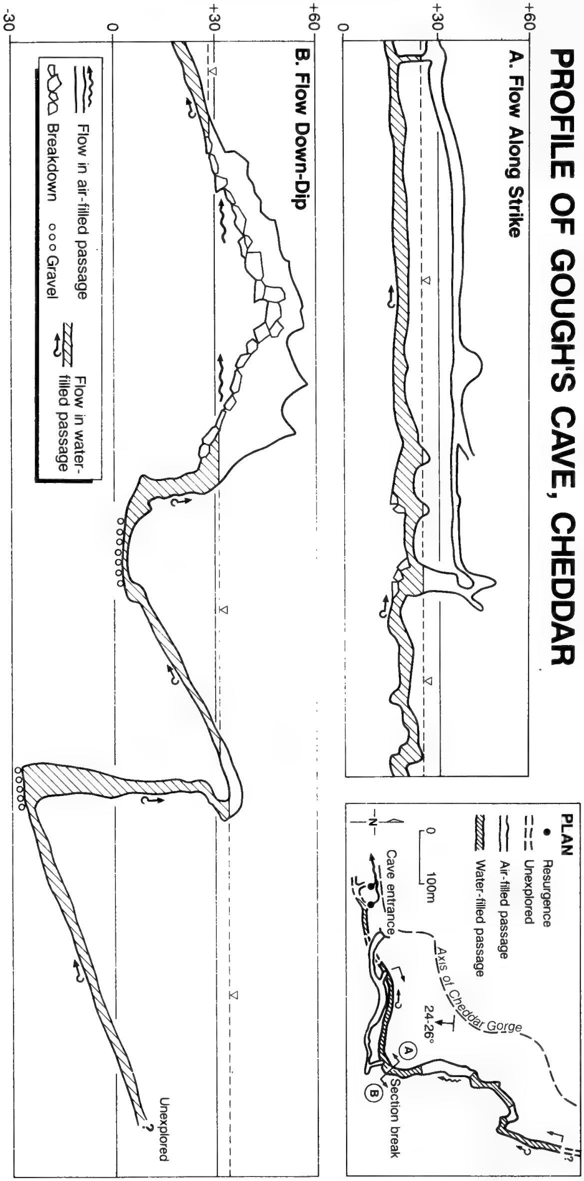


FIGURE 4. Profile along the active river passage in Gough's Cave, Cheddar, showing passage morphology perpendicular to and along strike (from Farrant, 1991). Elevations in metres above sea-level.

