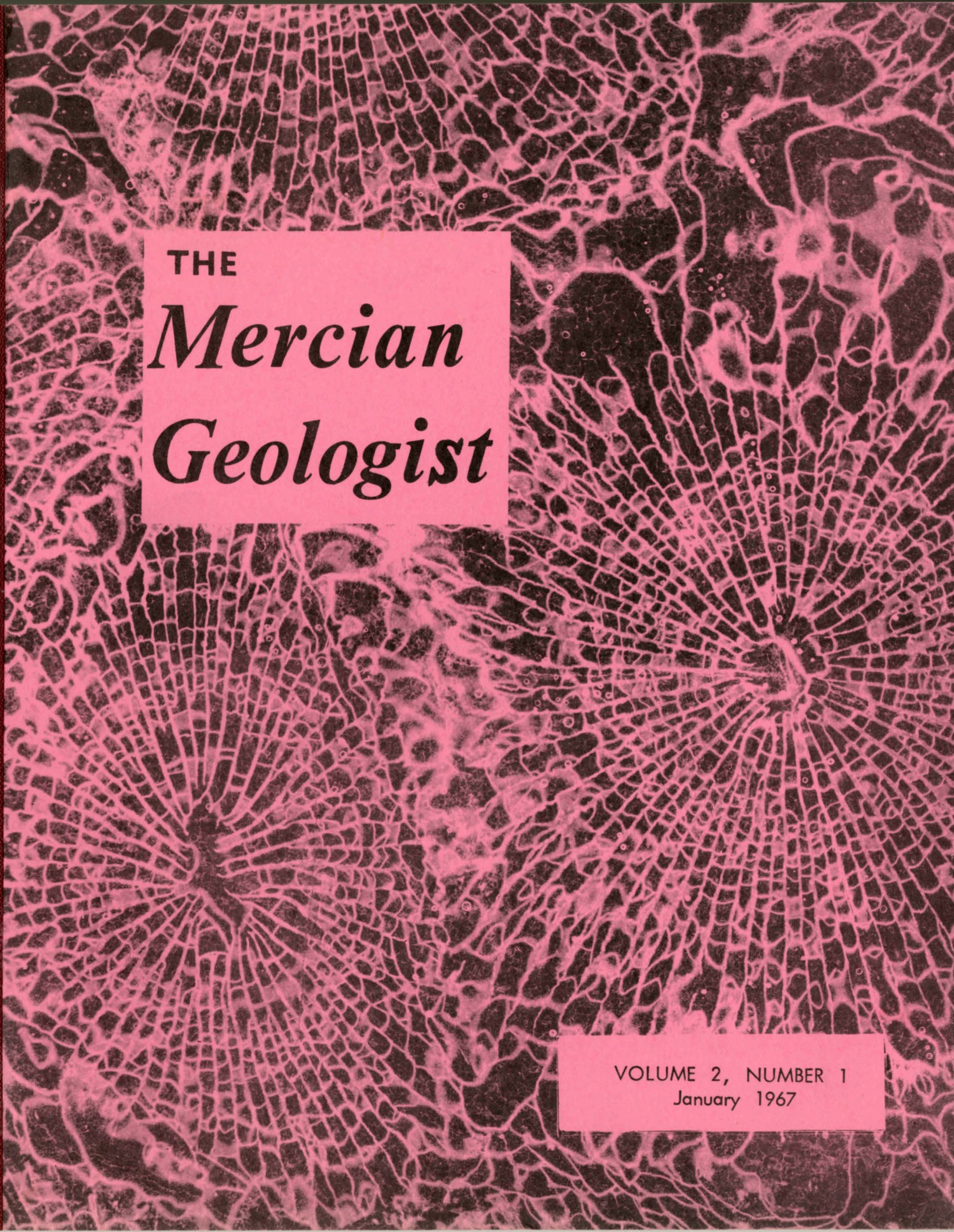
# THE *Mercian Geologist*



VOLUME 2, NUMBER 1
January 1967

# THE MERCIAN GEOLOGIST

JOURNAL OF
THE EAST MIDLANDS
GEOLOGICAL SOCIETY



VOLUME 2. NUMBER 1.

JANUARY, 1967

# ERRATUM

"Mercian Geologist" vol. 1 no. 4, 1966

p. 310. Morris, Table 1. The base of the Roches Grit should approximately correlate with the base of the Chatsworth Grit not with the top of the Kinderscout Grit as shown.

## CONTENTS

# THE EAST MIDLANDS GEOLOGICAL SOCIETY

## Council 1966




Address for Correspondence: The Secretary,
East Midlands Geological Society,
443, Meadow Lane,
Nottingham


The Cover: A transverse section of the Rugose coral *Palaeosmilia regia* (Phillips) $D_2$ Sub-Zone, Visean, Carboniferous Limestone, Coombsdale, Derbyshire.

Section and photograph by Dr. F.M. Taylor

# EDITORIAL

On February 1st, 1967, the East Midlands Geological Society will enter its fourth year of existence. Constitution specifies that the President and Ordinary Members shall not be available for re-election for more than three successive years; thus, at this point in time, the original Council, appointed when the Society was formed, will cease to exist.

Our President, Mr. Peter C. Stevenson, will have already left us, since he is departing in December to take up an appointment with the Geological Survey in Tasmania. Mr. Stevenson was born on 21st May 1928, at Ferring-by-Sea, Sussex. He studied at the University of Birmingham from 1950 to 1954, obtaining the degree of Bachelor of Science. He then took up appointment with Site Investigations Co. Ltd., of Southall, Middlesex: this involved geological work in South, Central and North Africa, Iran, the Persian Gulf region and Iraq. In 1960 he took up appointment as Research Assistanct in the Department of Physics, Royal Holloway College, London, where the successful presentation of a thesis on ground-water problems in the Middle East obtained for him the degree of Master of Science. In 1962 he took up appointment as Lecturer in Geology in Nottingham & District Technical College (now Nottingham Regional College of Technology); since that date, he has been undertaking research on diamonds at Nottingham University under the supervision of Professor W. D. Evans. Mr. Stevenson was a founder member of the East Midlands Geological Society; his steady leadership during the difficult early years has been a major contributory factor in the success of the Society. I am sure he carries with him, to his new home and appointment, the good wishes of all our members.

The original Council of the Society comprised, in addition to the present Secretary, Treasurer and Editor, the following eight members:- Miss F.I. Brindley, Mr. R.E. Elliott, Dr. T.D. Ford, Mr. P.M. Hanford, Mr. D.J. Salt, Mr. P.H. Speed, Dr. F.M. Taylor and Mr. R.J.A. Travis. Of the original Council, five were members of the group whose prior discussions brought the Society to birth - Dr. Frank Taylor, Mr. Edmund Taylor, Miss Brindley, Mr. John Travis and the writer: all others were founder members present at the formal inauguration. Miss Brindley and Mr. Salt resigned from Council at the first Annual General Meeting in 1965, Miss Brindley for family reasons and Mr. Salt on leaving Nottingham: Mrs. D.M. Morrow and Mr. L.J. Willies were elected in their stead. All six remaining original Ordinary members of Council now resign and cease to be available for immediate re-election in that capacity.

It has been decided by Council that the Presidential Address, which normally follows the Annual General Meeting, shall be replaced by a Foundation Lecture, to be given by a member of the Society but not necessarily by the President. This is not a stop-gap decision precipitated by Mr. Stevenson's departure; it is designed to lift from the shoulders of future Presidents, the burden of commitment to preparation of as many as 3 annual addresses - a burden which might well deter amateur geologists from accepting the office. Other proposed changes are increases in subscription rates (rendered unavoidable by the steep rise in printing and postal costs over the last 3 years) and the institution of appointment of local representatives; these matters will have been settled at an Extraordinary General Meeting before this goes to press.

The recent Nottingham meeting of the British Association proved both successful and interesting, though it is to be regretted that so few members of our Society were able to participate. The Society's exhibit, in the Geology Department of the University, attracted considerable attention. Unfortunately, "Mercian Geologist" 1:4 did not appear in time to be featured; as a result of circumstances outside the control of the Editorial Board, publication was delayed for fully three months.

Once again, it is my pleasure to record my thanks for those associated in the production of the current "Mercian Geologist"; to the members of the Editorial Board for their ever-willing assistance and for their support, and in particular to Mrs. D.M. Morrow, Dr. Frank Taylor, and their band of assistants for arranging the collation of the journal; this has brought a considerable reduction in costs. Professor W. David Evans has again generously supported us in our work at many levels; Mr. John Eyett again assisted in photography; and Mr. T. Foster prepared the new frontispiece. Our panel of referees has functioned with its usual anonymous efficiency; and ultimately, of course, all credit lies with the authors of papers, on the interest of whose results depends the reputation of the "Mercian Geologist".

We were distressed to learn, early in November, of the death of the Society's first Honorary Member, Emeritus Professor Henry Hurd Swinnerton. Professor Swinnerton, first Professor of Geology at Nottingham University, was a major figure in research on many aspects of Midlands geology; he was also a great populariser of the subject and his numerous books have been of immense value to many generations of amateur geologists. (An obituary is included in this number). In his passing, English geology has suffered an irreparable loss.

William A.S. Sarjeant

# DEEP WEATHERING, GLACIATION AND TOR FORMATION IN CHARNWOOD FOREST, LEICESTERSHIRE

by

Trevor D. Ford

## Summary

The significance of the deeply weathered zones in the Leicestershire igneous rocks, briefly noted long ago by Bosworth, is discussed in the light of new exposures in working quarries. The deep-weathering is shown to ante-date the Chalky Boulder Clay and is thought to be Tertiary in age. It is shown to have operated only where the impermeable seal of Keuper Marl was broken by erosion; much of the rotted material has been removed by glaciation. Evidence is presented that ice completely over-rode Charnwood Forest and considerably modified the exhumed Triassic mountain tops. Glacial scouring, followed by periglacial mass-movement, has sculptured some of the Charnian crags into tors.

## Introduction

"It may confidently be asserted that the landscape of those parts of the Forest founded upon ancient rocks, the characteristic Upland landscape, is one of Triassic date and character, emerging practically uninjured from its burial (in Keuper Marl)". So said Watts in his classic book on Charnwood Forest in 1947. Here, as elsewhere, Watts made out a case for the landscape of Charnwood Forest being essentially an exhumed Triassic landscape. In so doing, he overlooked the significance of his own record of Boulder Clay to a height of 750 feet O.D. on Bardon Hill. He also ignored the evidence offered by deeply weathered zones in a number of the Charnian outcrops. These had been noted by Bosworth (1912, pp. 37-39), who commented briefly "it is probable that there was intense weathering among these rocks before the glacial period, and that during the glaciation of Charnwood a great deal of the rotten stone was swept away". Bosworth went on to comment "comparison between parts of the rock covered by drift and parts now bare, shows that the decay has gone much deeper since the glacial period." Bosworth briefly described and figured some quarry faces with spheroidal core-stones in matrices of varying degrees of rottenness, but, as he was concerned with the Triassic rocks, he did not discuss the matter further.