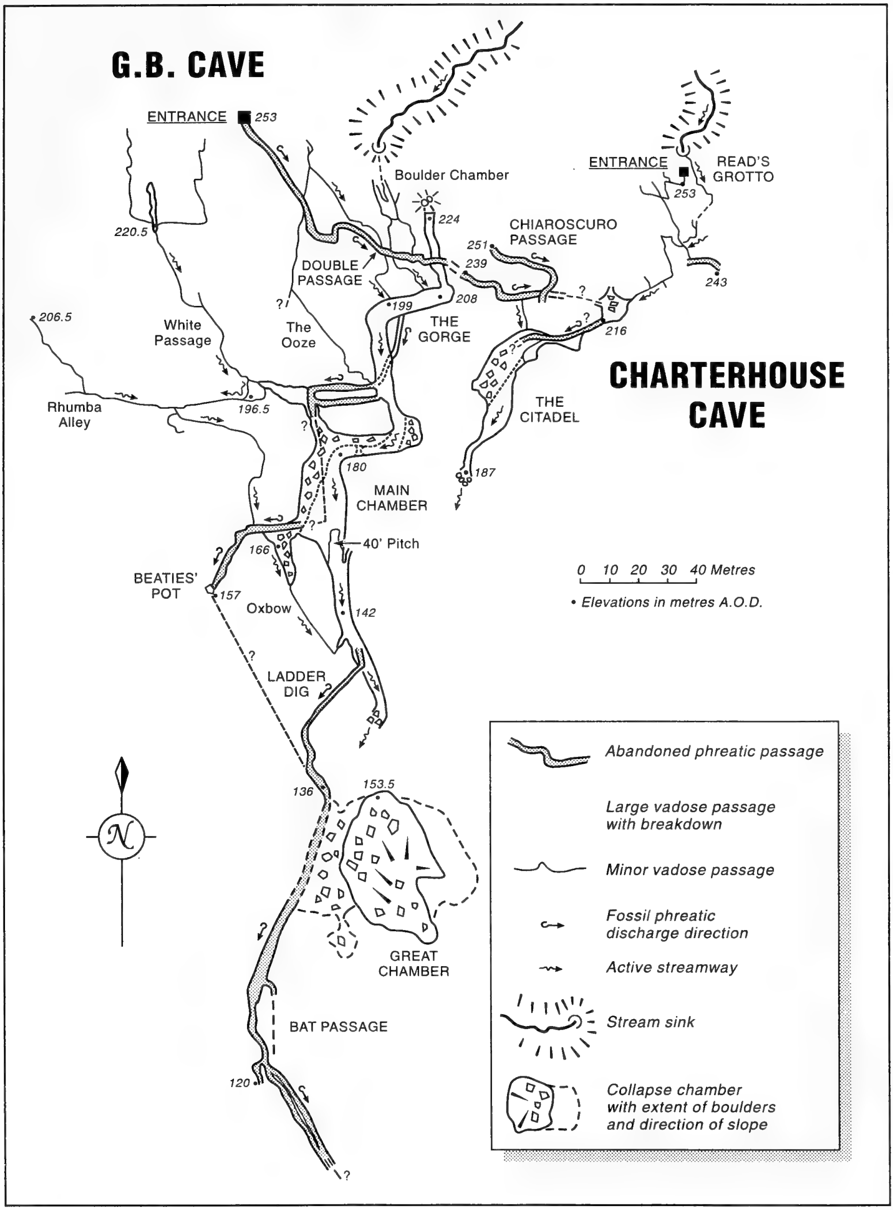


FIGURE 5. Plan of G. B. Cave and Charterhouse Swallet, showing the distribution of phreatic and vadose passage elements. Beaties Pot and the Ladder Dig represent abandoned phreatic distributary passages. Adapted from Ford (1963) and Smart et al. (1984).

deposition of ***speleothems*** (stalagmites, stalactites and flowstones) along the passage elements established during the initial phreatic phase. The filling in of former sinks by clastic material and subsequent development of new ones generates a number of inlet i passages reflecting the large number of sinks which the stream has utilised through time.

In this model, the water table was initially controlled by the lack of mature cave development, but fell rapidly to a stable ***base-level*** once a mature cave system had been established. Thus vadose cave development took place in a vertically extensive vadose zone, the sequence of captures and trenches being unrelated to base-level lowering. The discovery of the neighbouring Charterhouse Cave enabled Smart *et al.*, (1984) to test Ford's hypothesis. They concluded that rather than an initial period of phreatic development, followed by rapid base-level lowering and vadose drawdown, base-level probably fell slowly and intermittently, thus deepening the vadose zone slowly though time. Furthermore, it is clear from observations both in G. B. and at other sites at Westbury-sub-Mendip and in Cheddar Gorge that mature phreatic caves did exist at high level before significant base-level lowering. During base-level lowering, passage morphologies in G. B. Cave and Charterhouse Swallet reflect the transition from phreatic, through paraphreatic to entirely vadose conditions. The fall in the water-table ultimately led to the abandonment of the strike-orientated pressure-fed phreatic conduits in favour of free draining vadose dip-tubes and joint guided rifts.

FALLING WATER-TABLE.

As described previously, the base-level is ultimately controlled by the level of the impounding Mesozoic rocks, which are lowered by valley incision at the resurgence and this consequently has a major influence on cave development. If the level of the resurgence is lowered by erosion and valley incision, many of the cave passages will be abandoned in favour of new, more efficient conduits at a lower level. Thus, over time, given continued erosion, a vertically stacked sequence of cave levels is formed, each corresponding to a former resurgence level, with the oldest at the highest elevation. This is evident in Cheddar Gorge, where Great Oones Hole, Gough's Old Cave and Gough's Showcave are all abandoned former conduits for the River Yeo, which now flows through the recently discovered river passage in Gough's Cave (Farrant, 1991). In these abandoned passages, the elevation of former water-tables can be recognised by noting the position of the vadose-phreatic transition, or by the concordant elevation of the *loop crests* and *aven* terminations.

These former water-table levels are also recognised in the swallet caves where abandoned phreatic passages can be found (such as the Ladder Dig passage in G. B. and the Trouble series in Swildon's Hole), spanning a range of elevations. These passages functioned as phreatic distributaries, developed at or below the water-table, and subsequently abandoned by renewed passage incision at a lower level following a fall in the water-table. Each of these abandoned levels represents a former stage in the development of the cave system. Both Ford (1964) and Smart *et al.*, (1984) recognised at least two major phreatic rest levels in the G. B.–Charterhouse system; one in Double Passage at 238 m and a second just above Ladder Dig at 137 m O.D.. These levels and two further ones at 120 m and 93 m can also be seen in Manor Farm Swallet and

Longwood Swallet to the east. There is slender evidence for a fifth at *c.*70 m in Rhino Rift. Clearly, the accordance of these levels between the swallet caves suggests a common control.