Both Watts and Bosworth drew attention to what they called wind-eroded surfaces on the Mountsorrel granite and the South Leicestershire diorites, beneath the unconformable cover of Keuper Marl. Harrison had previously referred to these etched and terraced rocks at Sapcote as part of an ancient sea-beach, apparently of pre-glacial age (1877; photographs opposite pages 44 and 46). In 1884, Harrison (p. 10) noted sand and boulders of unspecified age overlying the sand-polished surface. Fox-Strangways (1903, plate 1 and p. 10) clearly stated that surfaces at Mountsorrel were wind-blasted terraces, and that they were buried in Keuper Marl. Raw (1934), in contrast, maintained that the surfaces at Mountsorrel were the result of erosion by icy winds sweeping across the Pleistocene tundra around the ice sheets, and that they were subsequently buried in boulder clay full of material derived from the Keuper Marl. Wills (1950, p. 120) supported Raw's claim of Pleistocene wind erosion in spite of Watts' (1945) assertion to the contrary, though it must be admitted that Watts was relying on the evidence of the quarry manager some 50 years earlier. Wills also (1950, p. 109) included a map showing the wide trail of erratic boulders derived from Charnwood Forest and carried as far as the Chalky Boulder Clay spread on the Cotswolds. Watts (1947, p. 115) claimed that "foreign" boulder clay with erratics from the north and north-east was to be found only on the flanks of Charnwood, and that ice from outside had not overridden either the central valleys or the heights, in spite of Lucy (1870) having noted a widespread distribution of flints over much of Charnwood.

There are obvious conflicts in the above statements:-

1. Either Charnwood was deeply eroded by ice or it was not.

2. The ice cover of Charnwood was either purely local or came from outside.

3. The wind-eroded surfaces are either buried in Triassic deposits or not.

4. The deep weathering in pre-glacial, or post-glacial, or both.

The implications for the Pleistocene history of Leicestershire carried in the answers to these questions are many, and to this end a resurvey of the nature of all available sections has been undertaken; the results are given below. Most of the original sections were described inadequately and have now been quarried away, but new sections are being provided by continued quarrying, and some of these are described herein.

For the purposes of this study, the region of Charnwood Forest is taken to include the Mountsorrel granite and the South Leicestershire diorite and microdiorite masses.

## Present Sections and Exposures

### (a) Croft

The large quarry in the Lower Palaeozoic microdiorite intrusion cuts into the south-eastern flank of Croft Hill (National Grid Reference SP/510967) which rises to an altitude of 420 feet O.D. The igneous rock is overlain unconformably by Triassic Keuper Marl, with the thicknesses up to about 50 feet in places. The top of the hill is formed entirely in the microdiorite, which thus rises above the Keuper Marl by about 100 feet. At the highest point of the quarry face, the microdiorite is deeply weathered and is in a rotten crumbly condition, to a depth of at least 40 feet in places. In places, the rotted zone passes into less rotten coherent rock forming spheroids, but elsewhere there is a sharp boundary along the prominent inclined joints. In the lower parts of the face, hydrothermal alteration of the igneous rock follows these joints; the most rotten material can be seen to pass downwards into the hydrothermally altered (pinked) rock, which is still hard. The rotted zone is now seen only where there is no cover of either Keuper Marl or glacial deposits. Beneath the cover of Keuper Marl the microdiorite is not rotted, though there are

| N. Europe | Alps | Zeuner | Charnwood |
|---|---|---|---|
| Weichsel | Würm | Last glaciation | Frost action and removal of waste leaving tors |
| | Interglacial | | weathering |
| Saale | Riss | Penultimate | Chalky Boulder clay. Lake Harrison clays etc. |
| | Interglacial | | weathering |
| Elster | Mindel | Antepenultimate | (Bubbenhall Till of Warwickshire) ? |
| | Interglacial | | weathering |
| Preteglen | Gunz | Early | ? deep weathering |
| | Pliocene | | ? |

Text-fig. 1 Correlation table to show the approximate time-scale of the events in Charnwood Forest in relation to the sub-divisions of the Pleistocene used elsewhere.

hydrothermal alteration zones.

The deeply weathered and rotted zone is at present seen on the south-western side of a sharp knob of microdiorite. On the other side of this knob, hard fresh microdiorite has a striated surface with the striations trending from north-east to south-west, in agreement with the trend of later ice movement in the area. The striated surface is covered with about 20 feet of bluish Chalky Boulder Clay.

The deduction to be made from this section is that the knob if igneous rock is effectively a buried roche moutonnee; that ice scoured the upstream (north-east) face and plucked both blocks of hard microdiorite and rotted material from the south-west (downstream) face, before both were buried in till, which has itself subsequently been partly eroded away. The rotting is thus older than the Chalky Boulder Clay, and it is possible to infer that the knob, indeed the whole hill, was once covered in a rotted mantle. A small section of rotted material, with core-stones, is visible in an overgrown quarry on the west face of the hill (SP/509968), underneath a hard rock layer.

In the disused Huncote Quarry (SP 512969) on the north-east side (upstream) of Croft Hill, a few feet of Chalky Boulder Clay are seen to overlie a foot or so of Keuper Marl, covering the igneous rock. In a few places, where the Keuper Marl was breached by pre-Chalky Boulder Clay erosion, there is a limited amount of rotting, penetrating to a depth of 6 feet or so. Thus, here, the inference is of ice from the north-east riding up the hill-face largely on the relatively plastic Keuper Marl, leaving a veneer of marl on the microdiorite.

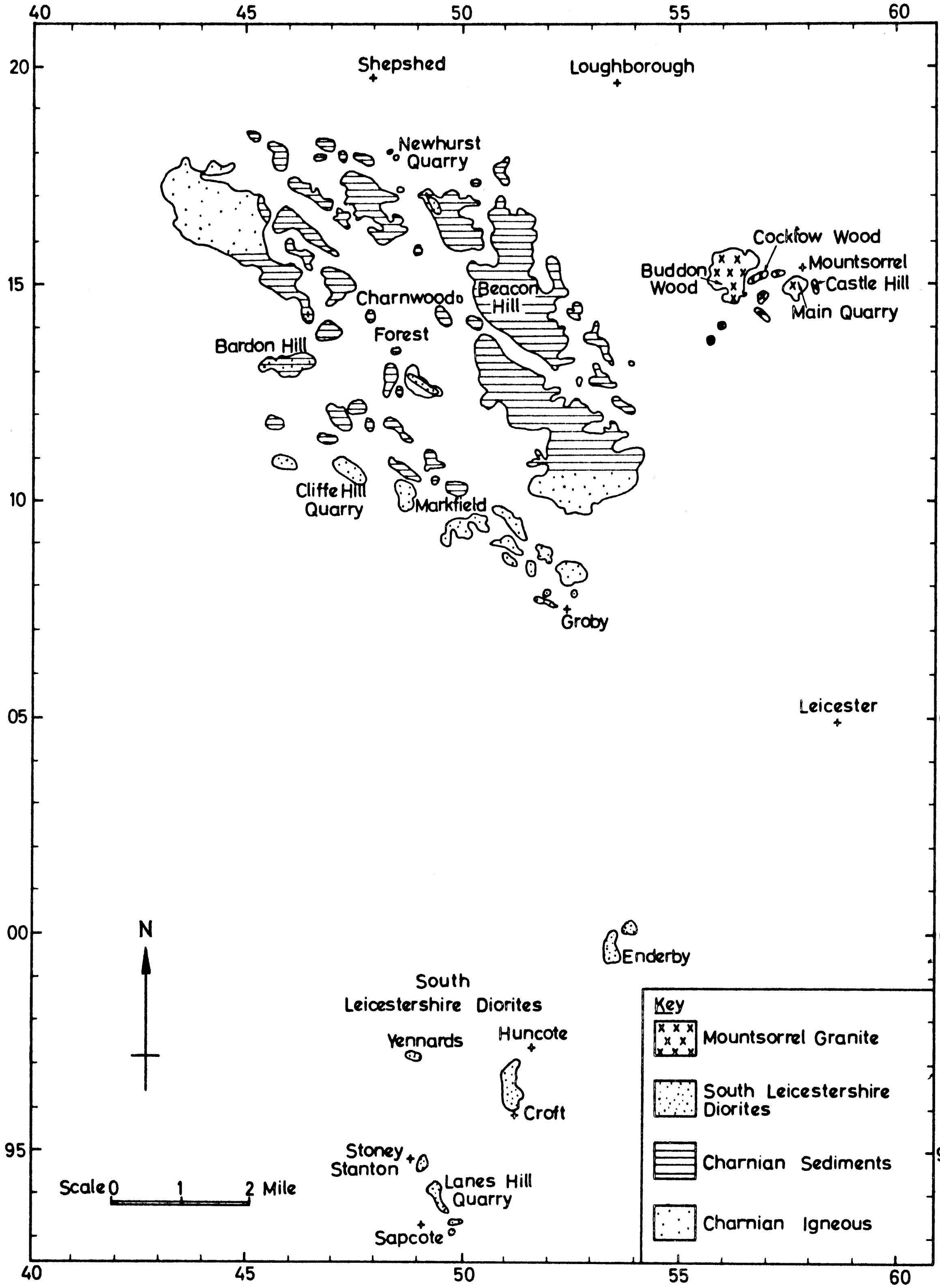
Taken together, these exposures suggest that the whole of Croft Hill acted as a large roche moutonnee, or crag-and-tail feature, from which the post-glacial River Soar has removed the tail.

(b) Sapcote

At the disused Calver Hill Quarry (SP/497932) some 8 to 10 feet of Chalky Boulder Clay is seen to rest on a striated surface of microdiorite. The striations trend N.W. to S.E. Windmill Hill Quarry (SP/497935), ¼ mile to the north, is now flooded and the tops of the faces overgrown, but a section near the top of the north face shows gravelly till overlying a few feet of Keuper Marl. Eastwood et al. (1923) recorded striations trending N.W. to S.E. on a "moutonnee" surface. Granitethorpe Quarry, a little further north, is also flooded but the north face is more accessible and shows an interesting section (SP/493942). The top of the microdiorite is fretted and grooved in a manner very like the photograph opposite page 44 of Harrison's book (1877). His photograph does not show the nature of the filling of the grooves in the fretted surface, but here they are clearly seen to be filled with basal Keuper Breccia, dolomite-cemented, with a few inches of Keuper Marl above. This is, in turn, overlain by gravelly till with flints. A few yards away to the west, the microdiorite has a deeply rotted zone, which clearly follows a hydrothermal vein system downwards between two walls of unaltered rock. The rotted zone appears to have been covered with the gravelly till at one time, and deep-weathering in pre-Chalky Boulder Clay times is again indicated. If Harrison's "Old Sea-Cliff" could be identified today, it might well turn out to be a Triassic wind-eroded surface!

(c) Enderby

A section high on the north-east side of the large Enderby Warren Quarry (SK/540001) shows the microdiorite to have two contrasted surfaces within a few yards of each other. One is a striated surface overlain directly by reddish boulder clay without flints, but containing Bunter pebbles passing up into Chalky Boulder Clay; and the other surface is still covered by about a foot thickness of basal Keuper Marl, with a thin breccia bed at the base showing dolomite cement. Both the sub-Triassic surface and the fragments in the basal breccia show the wind etching noted by Bosworth (1912, fig. 25). No deep-weathering was observed in the Warren Quarry, but in the adjacent disused village quarries spheroidal weathering


Shepshed
Loughborough
Newhurst Quarry
Cockfow Wood
Buddon Wood
Mountsorrel
Castle Hill
Main Quarry
Charnwood
Forest
Beacon Hill
Bardon Hill
Cliffe Hill Quarry
Markfield
Groby
Leicester
Enderby
South Leicestershire Diorites
Yennards
Huncote
Croft
Stoney Stanton
Lanes Hill Quarry
Sapcote
N
Scale 0 1 2 Mile
Key
Mountsorrel Granite
South Leicestershire Diorites
Charnian Sediments
Charnian Igneous

can be seen to penetrate down the hydrothermally altered (pinked) zones in several places - indeed the upper parts of such zones are sometimes almost entirely rotted material with few core-stones. This rotted materal is, however, overlain by angular boulders of relatively fresh rock apparently transported as a solifluxion scree from slightly higher parts of the hill. These sections permit only two conclusions; one, that ice over-rode the hill with sufficient power to scour and striate the microdiorite in places, but also left a veneer of basal Keuper in hollows; and the other, that deep weathering pre-dates the solifluxion scree. The relative dating of the two phenomena is not possible at Enderby alone at present.

(d) Stoney Stanton

The north-east face of the large flooded Lane Hills Quarry (SP/493941) which is now a Lido, shows an important section of microdiorite, Trias and Pleistocene deposits as well as deep-weathering. A reddish Chalky Boulder Clay with very large flints caps most of the accessible face to a depth of 10 feet or so, but none of the surface has been bared to show striations. Beneath the Boulder Clay is a patchy and variable thickness of Keuper Marl, covering basal boulder beds up to 20 feet thick. These boulder beds consist of subangular boulders of fresh microdiorite, patchily cemented with dolomite, which locally penetrates down into joints in the igneous rock beneath.

Most of the igneous rock is fresh, but one section, behind the club house, shows a completely rotted zone following the line of some small hydrothermal mineral veins and an associated hydrothermally altered rock zone downwards. This rotted zone is up to 6 feet wide, with nearly vertical boundaries against fresh rock - and it is overlain by a boulder bed with fresh rock boulders. The conclusion to be drawn here is that this zone was hydrothermally altered in pre-Triassic times, but was sufficiently coherent then to withstand scouring out by Triassic wadi streams. After burial in Triassic deposits it was selectively deep-weathered, the boulders above being both unaffected by hydrothermal action and protected by a skin of dolomite. Since the section was then over-ridden by ice, the deep-weathering must have been pre-Chalky Boulder Clay in age. This is confirmed by a section, near the entrance of the same quarry, which shows incipient spheroidal weathering in a pinked zone, truncated by the boulder clay base, with a few rotted boulders in the base of the latter.

Eastwood et al. (1923, pp. 112-113) recorded a section, now very inaccessible owing to flooding and also very overgrown, in what was then Top Quarry (SP/492942) and is now the north-west corner of Lanes Hill Quarry. In it, several layers of glacial deposits rested on a microdiorite surface with striations trending N.W. to S.E. The lowest till was reddish, without flints, and passed up into blue Chalky Boulder Clay containing sand-lenticles, apparently disturbed by cryoturbation (= disturbance of stratification by frost -heaving).

(e) Cliffe Hill Quarry, Markfield

This is one of the few quarries in Charnwood where the contact between the Charnian (Precambrian) diorite and the metamorphosed mudstones can be seen. The latter, now known as hornstones, tend to have a blocky fracture and slaty texture. Both of these contribute to the filling of Triassic wadis (= gullies eroded by torrential run-off after rare desert storms), which are unusual in two ways. One is the almost complete absence of dolomite cement, normally a characteristic means of identifying Triassic deposits; and the other is that the fills are overlain by some 4 feet of quartz sandstone, with rounded wind-blown millet-seed grains, at the bottom of the Keuper Marls (here only a few feet thick). The Keuper Marl is in turn overlain by some 8 feet of Chalky Boulder Clay. These various deposits are excellently exposed on the eastern side of the quarry where baring operations have taken place (SK/477106).

The most remarkable point of these sections is the presence of completely rotted diorite boulders in the wadi fills and in the quartz sandstone. At times these are enclosed in a fine gravel of rotted diorite fragments. The conclusion here is that the boulders were transported in Triassic times, for no great distance from the adjacent higher outcrops, in an unrotted condition, and that they have since rotted in situ through the unimpeded penetration of ground-waters in a period of deep weathering, before the Chalky Boulder Clay. The fine diorite gravel similarly was transported in a fresh state and has rotted in situ since.

About 100 yards further north along the quarry face, a small section of incipient spheroidal weathering is visible in the diorite.

(f) Bardon Hill Quarry

This large quarry rises from about 650 feet O. D. at the lower rim nearly to the highest summit in Leicestershire on Bardon Hill (912 feet O. D.). The highest rim is at about 850 feet O. D. (SK/458132). The igneous rock is a variety of Charnian "porphyroid" lavas, similar in composition to the diorites but of much finer grain. A little patchy deep-weathering is seen in a zone of structural disturbance on the highest quarry face, but the relationship to the surface is not visible. At the lower parts of the south-eastern face, however, there is an instructive section. The igneous rock is overlain by some 6 to 8 feet of Keuper Marl with a basal breccia, part of which passes into a thin sandstone with millet-seed sand-grains indicating aeolian transport. These Triassic deposits fill a wide shallow "wadi" between two higher rounded knobs of the igneous rock, and several other similar wadis are visible elsewhere in the quarry. This one is, however, overlain by some 10 feet of Chalky Boulder Clay, with lenses of water-laid (englacial ?) sand. This in turn is covered with a solifluxion scree, up to 8 feet thick, of sub-angular boulders in a reddish clay matrix containing small Bunter pebbles and flints. The solifluxion scree can be traced uphill along the quarry rim to well over 800 feet O. D., the flints and pebbles derived from Chalky Boulder Clay becoming less common. The solifluxion scree is last seen close to the lower limit of the clitter of large boulders mantling the summit of the hill.

The conclusions from this section are that Chalky Boulder Clay once extended much higher up the hill than the 750 feet O. D. noted by Watts (1947, p. 21) and that subsequent solifluxion has carried both relics of this boulder clay cover and a large quantity of frost debris downwards from the original summit.

(g) Mountsorrel

Much of the Raw-Watts controversy about wind-eroded surfaces was concerned with exposures no longer available owing to quarrying; the record here is of sections currently visible. Cocklow Wood Quarry (SK/569151) has removed most of the former Hawcliff Hill and shows two interesting sections. Immediately behind the lip of the south side of the quarry, a trench shows some 6 to 8 feet of deeply-weathered and rotten granite with occasional spheroidal core-stones, noted as long ago as 1870 by Lucy (p. 498). The overlying podzol soil has scattered flints and Bunter pebbles, suggesting a former cover of Chalky Boulder Clay or gravel derived from it. The existence of such a cover is further supported by temporary excavations in the field 100 feet to the south, which show Chalky Boulder Clay with a high proportion of Keuper Marl fragments.

The northern face of the same quarry shows some 15 feet of Keuper Marl overlying unweathered, but smoothed, granite. The basal beds of the Keuper Marl enclose numerous rounded and etched boulders of granite, with a surface texture very like that of the wind-fretted boulders noted at Enderby and elsewhere by Bosworth (1912). One such boulder, lying some 6 feet above the base of the Marl, is wind-fretted and is about 3 feet long by a foot thick; it is thus very reminiscent of Fox-Strangways' sketch (1903, fig. 2). A small wadi is filled with boulders, rounded in a manner suggestive of a wadi-bottom rock mill but showing fretted surfaces. In the entrance cutting to the quarry, immediately behind the face just described, the Keuper Marl is seen to be overlain by a rotted granite wash some 6 feet thick, with cryoturbation, and this in turn is covered by reddish Chalky Boulder Clay. Another section in the same quarry shows a scree of angular boulders overlying the rotted granite.

Mountsorrel main quarry (strictly Broad Hill Quarry but almost always known as Castle Hill Quarry) has the upper parts of its faces now rather inaccessible and overgrown, but sections at the south rim show Chalky Boulder Clay overlying both Keuper Marl and transgressing on to the granite. No rotted granite and no "wind-terraced" surfaces are visible, but the wind-fretted sub-Keuper surface was observed to be covered directly with boulder clay at one point.

The presence of rotted granite in the quarry faces is very suggestive of the conditions necessary for tor-formation, as outlined by Linton (1955); and the various naturally outcropping crags of the Mountsorrel granite mass were re-examined with this in mind. Crags above the old Nunckley Quarry (SK/569142) show slight rounding, with a thin rotted zone down joints. Castle Hill itself (SK/580150) has slightly rounded granite boulders at the top of the east face; an old quarry on the south side shows spheroidal weathering. A crag on the north-west slopes of Buddon Wood (SK/558154) shows more tor-like characteristics in that slightly rounded blocks of granite form the crest of a ridge, with evidence of spheroidal weathering and rotted material in joints lower down. The evidence is thus that poorly developed tors do exist at Mountsorrel; others may of course have been quarried away in the past, with no record left.

The precipitous contacts of Keuper Marl and granite at Hawcliff Quarry, described by Fox-Strangways (1903, p. 9-10), are either quarried away or buried in debris. The highest vertical face noted was only 20 feet, and present sections show similar occasional vertical steps in the sides of wadis.

## Boulder Clay in the Charnwood Forest Area

The cuttings in the recently constructed motorway through Charnwood Forest have served to show that Chalky Boulder Clay is much more widespread and thicker than had ever been supposed. Watts' contention that ice went round, rather than over, Charnwood can no longer be supported. Boulder Clay, to a thickness of 30 to 40 feet, was found at altitudes of over 700 feet around Copt Oak. It has long been known that Chalky Boulder Clay occurs at altitudes up to 800 feet O.D. to the east of Leicester, and to the north of the Trent, and it is thus difficult to escape the conclusion that the Chalky Boulder Clay glacier completely over-rode Charnwood Forest, with its highest point at 912 feet O.D. Most of its summits rise no more than 50 feet above nearby boulder clay, and it is difficult to envisage ice less than 50 feet thick depositing a similar thickness of boulder clay; the ice surface must thus have been well above 800 feet O.D. and most probably over 1,000 feet O.D.

The spread of erratics in the south Midlands, noted by Wills (1950, p. 109), indicates that a considerable amount of Charnwood weathered rock waste was transported out of the area; this would have to be restored, at least in volume, in any attempt to reconstruct the pre-glacial Charnwood Forest topography. The contrasted layers of boulder clay noted at Sapcote and Stoney Stanton are associated with striation trending N.W. to S.E., in contrast with the N.E. to S.W. trend under Chalky Boulder Clay elsewhere. These two trends confirm the observations of West and Donner (1956), but still provide no evidence as to whether or not two separate glaciations are represented.

Much still remains to be done in detailed mapping of boulder clay in Charnwood. Outwash sands and gravels and solifluxion screes are known to occur, but no sections with undoubted inter-glacial deposits have been recorded.