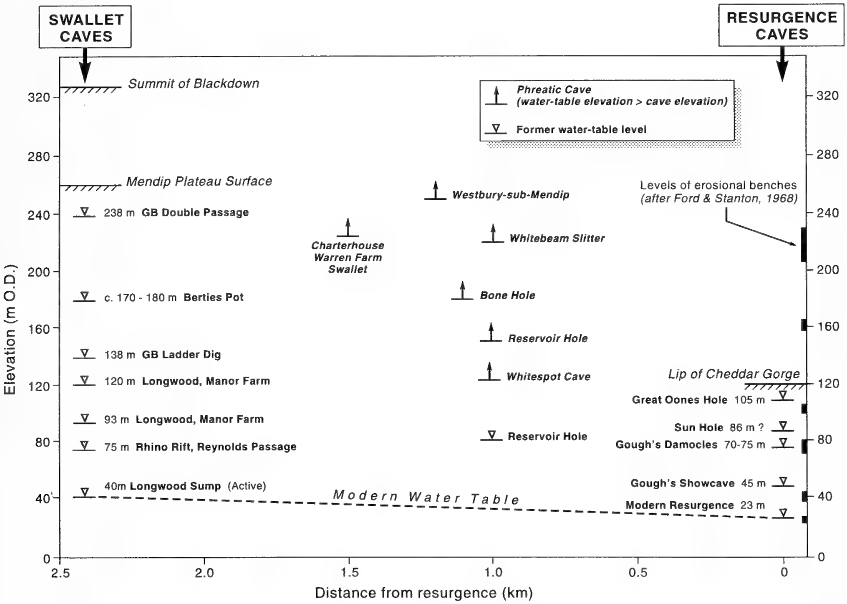


FIGURE 6. Correlation of water-table rest levels between the swallet and resurgence caves (from Farrant, 1995).

These levels also correspond to those seen at the resurgence in Cheddar (Farrant, 1995) (Fig. 6), indicating that base-level lowering at the resurgence is the ultimate control for cave development. Further east, Swildon's Hole contains phreatic levels at 168-183, 140-146, 127 m and below 100 m, but the neighbouring St. Cuthbert's Swallet only has one at 117m and shows a markedly different morphology. This suggests that Swildon's Hole and St. Cuthbert's Swallet, which both now drain to Wookey Hole, drained to different resurgences during much of their development.

CAVE DEVELOPMENT

As well as the passage morphology, useful information on the evolutionary sequence can be gleaned from the sequence of cave deposits such as gravel and speleothem. Extensive accumulations of gravel occur in many of the swallet caves. These are generally coarse, poorly sorted fluvial gravels, often derived from the Old Red Sandstone. They are thought to have been carried into the cave by stream action during periglacial periods (Drew, 1975) prior to complete blockage. Comparatively little clastic material is being carried into the caves under present climatic conditions. Much of the gravel is probably surface material weathered during interglacial periods and then carried into the cave system during the following periglacial episode as the climate deteriorated and slopes became unstable. Evidence for this transport of material can be seen in the temporary exposures at Longwood, where Old Red Sandstone Head overlies *in situ* Lower Limestone Shale.

Many of these gravel accumulations, such as those in G. B. Cave, are capped by or interbedded with stalagmite deposits. The latter form when the climate is warm enough for vegetation to generate higher soil carbon dioxide levels by root respiration and bacterial decomposition. This increases the acidity of the recharge water, allowing more dissolution of the bedrock. On reaching the underlying cave, degassing of the carbon dioxide into the well ventilated cave void occurs, lowering the acidity and causing the precipitation of dissolved calcium carbonate as stalactites and stalagmites. Thus the sequence of gravels and speleothem observed in many caves, such as G. B. Cave and Charterhouse Swallet (Smart *et al.*, 1984) records a series of alternating warm and cold climatic fluctuations.

The sequence of abandoned passages therefore provides a record of the caves' evolution through time, which can be elucidated by detailed examination of the passage morphology and clastic deposits. Furthermore, much of this record can be related to changes in climate and surface topography, about which little would otherwise be known because of the effects of surface erosion and weathering. However, although much is known about the geomorphology of the Mendip Hills, the rate and timing of its evolution is less well understood. When did the present landscape form? How old are the caves? Now that we have identified the main geomorphological features of the Mendips, it is time to examine how the landscape evolved through time.

LANDSCAPE EVOLUTION

The evolution of the Mendip landscape has been widely discussed over the years, but with little quantitative evidence to back up the ideas. Recent advances in dating methods such as uranium series and electron spin resonance dating (ESR) (Smart & Frances, 1991) have allowed quantitative age estimates of cave deposits to be obtained spanning the last million years. Speleothems (stalagmites, stalactites and flowstones) may be dated using both these methods, while undisturbed clays can be dated using palaeomagnetic stratigraphy.

One of the more widely accepted evolutionary models was proposed by Ford & Stanton (1969). They argued that an arm of the sea occupied what is now the Somerset levels during the Pleistocene, and that a series of marine benches were incised into the southern flank of the Mendip Plateau as sea level fell. Incision of the dry valleys and gorges, and the development of cave levels, were linked to the falling sea-level. This interpretation has since been challenged (Stanton, 1985; Farrant, 1995). A more plausible interpretation proposes that the Mendips were exhumed from under the Mesozoic cover as the Jurassic and Cretaceous scarps retreated progressively eastwards (Fig. 7). In this way the old relict Triassic landscape developed on the