## The Cliffe Hill "Rounded Boulders"

About 1937, quarrying on the south-western side of the Cliffe Hill Quarry broke into a fissure and over 50 large, almost spherical boulders rolled out and fell to the quarry floor. A few of these are preserved in the collections of the University of Leicester Geology Department. Almost all are diorite identical to that of Cliffe Hill, but one is a ganister-like sandstone with rootlet markings, almost certainly from the Coal Measures. The boulders are ovoid to spherical and commonly a foot in length; since the fissure in which they were found was near the highest point of outcrop of the diorite, it is clear that they have not been transported any distance, but have been rounded more or less in situ. No details of the fissure fill other than the boulders are known, but verbal information from R. J. King (then a schoolboy) is that the fissure was some 30 feet deep; the interpretation given to him by H. Gregory was that it represented some form of "glacier mill" (i.e. a pothole scoured out by boulders rotating under the force of water falling in a glacial mill water stream). This seems to be the most probable interpretation - milling and rounding of boulders by glacier melt-water near the summit of Cliffe Hill.

The presence of the rounded ganister precludes the possibility of the "rounded boulders" being core-stones from deep-weathering, without further erosion, although some such weathering may have freed the boulders in the first place. It is a pity that the relationship of the boulders to other Pleistocene deposits is unknown. It is just possible that these boulders represented a Triassic wadi rock mill, as in Cocklow Wood Quarry, but the boulder of ganister would be difficult to explain in such a deposit and the surface texture of the Cliffe Hill boulders is unlike the wind-blasted boulders at Cocklow Wood.

## The Sub-Triassic Surface

To quote Watts again (1947, p. 118) "... the upland landscape is one of Triassic date and character emerging practically uninjured from its burial ..." No one will deny that the Charnian peaks, as seen today, represent exhumed Triassic mountain tops, but are they "uninjured", in view of what has been recorded above? Taken literally, Watts' statement infers that the vertical-sided or overhanging crags, such as those on High Sharpley, Altar Stones, Beacon Hill, Hangingstones, Windmill Hill etc., are exhumed crags which had the same shape in Triassic times, possibly originally sculptured in Old Red Sandstone times (Watts 1903, p. 628). But the present sections through the Charnian-Triassic contact provided by quarrying show no such crags, nor were any recorded in any of Bosworth's detailed contour maps of the quarry edges in the early years of this century. Steep faces there may be, but they are the wadi margins, and the areas of inter-wadi Charnian are gently rounded hills, much wider than any of the present day crags. The conclusion becomes inescapable that the present day Charnian peaks are the highly modified remnants of much more gently rounded Triassic hills, and that the modification (injury!) is the result of the combined effects of deep-weathering, glacial scouring, and peri-glacial solifluxion.

The discovery of millet-seed sand-grains forming sandstones in the basal Keuper raises afresh the question of the wind-eroded surfaces at Mountsorrel and elsewhere. Originally ascribed to Triassic sandstorms by Watts (1903, p. 632 and fig. 12), these surfaces were claimed to have originated in Pleistocene times by Raw (1934), who postulated winds blowing across the unvegetated flats immediately after early ice melted, the flats being later covered in the till of a subsequent ice advance.

Watts (1945, pp. 34-36) restated his case that the wind-eroded surfaces were found embedded in Keuper Marl by a quarry manager. Bosworth also recorded numerous cases of wind-fretted boulders and surfaces underneath Keuper Marl. Now, the finding of millet-seed sandstones at Bardon Hill and Cliffe Hill, Markfield, appears to confirm the original opinion of Watts, though it is not impossible that some wind-erosion also took place in the Pleistocene and is no longer visible. As the wind-blasted surfaces were at an altitude of about 320 feet O.D. they would have been about 150 feet up the side of the proto-Soar valley before it was drowned by the pro-glacial Lake Harrison (Shotton, 1953); it is difficult to envisage the wind being able to blow consistently in the direction required by Raw's hypothesis.

## The Charnwood Crags as Tors

Linton (1952) briefly referred to the possibility of the crags of Charnwood having originated as tors like those on Dartmoor, the Cairngorms of Scotland, or the Millstone Grit scarps of the Pennines, i.e. by peri-glacial removal of rotted material resulting from weathering during the previous interglacial.

The present investigation of the Charnwood crags supports Linton's hypothesis. If the solifluxion be accepted as Last Glaciation in age, it is clear that the deep weathering now visible is older than the Last Interglacial, and older than the preceding Chalky Boulder Clay.

The Charnwood crags are in a heterogeneous assemblage of rock types, with the further complication of an exhumed Triassic landscape, where the periglacial removal of loosened and rotted material could take place whatever the date of that loosening and rotting. The Charnwood crags are not all composed of igneous rocks capable of being deeply-weathered as are the granites of Dartmoor and the Cairngorms; some are cleaved and jointed hornstones. Since both of these partings are more or less vertical, and more strongly developed than bedding in many cases, it seems possible that the early plucking by ice could have been developed later by frost action; solifluxion of the resultant loose blocks could leave the tor-like residuals seen today.

## Pleistocene Chronology

It now becomes possible to draw some overall conclusions and to make some suggestions about the more recent phases of landscape evolution in the Charnwood region.

Deep-weathering is clearly more ancient than the onset of the ice which deposited the Chalky Boulder Clay (i.e. Penultimate or Saale Glaciation) but is younger than the Triassic formations. Indeed it has only been found in positions where the Trias is missing or where it is sufficiently porous to have admitted freely moving groundwater (e.g. Cliffe Hill Quarry). In general, the Keuper Marl formed a seal which prevented deep-weathering by virtue of impermeability. Since deep-weathering is generally associated with a warm moist climate, the period of such weathering could be either the Interglacial previous to the Chalky Boulder Clay or any earlier period. It is debatable whether the climate of the Great Interglacial was warm enough for long enough to allow weathering to have penetrated 40 feet at least, as at Croft. Thus it seems reasonable to postulate that the deep-weathering took place in the Tertiary, as has been suggested for comparable occurrences in north-east Scotland by Fitzpatrick (1963). He suggested that the Cairngorm Tors may have resulted from Pliocene deep-weathering.

The Croft and Mountsorrel occurrences would then lie well below the altitude of some of the Pliocene erosion surfaces (cf. Rice, 1965, p. 109). The Chalky Boulder Clay at Sapcote and Enderby passes down into a red till without flints, covering a surface with N.W. - S.E. striations. This may either represent the Bubbenhall Till of Shotton (1953) and thus the Elster Glaciation, or it may simply be an early phase of the Saale Glaciation ( cf. West and Donner, 1956). Clearly more study of this problem is required.

It is notable that the present examples of deep-weathering are confined to the coarser-grained granitic or dioritic rocks, and that no examples have been seen in hornstones or lavas. It is important, however, to realise that the examples seen are the few which survived glacial erosion, and that a much more general spread of rotted material probably once covered the igneous rocks.

Whatever the date of the deep-weathering, the next phase in the modification of the Triassic hilltops was clearly glaciation. The ice which deposited the Chalky Boulder Clay over-rode Charnwood, striated rock surfaces here and there or left a veneer of Keuper Marl, and spread erratic boulders far and wide over the south Midlands. In so doing, there is little doubt that it removed both some of the Keuper Marl cover and most of the rotted material, as Bosworth suggested, also accomplishing some degree of plucking to form roches moutonnées. Since ice-flow would tend to concentrate in the valleys of Charnwood, both at the onset and during the waning of the glaciers, it follows that the flanks of the exhumed Triassic peaks would have been scoured, plucked and thus steepened by ice erosion. The ice-dammed Lake Harrison (Shotton 1953) must have lapped at the southern flanks of Charnwood Forest, but no evidence of its effects or deposits is yet forthcoming, though stoneless clays have been noted in unpublished work by J.F.D. Bridger.

In the Last Interglacial, the present River Soar became established and the deposits of the previous glaciation were gradually removed. This removal probably includes the formation of the stream-captures and gorges in Charnwood, and these also require further investigation in detail. The Last Glaciation (Würm) saw no ice in Leicestershire, but it was a phase of cold periglacial conditions. The exposed peaks of Charnian were subject to frost action; solifluxion carried detached blocks away from the steep flanks (with their strong jointing and cleavage), finally leaving the cores of both the ancient hornstone hills and the igneous intrusions standing up as near-vertical crags or tors. Little alteration of these has taken place since.

## Acknowledgements

The constant stimulation by discussion both in and out of the field by R.J. King and R.J. Rice is gratefully acknowledged. Thanks are also due to the quarry owners for allowing visits to their quarries.

T.D. Ford, B.Sc., Ph.D., F.G.S.,
Department of Geology,
The University,
Leicester

## REFERENCES

BOSWORTH, T.O. 1912 The Keuper Marls around Charnwood, Leicester. Leic. Lit. & Phil. Soc. Leicester. 129 pp. 47 figs. & pls.

EASTWOOD, T., GIBSON, W, CANTRILL, T.C. & WHITEHEAD, T.H. 1923 The Geology of the Country around Coventry. Mem. Geol. Surv. E & W., 149 pp.

FITZPATRICK, E.A., 1963 Deep-weathering of granite beneath and around till. J. Soil. Sci., Vol. 14, pp. 33-43.

FOX-STRANGWAYS, C. 1903 The Geology of the Country near Leicester. Mem. Geol. Surv. E & W., 122 pp., Pls. I & II

HARRISON, W.J. 1877 A Sketch of the Geology of Leicestershire and Rutland. Sheffield 67 pp., 12 pls.

1884 The Syenites of South Leicestershire. Midld. Nat. Vol. 7, pp. 7-11 and 41-42

LINTON, D.L. 1952 Comments on Prof. Hollingworth's note (on the use of marginal drainage in the recognition of unglaciated enclaves). J. Glaciol. Vol. 2., pp. 108-9.

1955 The problem of tors. Geogr. J., Vol. 121, pp. 470-487

LUCY, W.C. 1870 Note on the occurrence of the Post-Pliocene drift of Charnwood Forest. Geol. Mag., Vol. 7, pp. 497-499.

RAW, F. 1934 Triassic and Pleistocene surfaces on some Leicestershire igneous rocks. Geol. Mag., Vol. 71, pp. 23-31, Pls. II & III

RICE, R.J. 1965 The Early Pleistocene Evolution of North-eastern Leicestershire and parts of adjacent counties. Trans. Inst. Brit. Geogrs. Pubn. No. 37, pp. 101-110.

SHOTTON, F.W. 1953 The Pleistocene deposits of the area between Coventry, Rugby and Leamington, and their bearing on the topographic development of the Midlands. Phil. Trans. Roy. Soc. Ser. B., Vol. 237, pp. 209-260

WATTS, W.W. 1903 A buried Triassic Landscape. Geogr. J., Vol. 21, pp. 623-636

1945 Leicestershire Climate in Triassic time. Geol. Mag., Vol. 82, pp. 34-36.

1947. Geology of the Ancient Rocks of Charnwood Forest. Lit. & Phil. Soc. Leicester. 160 pp., 43 figs. & pls.

WEST, R.G. & DONNER, J.J. 1956 The Glaciation of East Anglia and the East Midlands: a differentiation based on stone-orientation in the tills. Quart. J. Geol. Soc. Lond., Vol. 112, pp. 69-92

WILLS, L.J. 1950 The Palaeogeography of the Midlands. University of Liverpool, 2nd edition, 147 pp., Pls. I - V.

Manuscript received 5th July, 1966

# THE NAMURIAN SUCCESSION IN THE AREA AROUND THE COMBES BROOK, NEAR LEEK, NORTH STAFFORDSHIRE

by

Paul Geoffrey Morris

## Summary

A succession of Upper Carboniferous (Namurian) rocks outcropping in the vicinity of the Combes Brook, near Leek, North Staffordshire, is described. An account of certain fossil localities occurring in the area is given and correlations of some of the fossil bands are made with other localities in the central and southern Pennines.

## Introduction

The Combes Brook rises near Ipstones Station (SK 03055214), some four miles south-east of Leek, in North Staffordshire (see Text-fig.1). The brook flows in a north-north-westerly direction until Gorsthead Mill (SK 02405351) is reached. Here it swings to flow in a west-south-westerly direction. Finally, near Cloughmeadow Cottage (SK 00725268), the stream flows generally in a south-south-westerly direction.

The positions of the localities mentioned in the text are indicated on the map (Text-fig. 1). Exact positions are listed at the end of the paper, with grid references as an additional check.

The area has received only passing attention up to the present time. Indeed, the only references to faunas occurring here are those of Wardle (1862) and Hull and Green (1864; 1866). These authors recorded goniatites and other fossils from a locality downstream from Cloughmeadow Cottage.

## The Stratigraphic Succession

A geological map of the Combes Brook area is presented in Text-figure 2. Because of faulting and the absence of diagnostic faunas some outcrops are not easy to date, but a generalised succession is given in Text-figure 3.

The lowest beds represented in the area, the Morredge Grits, were named by Challinor (1929, p.111) after the prominent escarpment which they form. Hudson (1945a, pp. 320-321) redefined the term Morredge Grits and divided them into an upper group, the Thorncliffe Sandstones, a middle group, the Crowstones, and a lower group, the Onecote Sandstones. The latter unit was shown to be of Upper Viséan ($P_2$) age. Hudson considered that one of the sandstones of the Onecote Sandstones group formed the top of Morredge.

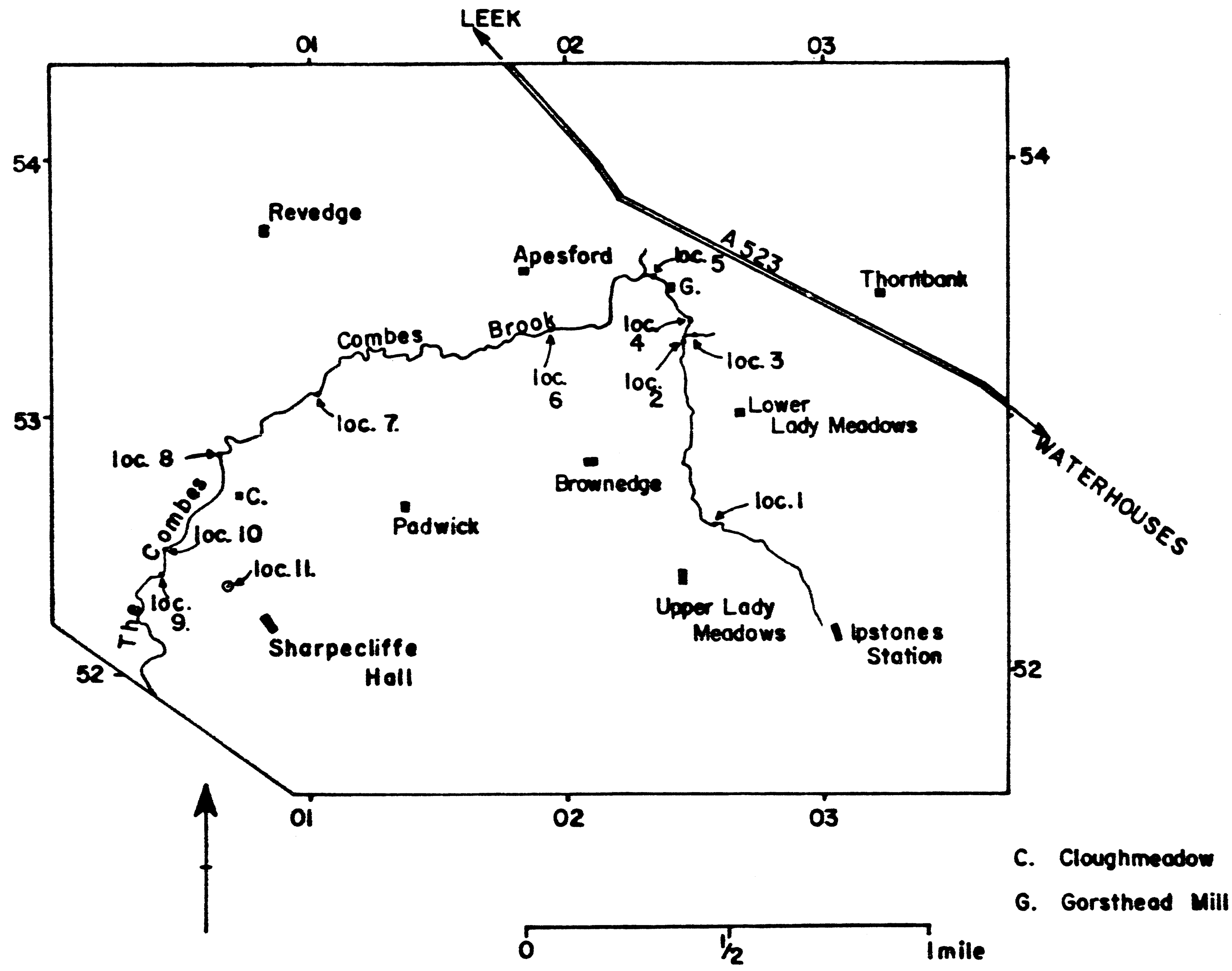



Fig. 1. Map showing fossil localities and other points mentioned in the text.

Recent investigations in the Morredge area (Morris 1966) have shown that the Onecote Sandstones do not outcrop on Morredge. In addition, Holdsworth (1964) has demonstrated that the term Crowstones has been used in widely differing senses for rocks of Namurian age in the southern Pennines.

The Thorncliffe Sandstones and "Crowstones" of Hudson are not well exposed except upstream of Thorncliffe village. Therefore, since the two groups of rocks cannot be separated on a geological map, there seems to be little point in introducing a new stratigraphic name for the "Crowstones" on Thorncliffe Bank or for retaining the term Thorncliffe Sandstones. The two terms are therefore abandoned in favour of the term Morredge Grits, which is also restricted to beds of Lower ($E_1$) and Upper ($E_2$) Eumorphoceras age.

The Morredge Grits are succeeded by mudstones and shales containing, near their base, the goniatite Homoceras cf. subglobosum Bisat (Hester 1932, p. 38). The outcrop from which this species was collected is no longer exposed and only a few other fossiliferous localities occur in the shales, none of which have yielded diagnostic goniatites. The mudstones and shales are succeeded by sandstones and shales, which are here called the Ipstones Edge Sandstones and which will be shown to be of Upper Namurian ($R_1$) age.

Consequently, the mudstones and shales underlying the Ipstones Edge Sandstones, which have been referred to by Hester (1932, p.43) as the Churnet Shales, can only be regarded as equivalent to a small part of the Churnet Shales succession described by Challinor (1929, pp. 111-113) in the area north of Thorncliffe, north-east of Leek, the type area of the Churnet Shales. In this latter area the Churnet Shales range from the top of the Upper Eumorphoceras ($E_2$) Stage to the base of the Roches Grits which belong in the Upper Reticuloceras ($R_2$) Stage.

## Descriptions of selected sections

### The Combes Brook

Between Ipstones Station and Gorsthead Mill, the ground to the east of the brook is flat, low-lying and underlain by mudstones and shales covered by a thin veneer of boulder clay. However, the ground on the western side of the Combes Brook rises abruptly, presenting a marked feature. Outcrops in the brook are not abundant and, for some 200 yards or so downstream from Lower Lady Meadows farm (SK 02685300), they consist solely of mudstones, often heavily iron-stained and badly shattered, together with thin ironstone bands. At only one point (locality 1) are fossils found upstream of Lower Lady Meadows; here, fragments of pectiniform lamellibranchs occur.

Elsewhere, notably in the river cliffs lying E.N.E. of Upper Lady Meadows (SK 02435238), the mudstones are of interest for the occurrence of thin lenses of coal, usually no more than 1/4" thick. These mudstones also contain fragments of slightly crushed, petrified plant stems. Downstream from Lower Lady Meadows the mudstones give way to thin siltstones, which are overlain by a further sequence of shales and shaly mudstones. The siltstones are well exposed at locality 2 where these beds are faulted. The fault at this locality runs more or less along the strike, and though the fault plane is not well exposed, the fracture can be seen to be a high angled reverse fault. Only a few yards downstream from locality 2, two further fossiliferous horizons (localities 3 and 4) occur in mudstones which are dipping in an easterly direction. These localities are only sparsely fossiliferous. The mudstones at locality 3 yields a small fauna consisting of the lamellibranchs Leiopteria longirostris Hind and Posidoniella sp. Coalified plant fragments are not uncommon, including pinnules of Neuropteris sp.