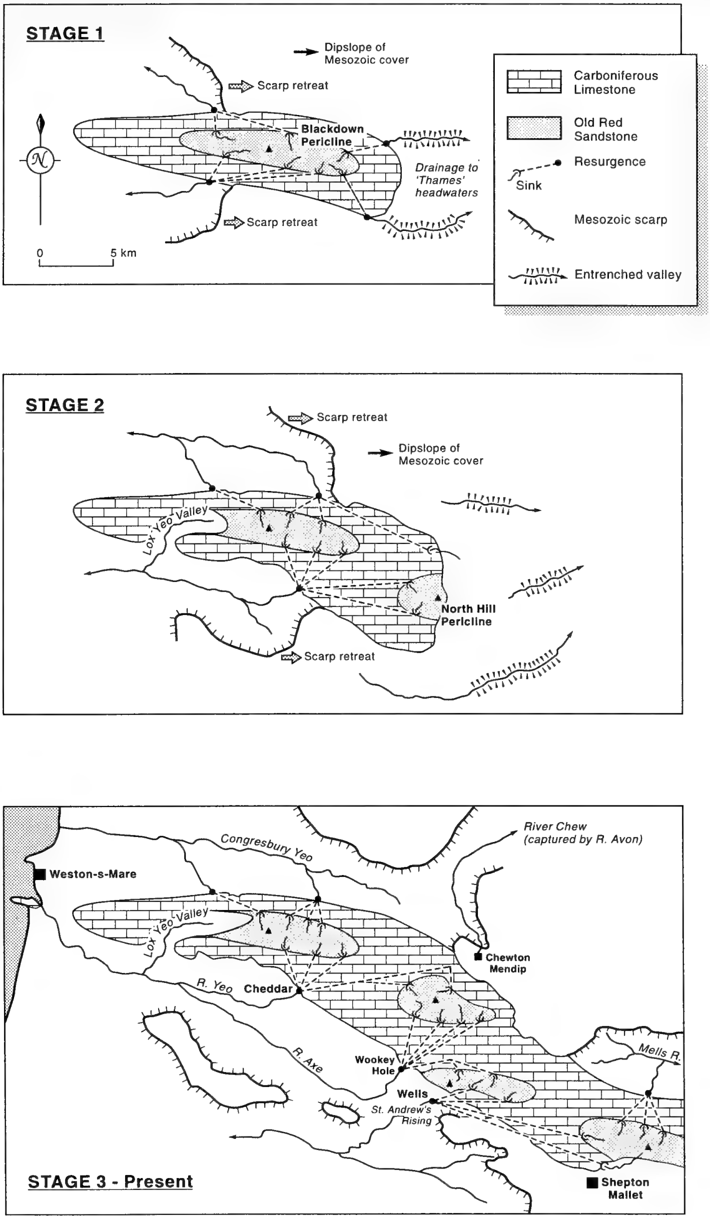
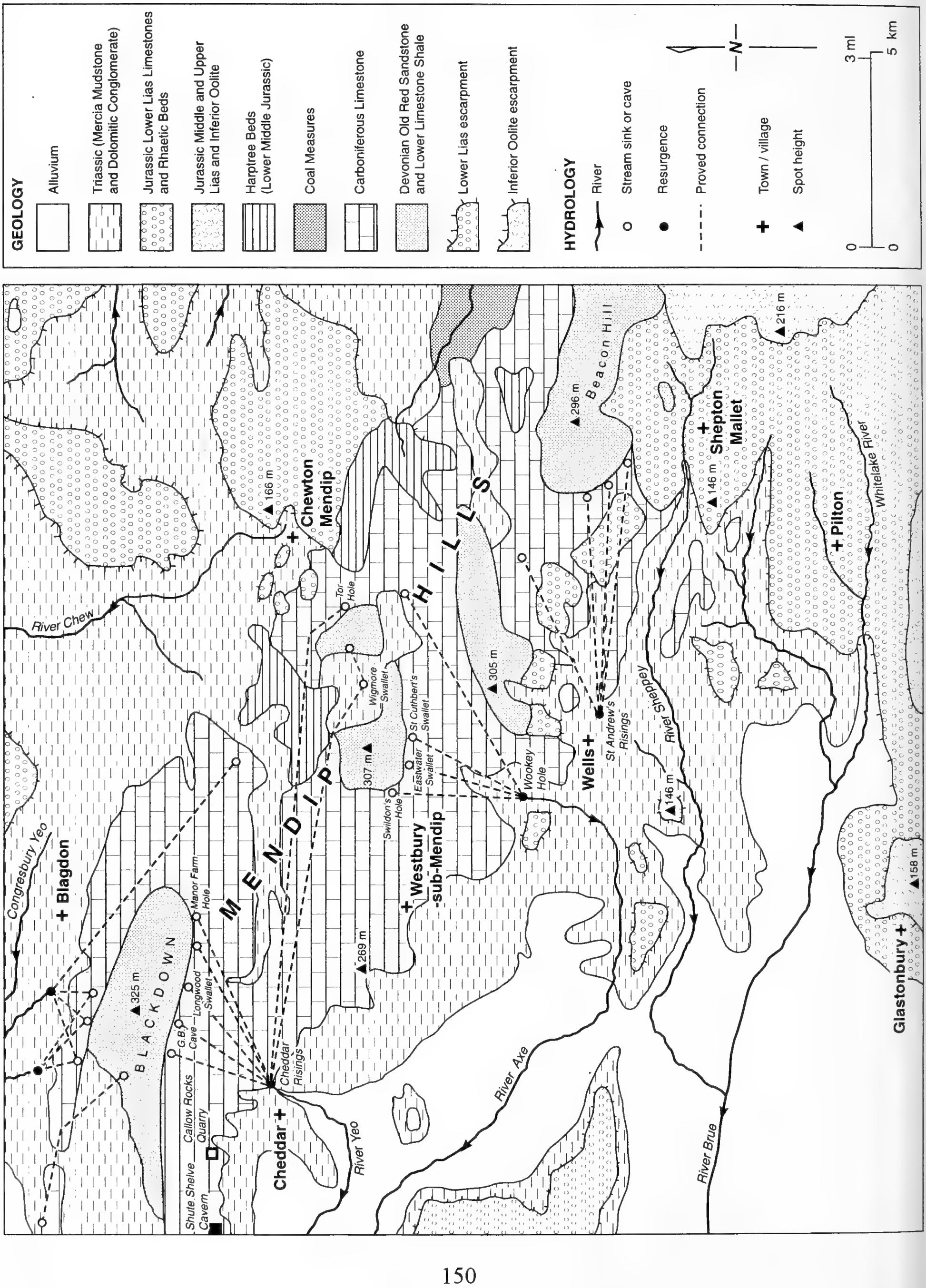


FIGURE 7. Schematic progressive exhumation of the Mendips by scarp retreat, showing the development of the karst drainage system.