Locality 4, a river-bluff a short distance downstream from locality 3, consists of some 13 feet of ferruginous mudstones. The lowermost 30" of the beds are sparsely fossiliferous, the remainder of the sequence being barren. The fauna collected from the base, consists entirely of small lamellibranchs and includes:

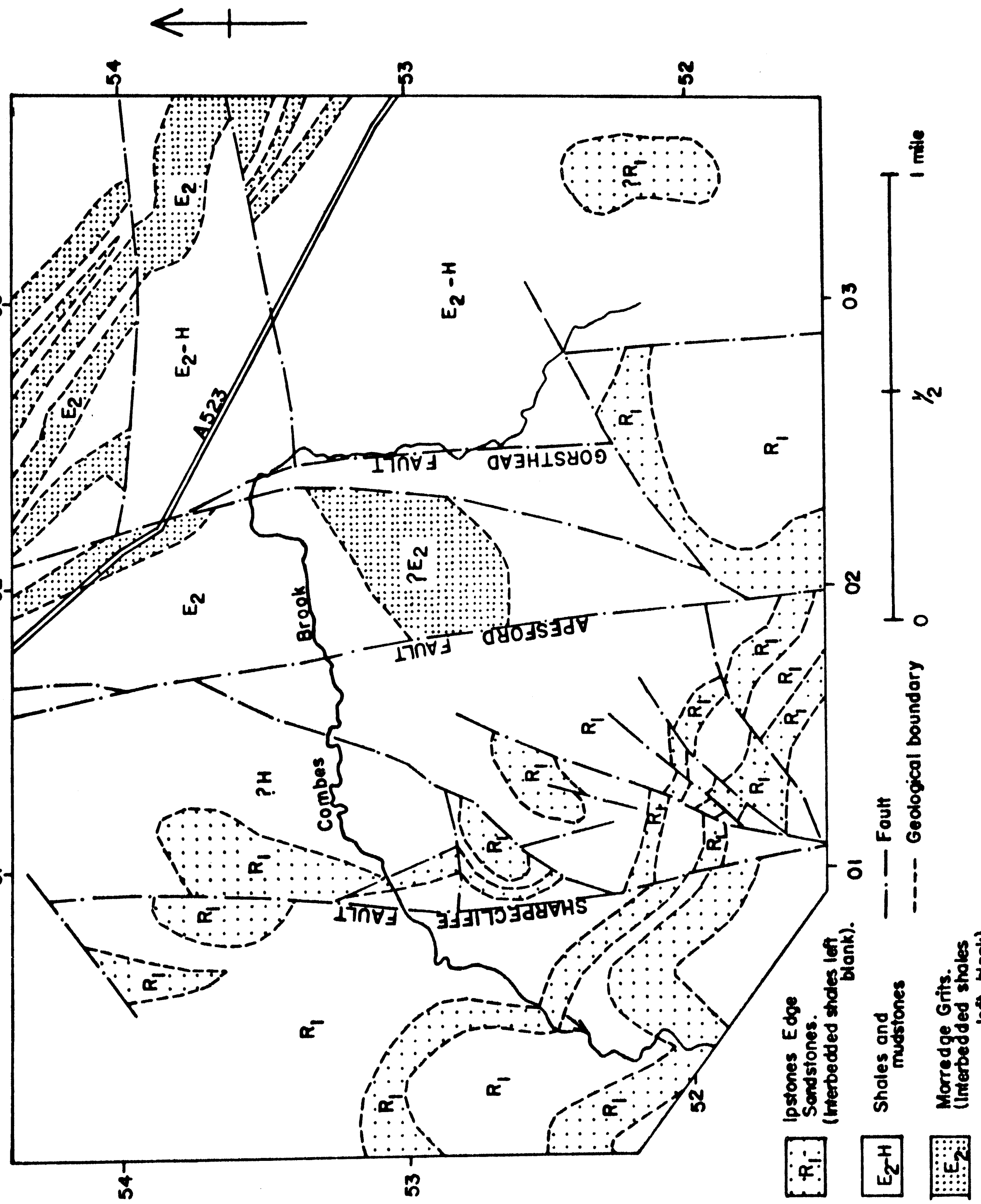



Fig. 2. Geological map of the area adjacent to the Combes Brook.

Posidoniella cf. variabilis Hind

? Posidoniella sp.

Myalina sublamellosa Etheridge

Leiopteria longirostris Hind

Actinopteria sp.

Pectiniform fragments

The entire fauna occurring at this locality is composed of small specimens.

No further exposures are seen downstream until the footbridge at Gorsthead Mill is reached. Here (locality 5), alongside a small weir, is an exposure in which the following succession is seen:

| | | |
|---|---|---|
| 3. | Massive, fine-grained sandstones separated by siltstone partings into four bands | 9' 6" |
| 2. | Shales. Poorly exposed, apparently barren and with very thin sandstone bands | 13' 10" |
| 1. | Fine-grained sandstones | 1' 10" |

——————— Fault plane obscured by vegetation ———————

Sandstones

Beds 1, 2 and 3 dip steeply east-north-east; the beds on the western side of the fault plane dip steeply west-south-west. The direction of the dip on the eastern side of the fault plane is the same as that at locality 2, although the amount of dip at the latter locality is rather less. The faults seen at localities 2 and 5 are regarded as the same fracture. It is likely that this fault continues southwards along the western bank of Combes Brook; the marked feature seen on this bank is therefore possibly a fault scarp. The presence of a fault would also account for the very marked easterly dips seen in the exposures near Lower Lady Meadows.

The age of the beds to the east of this fault line is problematical.

On the northern side of the Waterhouses - Leek road the uppermost beds of the Morredge Grits occur; their apparent top is marked by a very abrupt change of slope. This boundary is probably high in the Upper Eumorphoceras ($E_2$) Stage. Thus the succeeding beds may belong to higher $E_2$ horizons and to the succeeding Homoceras Stage. The sandstones outcropping on the east side of the fault around Gorsthead Mill are thought to represent some of the highest beds of the Morredge Grits. The mudstones forming the ground between the fault scarp and Thornbank farm (SK 03215347) would therefore represent horizons high in the Upper Eumorphoceras ($E_2$) Stage and possibly in the Homoceras (H) Stage. Palaeontological evidence for such a conclusion is unfortunately still lacking in the Combes Brook area. Diagnostic goniatites have not been found, but the lamellibranch faunas seen at localities 3 and 4 may represent horizons somewhat higher than those met with at other Upper Eumorphoceras Stage localities in neighbouring areas on Morredge.

Continuing downstream from Gorsthead Mill footbridge, a succession of mudstones, silty shales and siltstones are seen with a general westerly dip. Occasional dips at variance with the main W. - S.W. trend indicate the presence of slight folds or minor faulting. The siltstones and thin sandstones outcropping in the river bluff due east of Apesford (SK 01805355) commonly show ripple marks and worm tracks. Similar tracks may also be seen on sandstone slabs in the banks of a small stream about 100 yards west of the ford at Gorsthead Mill. Exposures downstream of the Apesford river bluff become fewer and smaller, consisting predominantly of mudstones. One of these mudstone outcrops (locality 6) to the south-west of Apesford yields rare fragmentary specimens of the lamellibranch Actinopteria cf. persulcata with plant fragments. Lithologically, the mudstone has a characteristic "soapy" texture.

No exposures of any significance occur downstream from locality 6 until a sharp bend in the brook is reached in Sixoaks Wood. Here, a mudstone outcrop (locality 7) some 30' high contains large but virtually barren bullions. Fragmentary lamellibranchs (Posidoniella sp. and Posidonia sp.) occur with rare orthocone nautiloids.

Exposures become more abundant and prominent downstream from locality 7. As the stream passes through Sixoaks Wood it cuts down through massive sandstones. Outcrops of these sandstones show a westerly dip of 70° - 80° and the sandstones can be traced as a distinct ridge running south-south-east through Sixoaks Wood. In the upper part of this wood, between Padwick (SK 01345263) and Cloughmeadow Cottage, sandstones with a gentle south-easterly dip outcrop as a capping to the hill. A small E - W fault is thought to separate the sandstones in the northern and southern parts of the wood. A further fault also separates the steeply dipping sandstones from those extending towards the wood from the neighbourhood of Revedge (SK 00825370). Further sandstones occur downstream of the weir in Sixoaks Wood where the brook bends sharply southwards. It is considered that the line of the Sharpecliffe Fault (see fig. 2) passes between this series of sandstones and those forming the ridge in Sixoaks Wood.

A further series of large shale and mudstone outcrops occur downstream from Sixoaks Wood but only one (locality 8) is fossiliferous. At this point, some 200 yards N. N. W. of Cloughmeadow are shaly mudstones and thin earthy limestones. The succession here is:

| | | | |
|---|---|---|---|
| 5. | Iron-stained shales and shaly mudstones with occasional plant fragments | 15' | 0" |
| 4. | Thin, earthy, fossiliferous limestones | 0' | 3" |
| 3. | Shaly mudstones, calcareous mudstones and thin earthy limestones | 5' | 2" |
| 2. | Fossiliferous earthy limestone | 0' | 6" |
| 1. | Shales with small unfossiliferous nodules | 3' | 0" |

Band 2 yields the lamellibranchs Dunbarella sp., Posidoniella variabilis Hind, Myalina sp. and Posidonia sp. and a goniatite, Dimorphoceras (Paradimorphoceras) sp. nov. From band 4 the following have been obtained; Dunbarella sp., Posidoniella sp. and Dimorphoceras sp., the latter represented by casts showing external ornament only. This ornament closely resembles that seen in the specimens from Band 2; the forms from the bands 2 and 4 are therefore regarded as conspecific.

The vertical distribution of known species of Paradimorphoceras is limited, with large parts of the stratigraphical succession in which the sub-genus is unrepresented. For instance, the earliest member of the sub-genus is the Upper Viséan ($P_2$) form Dimorphoceras (Paradimorphoceras) marioni Moore, which is succeeded in the Lower Namurian ($E_1$) by D. (P.) plicatile Moore. No further species are known until D. (P.) looneyi (Phillips) appears in the Kinderscoutian ($R_1$). Therefore, although the form Dimorphoceras (Paradimorphoceras) sp. nov. appears from a sutural point of view to be intermediate between D. (P.) plicatile and D. (P.) looneyi, its exact stratigraphic position cannot be deduced. The field evidence suggests a horizon in high $E_2$, or H, but no more accurate assessment can be made at present.

In the stream running down from Backhill Wood towards Cloughmeadow Cottage are a number of outcrops of mudstones and shales. Occasional thin calcareous and ferruginous silty bands occur. The only organic remains so far seen consist of indeterminate plant fragments. The beds maintain a steep dip of

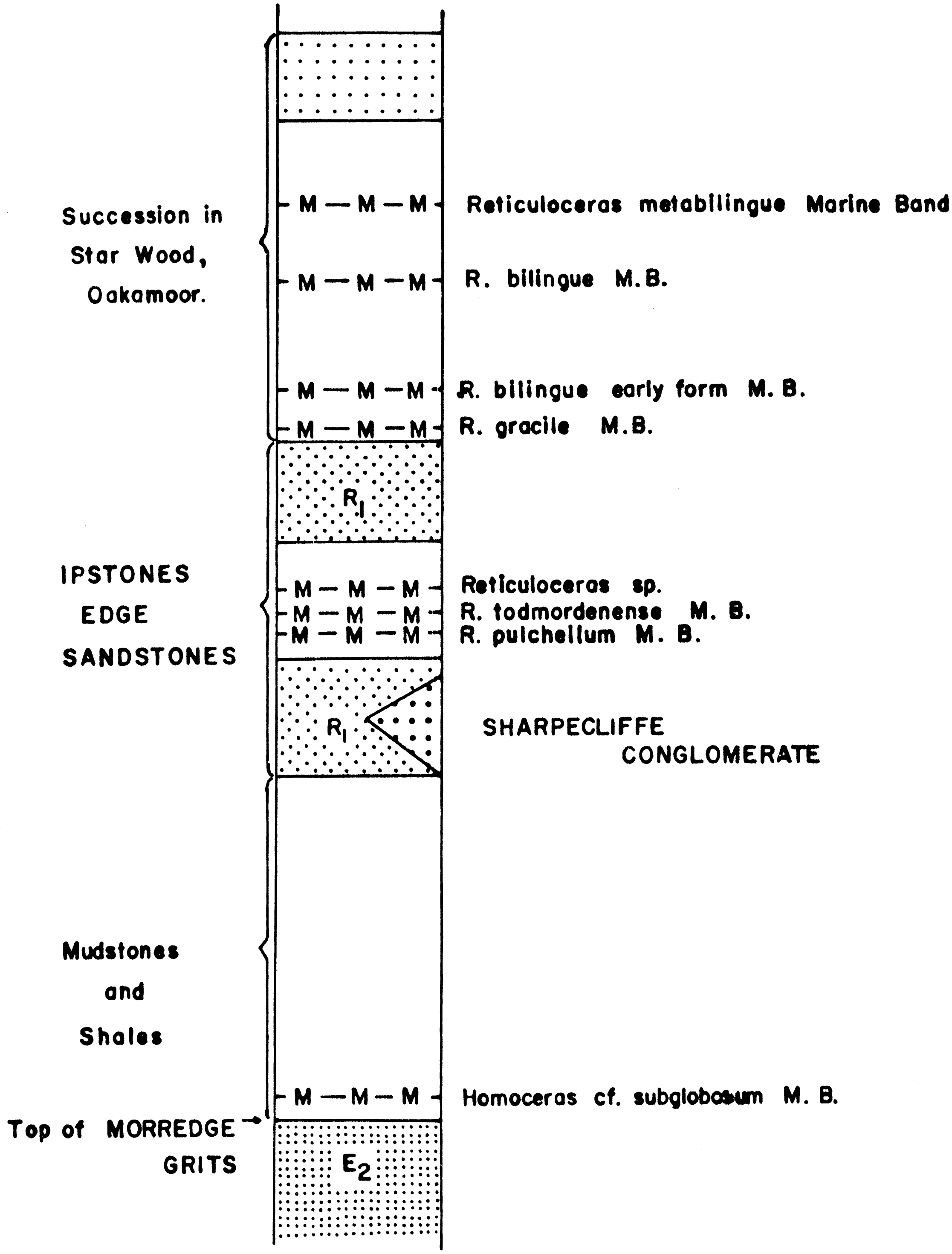



Fig. 3. COLUMNAR SECTION (not to scale) SHOWING THE SUCCESSION IN THE COMBES BROOK AREA AND THE ADJACENT AREA TO THE SOUTH.

about 45° at W 25° S along the whole course of the stream and underlie the sandstones of Ipstones Edge, shown later to be of Lower Reticuloceras ($R_1$) age. The mudstones in the vicinity of Cloughmeadow Cottage, then, are of lowermost $R_1$ or possibly of Homoceras (H) Age.

A short distance downstream of Cloughmeadow, in the wood known as The Combes, the lowest band of the Ipstones Edge Sandstones outcrops. Further downstream, at a point (SK 00435238) some 100 yards below Horsley's Stone, is a thin sequence of badly weathered black shales and mudstones (locality 9) containing three marine bands. The fossils in these bands are commonly pyritised; the bedding planes and joint surfaces are usually strongly iron-stained, presumably a result of the oxidation of the pyrites. Exposure at the time of examination of this river cliff was not good and the cliff itself has been almost completely hidden by a land-slip, the result of storms in the winter of 1960-61.

Bullions consisting for the most part of fine-grained argillaceous limestone, but occasionally with large amounts of coarsely crystalline calcite, gradually weather out and may be found either *in situ* or in the stream bed. The succession at this point is:-

| | | | |
|---|---|---|---|
| 6. | Poorly exposed mudstones, weathering into iron-stained laminae. Some bands remain relatively unstained and retain a blue-grey colour. These beds become soft and rather greasy to the touch. | 5' | 0" + |
| 5. | Mudstones. Faunal band C | 0' | 9" |
| 4. | Poorly exposed mudstones similar to those of band 6 | 9' | 0" |
| 3. | Mudstones weathering out into shaly laminae. Crowded with fossils, mostly goniatites with some lamellibranchs. Fossils become sparse towards the top. Occasional bullions. Faunal band B. | 3' | 2" |
| 2. | Unfossiliferous blue-grey clay | 0' | 10" |
| 1. | Mudstones cleaving along certain planes with difficulty. Mostly unfossiliferous but the top 8" yield goniatite impressions. A single bullion. Faunal band A. | 3' | 8" |
| | | 22' | 5" + |

The Combes does not appear to have attracted much attention from geologists, the main reference occurring in the account of North Staffordshire given by Hull and Green (1866). These authors record the following fauna, presumably from locality 9 of the present account:-

| | |
|---|---|
| Goniatites | *Glyphioceras micronotus* ?<br>*G. reticulatus*<br>*Glyphioceras* sp. |
| Nautiloids | *Orthoceras cinctum* Sowerby<br>*Nautilus subsulcatus* |
| Lamellibranchs | *Anthracoptera* sp.<br>*Aviculopecten papyraceus* Goldfuss<br>*Cardiomorpha* sp.<br>*Ctenodonta gibbosa* |

| | |
|---|---|
| Brachiopod | Discina nitida Phillips |
| Worm tubes | Spirorbis carbonarius M'Coy |
| and | Annelid tracks |

In a slightly earlier reference to the area, Wardle (1862), writing in John Sleigh's "Ancient History of Leek", mentions the fossils of The Combes, some of which are figured on Plate 4 of the above history.

Of the fauna recorded by Hull and Green, the occurrence of several fossils has not so far been confirmed in the present work; these include the lamellibranchs Anthracoptera sp., Cardiomorpha sp. and Ctenodonta gibbosa Salter (= Nucula gibbosa Fleming 1828). "Solid" coiled nautiloids have not been collected and fragmentary internal casts of nautiloid whorls preserved in mudstone have proved to be indeterminate. Orthocone nautiloids are not uncommon in the mudstones of faunal band B, locality 9. Very small incomplete specimens have been collected from bullions but these have proved to be generically indeterminate.

Vague tracks are occasionally seen and spirorbids occur, usually as very small specimens associated with fragments of plant stems. Dunbarella rhythmica (Jackson) is not uncommon in the mudstones and is presumably the form recorded as Aviculopecten papyraceus Goldfuss by Hull and Green. The goniatite fauna is an extremely interesting one, with the genera Dimorphoceras, Homoceras and Reticuloceras well represented. Fossils recorded from the three faunal bands are as follows:--

Faunal band A

| | |
|---|---|
| Goniatites: | Reticuloceras pulchellum (Foord)<br>R. "davisi" (Foord and Crick)<br>Reticuloceras sp. nov.<br>Homoceras aff. striolatum (Phillips)<br>? Homoceratoides sp.<br>Dimorphoceras sp. |
| Lamellibranchs: | Dunbarella rhythmica (Jackson)<br>Posidoniella sp. |
| Brachiopod: | Orbiculoidea nitida (Phillips) |

Faunal band B

| | |
|---|---|
| Goniatites: | Reticuloceras todmordenense Bisat and Hudson<br>R. paucicrenulatum Bisat and Hudson<br>R. umbilicatum Bisat and Hudson<br>R. pulchellum (Foord) - a late form<br>Reticuloceras sp. - (see Bisat and Hudson 1943 Pl. xxiv fig. 5)<br>Dimorphoceras sp. |
| Lamellibranchs: | Dunbarella rhythmica (Jackson)<br>Posidoniella laevis (Brown) |
| Brachiopods: | Orbiculoidea nitida (Phillips)<br>Lingula sp. |

Worm tubes: Spirorbis sp.

Conodonts: Hindeodella sp.

Faunal band C

Goniatites: Reticuloceras sp.
Homoceras sp.
Dimorphoceras sp.

Lamellibranchs: Posidonia obliquata (Brown)
Caneyella aff. rugata (Jackson)
Dunbarella sp.
Posidoniella sp.

The conodonts (Hindeodella sp.) occurring in faunal band B are commonly present as an amorphous calcium sulphate, presumably the result of attack by sulphuric acid derived from the oxidation of pyrites, on the original calcium phosphate.

Bisat and Hudson (1943) divided the Lower Reticuloceras Stage into six zones. Later, Hudson (1945b) emended this sub-division so that the original six zones now become sub-zones thus:-

Table 1

| Stage 1 | Zone | Sub-zone |
|---|---|---|
| Kinderscoutian or Lower Reticuloceras Stage | R. reticulatum (= $R_{1c}$) | R. co-reticulatum |
| | | R. reticulatum |
| | R. eoreticulatum (= $R_{1b}$) | R. nodosum |
| | | R. dubium |
| | R. inconstans (= $R_{1a}$) | R. todmordenense |
| | | R. inconstans |

Ramsbottom (in Ramsbottom et al. 1962 p. 125) has suggested that the zonal index of Zone $R_{1a}$ should be changed to Reticuloceras circumplicatile (Foord) because the species R. inconstans cannot be identified with any certainty.

The Reticuloceras todmordenense sub-zone is only thinly developed in the Central Pennines. For instance, at Lumbutt's Clough and Salmesbury it is about six feet thick (Bisat and Hudson 1943, p. 431). The sub-zone contains a fauna which included R. todmordenense, R. paucicrenulatum, R. aff. umbilicatum and occasional Homoceras aff. striolatum. The fauna from the outcrops seen in The Combes at locality 9 allow these beds to be accurately dated (see Table 1). Faunal band B of locality 9 in The Combes may be placed in the R. todmordenense sub-zone. The band (A), below, contains a fauna including R. pulchellum and Homoceras aff striolatum. Bisat and Hudson (1943, p.430) record a fauna from Wharfedale, Yorkshire and from the Ashop road cutting at Edale, Derbyshire, in which R. pulchellum occurs. These authors place the fauna in their R. inconstans zone. It therefore appears that the faunas from Wharfedale, the Ashop cutting and Band A in The Combes can be correlated. Faunal band A is placed at or just below the junction of the R. inconstans and R. todmordenense sub-zones.

Band C in The Combes contains a fauna with Reticuloceras sp. and Homoceras sp., the latter being fairly common. This fauna may lie within the R. dubium sub-zone.

The succession at locality 9 in The Combes is the only one seen in the area south - and south-east of Leek which yields a Kinderscoutian goniatite fauna. It is therefore of some importance in dating the underlying and overlying strata. Mapping has shown that the mudstones outcropping at locality 9 are some 40 feet thick. They are overlain and underlain by sandstones, which are well exposed in the valleys sides and also to the east of Sharpecliffe Hall, where the lower bed locally becomes conglomeratic.

Sandstone development is unusual at this horizon in the Central Province. The lower part of the Lower Reticuloceras ($R_1$) Stage consists of shales only, in the Longnor area of North Staffordshire, in North Derbyshire, in the Huddersfield - Halifax area and in the Wharfe Valley. Indeed, the only areas where sandstones are recorded are in the Ingleton - Clapham and Knoaresborough Forest areas. In the former area, the Clapham Grit Group may represent the whole of the H, $R_1$, $R_2$ and $G_1$ Stages of the Namurian (Bisat and Hudson 1943, p. 400). In the Knaresborough Forest area, beds lying immediately below shales containing Reticuloceras of the R. inconstans group are known as the Upper Follifoot Grit.

The top of the sandstone group, outcropping in The Combes and forming Ipstones Edge and here referred to as the Ipstones Edge Sandstones, is taken to lie at the base of the Reticuloceras gracile Bisat Marine Band. This band occurs in Star Wood, Oakamoor, and is succeeded by a series of mudstones with a sequence of marine bands containing R. bilingue (Salter) early form, R. bilingue (Salter) and R. metabilingue Wright (see Morris 1966). The Ipstones Edge Sandstones are therefore to be equated with the Kinderscout Grit Group of the Central Province.