GEOLOGY
Alluvium
Triassic (Mercia Mudstone and Dolomitic Conglomerate)
Jurassic Lower Lias Limestones and Rhaetic Beds
Jurassic Middle and Upper Lias and Inferior Oolite
Harptree Beds (Lower Middle Jurassic)
Coal Measures
Carboniferous Limestone
Devonian Old Red Sandstone and Lower Limestone Shale
Lower Lias escarpment
Inferior Oolite escarpment
HYDROLOGY
River
Stream sink or cave
Resurgence
Proved connection
Town / village
Spot height
N
0
3 ml
0
5 km
MENDIP HILLS
BLACKDOWN
Beacon Hill
Blagdon
Chewton Mendip
Westbury -sub-Mendip
Wells
Shepton Mallet
Pilton
Glastonbury
Cheddar
Cheddar Risings
Wookey Hole
St Andrew's Risings
Swildon's Hole
Eastwater Swallet
St Cuthbert's Swallet
Wigmore Swallet
Tor Hole
Manor Farm Hole
Longwood Swallet
G.B. Cave
Callow Rocks Quarry
Shute Shelve Cavern
River Chew
Congresbury Yeo
River Yeo
River Axe
River Sheppey
River Brue
Whitelake River
325 m
307 m
305 m
296 m
269 m
216 m
166 m
158 m
146 m
146 m

Palaeozoic rocks has been gradually revealed, to be modified by modern erosion. In the eastern Mendips, close to the current location of the Jurassic Inferior Oolite scarp, which impinges on the southern flank of the Mendips at Shepton Mallet, the older Palaeozoic rocks have only recently been exhumed and so the karst landscape is still comparatively immature. This is shown by the small size, number and immaturity of caves in this area, such as Thrupe Lane Swallet, and the lack of well-defined karst features such as blind valleys and dolines. Further west, the more mature karst landscape reflects the longer time the limestone has been exposed.

Conversely, western Mendip suffered extensive erosion. The large-scale removal of the Mesozoic sediments revealed Winscombe Vale, originally formed during the Triassic by the preferential removal of the more porous Old Red Sandstone, which is more susceptible to salt weathering than the Carboniferous Limestone in the Triassic desert climate. The limestone is now isolated as two ridges on opposite sides of the pericline, but both contain remnants of once more extensive phreatic systems, such as the Banwell Bone and Stalactite Caves. At the head of Winscombe Vale, lie the recently discovered caves at Shute Shelve (Farrant & Gray, 1993) and Callow Rocks (Farrant, 1995). The former is a major abandoned down-dip phreatic tube, leading to a high level resurgence in the vicinity of Axbridge. The latter is a sediment infilled cavity exposed in a quarry, and contains Lower Lias and Mercia mudstone sediments. These sediments were probably derived from a once extensive Mesozoic cover in the Winscombe area, which probably provided a catchment for the major caves such as Shute Shelve Cavern. Later removal of this impermeable cover and the re-exposure of the ancient Triassic Lox Yeo Valley has captured streams feeding these now abandoned and fossil systems.

At the present time erosion is occurring headward along the outcrop of the Lower Limestone Shale, capturing the runoff from Blackdown and the springs fed from the Lower Limestone Shale, hence diverting the drainage away from the swallets to the surface streams. This can be seen in the Longwood valley where headward erosion had captured flow from the stream sinking into G. B. Cave. This erosion may explain several features, including the lack of a stream sink at Tyning's Barrow Cave, since captured by the surface valley west of Tyning's Farm; and the reduced size of the G. B. stream, compared to that which previously formed the Gorge passage in G. B. Furthermore, the capture of water from the G. B. sink increased the flow down the Longwood valley, so that a deeper valley was incised during glacial periods. This is in contrast to G. B. sink, which occurs in a closed valley, where the existing cave was able to cope with the smaller discharge, with only limited overflow and ponding during glacials.

Further evidence for the scarp retreat model comes from studies of the hydrology of the western and central Mendip Hills. Dye tracing studies over the last 20 years have shown that nearly all the major resurgences in central Mendip are mainly fed by swallets to the east (Fig. 8). In contrast, in eastern Mendip, many resurgences are fed by swallets to the west. This mirrors the surface drainage patterns on the Jurassic cover,

FIGURE 8 (opposite). Geological map of the central southern Mendips. The location of the modern Mesozoic scarps and the westward orientation of the underground drainage can be clearly seen (from Farrant, 1995).

which are generally oriented east-north-east down the dip slope towards the River Frome (Frey, 1975). However, here the situation is complicated by the rejuvenation of the River Frome and its tributaries due to the capture of the former Thames headwaters by the River Avon via the Claverton Gorge (Frey, 1975; Stanton, 1977; Bradshaw & Frey, 1987). This capture caused renewed valley incision in the eastern Mendips in response to major downcutting of the upper Avon. Many of the original east-flowing dipslope rivers, such as the Nunney Brook, were rejuvenated and cut through the Jurassic cover to become superimposed on the underlying Palaeozoic strata. The Mells river has taken advantage of the structural weakness of the Coal Measures and eroded headwards along the strike to the west (Stanton, 1977), creating the Mells valley. Thus much of the surface and underground drainage is still to the east.

However, across most of the region, as the Inferior Oolite and Lower Lias scarps retreat eastward, and the Carboniferous Limestone is exposed, the eastward oriented surface drainage pattern is captured underground to emerge at resurgences developed at the foot of the scarp to the west. Essentially, cave development responds to the changing hydraulic gradient within the Carboniferous Limestone, which is oriented to the west once scarp retreat has affected the area, rather than to the east when the limestone is still impounded. This reorientation is clearly seen in the Chewton Mendip area (Fig. 8). Here, water flowing off the Old Red Sandstone and sinking into the Carboniferous Limestone at Tor Hole would normally be expected to flow down dip to emerge at springs at Chewton Mendip, 2 km to the north-east. However, until relatively recently, the Carboniferous Limestone in the Chewton Mendip area was still buried by a thick cover of Lower Lias clays. This 'dam' of clay had the effect of maintaining a higher water table in this area. To the west, where the Mesozoic 'dam' had been removed, the water table is much lower. Consequently, water sinking at Tor Hole flows down the maximum hydraulic gradient, against the geological structure, to resurge at Cheddar, over 11 km to the west. With continued erosion at Chewton Mendip, the underground drainage may eventually be captured by the headwaters of the River Chew.

This reorientation of drainage may also explain the anomalous nature of Swildon's Hole as outlined earlier, which now drains to the Wookey Hole resurgence where the water reappears at the surface. Swildon's Hole shows a suite of high level abandoned water table passages which, as noted by Ford (1963), match remarkably with those seen in the Cheddar caves, and show no evidence of prolonged impoundment as in the neighbouring St. Cuthbert's system, 1 km to the east, which also drains to Wookey Hole. It is possible that Swildon' s Hole originally drained west to Cheddar. Subsequently, erosion of the impounding Jurassic clays has allowed the development of the Wookey Hole resurgence, thus altering the hydraulic gradient in favour of Wookey Hole, and causing the capture of the Swildon's stream to Wookey. This capture hypothesis also helps to explain the anomalous dye traces from Waldegrave Swallet which flows to both Rodney Stoke Rising and Wookey Hole. The initial drainage was west to Rodney Stoke and is in the process of being captured to Wookey Hole. Similarly, many of the dry valley networks are oriented to the west, such as the headwaters of Cheddar Gorge and Burrington Combe.

Thus, the scarp retreat model explains many of the features of both the surface and underground geomorphology. Modern methods allow the dating of the resurgence caves formed at the foot of the scarp and the associated swallet caves, and so permit estimation of the previously unknown scarp retreat rates. According to the model, the most mature and/or oldest resurgence caves should occur in the western Mendips, with progressively younger and less mature resurgences to the east. Quantification of scarp retreat rates can then permit age estimates for the Mendips to be calculated.

THE AGE OF THE MENDIP LANDSCAPE

Dating of speleothem deposits in G. B. Cave, Longwood Swallet and Rhino Rift near Charterhouse (Atkinson *et al.*, 1978, 1984; Farrant, 1995) has shown that the highest level phreatic passages (238 m O.D.) had developed and were drained by about 800 ka. (800,000 years ago). Similarly, the large cave exposed at Westbury-sub-Mendip (*c.* 246m O.D.) was infilled with sediment earlier than 780 ka (Yassi, 1983). Furthermore, sedimentological and faunal studies (Bishop, 1974, 1982; Andrews, 1990), indicate that the cave was abandoned and the roof had collapsed by the Cromerian interglacial, about 500 ka. This evidence suggests that the limestone was exposed and active cave formation had begun in the Cheddar area by at least 800 ka. Further dating work in the Cheddar caves (Gough's Cave, Great Oones Hole, Reservoir Hole and other caves in the Gorge - Smart *et al.*, 1988; Farrant, 1995), has shown that Cheddar Gorge has been incising at an average rate of about 20 cm per thousand years over the last *c.*400,000 years. Extrapolated back, assuming constant incision rates, this gives an age of about 1.2 Ma for the plateau surface. When dissolutional lowering of the plateau surface is taken into consideration, an age of *c.*1.5 Ma is obtained. This value is similar to that proposed by Stanton (1977), who used data on solutional erosion rates from Atkinson (1971) to calculate the length of time the limestone has been exposed, assuming that the summit of Blackdown represents the elevation of the original limestone surface.

SCARP RETREAT

Further west, dating evidence from Shute Shelve Cavern (Farrant, 1995; Farrant & Gray, 1993) suggests that the base-level here had fallen to below 45 m O.D. before 780 ka. Base-levels in the Cheddar area were probably still over 200 m, indicating a considerable gradient between Cheddar and Shute Shelve at that time. The most likely explanation for this is that the Inferior Oolite and Lower Lias scarps had retreated east as far as Axbridge by at least *c.*80 ka. Thus dating of cave deposits suggests that the Mendip central plateau was exhumed by about 1- 1.5 Ma. The modern scarp now lies just east of Shepton Mallet, and has thus retreated at a maximum rate of about 30 m per thousand years during this time. However, this rate is exceptionally high compared to other rates quoted in the literature (e.g. 0.5 - 6.7 mka^{-1} , Schmidt, 1989). Much of the retreat probably occurred during the many cold periods during the last 780 ka. Many of the Mesozoic clays and mudstones are highly susceptible to solifluction and landslipping under a harsh periglacial climate (Stanton, 1977). Direct glacial erosion can be ruled out as there is no conclusive evidence for glaciation of the Mendip area, except for the possible till deposits near Clevedon (Hawkins & Kellaway, 1971; Andrews *et al.*, 1984; Kellaway, 1991).

The Mendip landscape is still evolving. Natural events such as the floods of 1968 can cause major changes both on the surface and underground (Savage, 1969; Hanwell & Newson, 1970). However, perhaps the biggest modern agents of 'geomorphological' change are the quarry companies. Already, these have removed large chunks of the Eastern Mendips and altered the hydrogeology and, if continued unchecked, threaten to obliterate the million-year-old landscape in a matter of decades.

CONCLUSIONS

It is argued that many of the geomorphological features of the Mendip Hills can be explained by the retreat of a Mesozoic scarp eastwards from the coast to its present location in the Frome-Shepton Mallet area. This retreat progressively revealed the relict Triassic landscape, which was later modified by modern weathering and erosion processes, giving karst features such as caves, depressions, dry valleys and gorges. Dating of cave deposits provides a method of quantifying rates of erosion, valley incison and scarp retreat, and provides estimates for the age of the Mendip landscape. It appears that much of the modern Mendip landscape has developed over the last 1-1.5 million years, following scarp retreat. Further work on dating some of the other resurgence caves such as Wookey Hole needs to be undertaken to give closer limits on scarp retreat rates. Also, a critical re-examination of the older high level caves (such as White Pit at Westbury-sub-Mendip and those in western Mendip) in the light of the scarp retreat model is now due. Similarly, work on the East Mendip caves may help to constrain the timing of the incision of the River Frome and its tributaries.

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GLOSSARY OF TECHNICAL TERMS

Aven: a high, often narrow, rift or shaft ascending vertically or nearly vertically from a passage; commonly formed along joints.

Base-level: the lowest point at which water can escape from the limestone aquifer. On Mendip, this is usually the lowest outcrop of limestone, which is determined by the erosion of the Triassic marls along the flanks of the Mendips.

Doline: a simple closed depression, usually circular or oval in shape, of a wide range of sizes; a swallow-hole or swallet (or in USA, a sink-hole).

Loop crest: the highest section of a phreatic loop, which is the first part to be incised by a vadose stream following lowering of the base-level.

mka^{-1} : metres per thousand years.

Phreatic: refers to passages formed below the contemporary water-table, which are thus totally water-filled. These passages are often elliptical in section.

Scallops: rounded asymmetrical solutional flutings on passage walls. Can be used as an indicator of flow velocity and direction.

Speleothem: any form of secondary mineral deposit found in a cave, but usually calcitic. Includes stalagmites, stalactites and flowstones.

Vadose: refers to passages formed above the contemporary water table by a freely draining stream. Usually they are trench-like, and much higher than wide.

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***Proceedings of the Society*, Volume 55, for 1995.**

Besides the annual reports on botany, invertebrates and mammals in the Bristol District, this issue contains original papers on the Mendip Hills: their agriculture, ancient ponds,botany, botanical history, plant galls, dragonflies, creatures under logs and stones, reptiles and amphibians, mammals, birds, geomorphology, geology and the effects of heavy metals in the soil.
The annual Avon Bird Report is published separately by the Society and Bristol Ornithological Club, whose members receive copies. Others may be bought from Dr H. E. Rose, 12 Birbeck Road, Bristol BS9 1BD.

Printed for the Society by **Healeys Printers Ltd,**
49-55 Fore Street, Ipswich IP4 1JL
ISSN 0068–1040