## The area to the south of The Combes Brook

The area may conveniently be divided into two for the purpose of description. Firstly, in the south-west is the high ground of Ipstones Edge in the vicinity of Sharpecliffe Hall. Secondly, between Ipstones Edge and The Combes Brook is the slightly less elevated ground on which stand the farms Padwick and Brownedge.

## The Ipstones Edge area

Ipstones Edge is a prominent escarpment running south-eastwards from near Sharpcliffe Hall towards Black Heath where it dies away near Windy Harbour (SK 06034850). The escarpment is very variable in form. For instance, in the area under discussion in the neighbourhood of Sharpecliffe Hall, it is a relatively small feature some 20 feet high formed from a single band of pebbly sandstone. Further south-east the escarpment becomes much more prominent, notably in the area between the Red Lion Inn (SK 02805124) and Hallbarn (SK 04535089). Eastwards again the escarpment gradually becomes less prominent until it is no longer seen near to Windy Harbour. The escarpment is formed from a series of sandstones interbedded with mudstones, shales and silty shales, a group of rocks which have been referred to above as the Ipstones Edge Sandstones.

The sandstones naturally form the strongest features and probably represent the thickest members of the group. Lithologically the sandstones are somewhat variable. Over most of the area the beds are medium to coarse-grained, occasionally becoming very coarse-grained and pebbly. In the vicinity of Sharpecliffe Hall (SK 00845218) the lowermost sandstone unit becomes highly conglomeratic. Elsewhere, apart from variations in grain-size, the mineral content remains fairly uniform with occasional flakes of mica forming the main accessory mineral.

Good exposures of these sandstones occur on the valley sides in The Combes just below Cloughmeadow Cottage. In the area between The Combes and Summer Hill (SK 02175155) two distinct sandstones occur. The lower sandstone can be seen in the valley bottom some 250 yards south-west of Cloughmeadow. Here the sandstone is vertical, probably the result of local faulting, and is coarse-grained though containing few pebbles. Overlying this sandstone are the fossiliferous mudstones described above (p. ). These beds are in turn overlain by a further series of sandstones which are well exposed high up on the eastern side of the valley about 250 yards west of Sharpecliffe Hall.

The south-eastward extension of both of these sandstone bands can be traced quite easily in the vicinity of Sharpecliffe Hall. In particular, the lower sandstone produces the prominent scarp eastwards through Sharpecliffe Wood and Sharpecliffe Rocks Plantation. The area east of Sharpecliffe Hall is much faulted. This is emphasised by the displacement of the sandstone outcrops, particularly in the area between Home Farm (SK 01005207) and Little Rocks Plantation. Most of these faults have a relatively small throw and represent branches of the main Sharpecliffe Fault which strikes towards Revedge. The line of the Sharpecliffe Fault can be traced between Home Farm and the Hall; the fault strikes southwards from the Hall towards Collyhole (SK 00895109). The northerly line of the fault has already been referred to (see p. ).

As mentioned above, the lowermost sandstone unit of the Ipstones Edge Sandstones locally becomes conglomeratic. This development is seen in a small buttress in Sharpecliffe Rocks Plantation where about 20 feet of rocks may be grouped thus:-

3. An upper conglomeratic unit.
2. Coarse-grained sandstone unit in which current-bedding is prominent. The "set" of the current-bedding planes is predominantly southerly.
1. A lower, more massive conglomerate.

The conglomerate consists predominantly of quartz pebbles ranging from the size of a pea up to two inches in diameter. A pinkish feldspar is not uncommon, some crystals being half an inch or more in cross-section. One of the most curious features of this conglomerate is the presence of thin slabs of iron-stone, some measuring up to six inches in diameter but usually no more than half an inch thick. These slabs lie at various angles and are not aligned in any way.

The provenance of the material is problematical, for vein quartz is not seen affecting any of the beds of the area beyond that under discussion. In addition the feldspars are probably derived from a not too distant source which is at present unknown. The iron-stone slabs might be more local in origin, for Wardle (1862, p. 250) comments on the remains of old workings on the hillside not far from Winkhill. These old workings are still to be seen, in beds which are now known to be of Upper Eumorphoceras ($E_2$) age (Morris 1966). There is, however, no evidence of uplift and erosion in the area and it is thought unlikely that the Winkhill area represents the source of the iron-stone slabs.

Few outcrops of the interbedded mudstones are seen in the Ipstones Edge Sandstones succession. The main outcrop has already been described as locality 9 in The Combes. Two further outcrops of these mudstones yielding sparse faunas have been located. One, locality 10, lies some 30 yards upstream from Horsley's Stone and Dunbarella sp. and Posidoniella sp. have been obtained from it. From the second outcrop, locality 11, high up on the valley side about 250 yards north-west of Sharpecliffe Hall only occasional specimens of Posidoniella sp. have been recorded.

## The area between Ipstones Edge and Gorsthead Mill

Between the stream running from Backhill Wood towards Cloughmeadow and the Gorsthead Mill - Upper Lady Meadows section of the Combes Brook, there lies the high ground on which stands the farms of Padwick and Brownedge. This area is much faulted and it is not easy to correlate the sandstones which cover the areas of Brownedge, Padwick and the south-eastern part of Sixoaks Wood with other areas, particularly in the absence of diagnostic fossils.

The sandstone outliers may be correlated with the Morredge Grits and they would therefore represent up-faulted blocks. There is some support for this suggestion in the Gorsthead Mill area, where high-angle reverse faulting occurs (see p. ). The outcrops on Brownedge are here regarded as part of the Morredge Grits. Other outcrops near Padwick and in Sixoaks Wood might be correlated with the Ipstones Edge Sandstones, but their true affinities are at present uncertain.

## The area to the north of Combes Brook

North of the Combes Brook, about Revedge (SK 00825370), sandstones occur again. The main outlier of sandstone, capping the hill of Revedge itself, can be mapped fairly easily along its northern and eastern boundaries. The western boundary, also easily mapped, represents the line of the northward extension of the Sharpecliffe Fault. West of this fault is another small, arcuate outcrop of sandstone (on which stands the farm, Revedge) and north-west of this is yet another small knoll, comprised of sandstone affected by faulting, in the area of Roost Hill (SK 00615386). The age of these sandstones is uncertain and they are here tentatively correlated with the lower band of the Ipstones Edge Sandstones.

Between Revedge and Bradnop the ground is fairly flat and featureless, except for a small sandstone outlier forming a knoll just south of Bradnop Station. The sandstones comprising this knoll are correlated with the sandstones outcropping in Bradnop village, which are part of the Morredge Grit succession.

## Acknowledgements

My sincere thanks are due to Mr. and Mrs. G.A. Lovenbury of Cloughmeadow Cottage, Bradnop, for their many kindnesses during the author's visits to North Staffordshire.

P.G. Morris, B.Sc., Ph.D., F.G.S.,
Department of Geology,
Chelsea College of Science and Technology,
Manresa Road,
LONDON, S.W.3.

## List of localities

1. A stream-section 1050 yards S 10° E of Gorsthead Mill, Bradnop (SK 02565369)
2. A stream-section 235 yards S 12° E of Gorsthead Mill, Bradnop (SK 02445330)
3. A stream-section 220 yards S 21° E of Gorsthead Mill, Bradnop (SK 02475332)
4. A stream-section 197 yards S 29° E of Gorsthead Mill, Bradnop (SK 02485335)
5. A stream-section 53 yards W 31° N of Gorsthead Mill, Bradnop (SK 02355354)
6. A stream-section 540 yards W 22° S of Gorsthead Mill, Bradnop (SK 01935322)
7. In Combes Brook 543 yards N 39° of Cloughmeadow Cottage, Bradnop (SK 01035306)
8. In Combes Brook 190 yards N 30° W of Cloughmeadow Cottage, Bradnop (SK 00645285)
9. In "The Combes" some 510 yards W 25° N of Sharpecliffe Hall, Bradnop (SK 00425239)
10. In "The Combes" some 30 yards upstream of Horsley' Stone, Bradnop (SK 00425248)
11. In Spiritholes Wood 247 yards W 42½° N of Sharpecliffe Hall, Bradnop (SK 00685233)

## REFERENCES


BISAT, W.S. & HUDSON, R.G.S. 1943 The Lower Reticuloceras ($R_1$) Goniatite succession in the Namurian of the North of England. Proc. Yorks. geol. Soc., Vol. 24, pp. 383-446 1 text-fig., 8 plates.

CHALLINOR, J. 1929 Notes on the Geology of the North Staffs. Moorlands. Trans. N. Staffs. Fld. Cl., Vol. 63, pp. 111-113, 1 plate.

HESTER, S.W. 1932 The Millstone Grit Succession in North Staffordshire. Summ. Progr. geol. Surv. Gr. Br. for 1931, pp. 34-48, 1 text-fig., 2 tables.

HOLDSWORTH, B.K. 1964 The "Crowstones" of Staffordshire, Derbyshire and Cheshire. N. Staffs. Journ. Fld. Studies, Vol. 4, pp. 89-102.

HUDSON, R.G.S. 1945a (in appendix II of Hudson R.G.S. & Cotton, G.) The Upper Viséan and Lower Namurian of North Staffordshire Proc. Yorks. geol. Soc., Vol. 25, pp. 318-330, 1 text-fig.

1945b The Goniatite Zones of the Namurian. Geol. Mag., Vol. 82, pp. 1-9

HULL, E. & GREEN, A.H. 1864 On the Millstone Grit of North Staffordshire. Quart. J. geol. Soc., Lond., Vol. 20, pp. 242-267

1866 The Geology of the Country around Stockport, Macclesfield, Congleton and Leek. Mem. Geol. Surv. Gr. Br., pp. 1-102, 1 plate.

MORRIS, P.G. 1966 The Stratigraphy and Palaeontology of the Upper Dinantian and Namurian Rocks in the area east and south-east of Leek, North Staffordshire. (Ph. D. Thesis, University of London).

RAMSBOTTOM, W.H.C., RHYS, G.H and SMITH, E.G. 1962. Boreholes in the Carboniferous Rocks of the Ashover District Derbyshire. Bull. Geol. Surv. Gr. Br., No. 19, pp. 75-168

WARDLE, T. 1862 On the Geology of the neighbourhood of Leek. (In John Sleigh's "Ancient History of Leek"). Leek. (Reprinted separately in 1863 with the same pagination). pp. 225-291, 4 plates.

Manuscript received 8th June, 1966

# RATE OF SEDIMENTATION IN CROPSTON RESERVOIR, CHARNWOOD FOREST, LEICESTERSHIRE

by

W.A. Cummins and H.R. Potter

## Summary

Cropston Reservoir was emptied in 1965 for the first time in 95 years of use. The thickness of the mud on the floor of the reservoir was measured and an isopach map constructed. After allowance had been made for the volume of mud cracks and of water in the mud, the total volume of sediment was estimated. The mean annual supply of sediment to the reservoir was found to be 6,214 cubic feet. The reservoir loses capacity at ten times this rate because the mud settling in it incorporates about ninety per cent of water by volume. At this rate the reservoir will be completely silted up in 1,433 years.

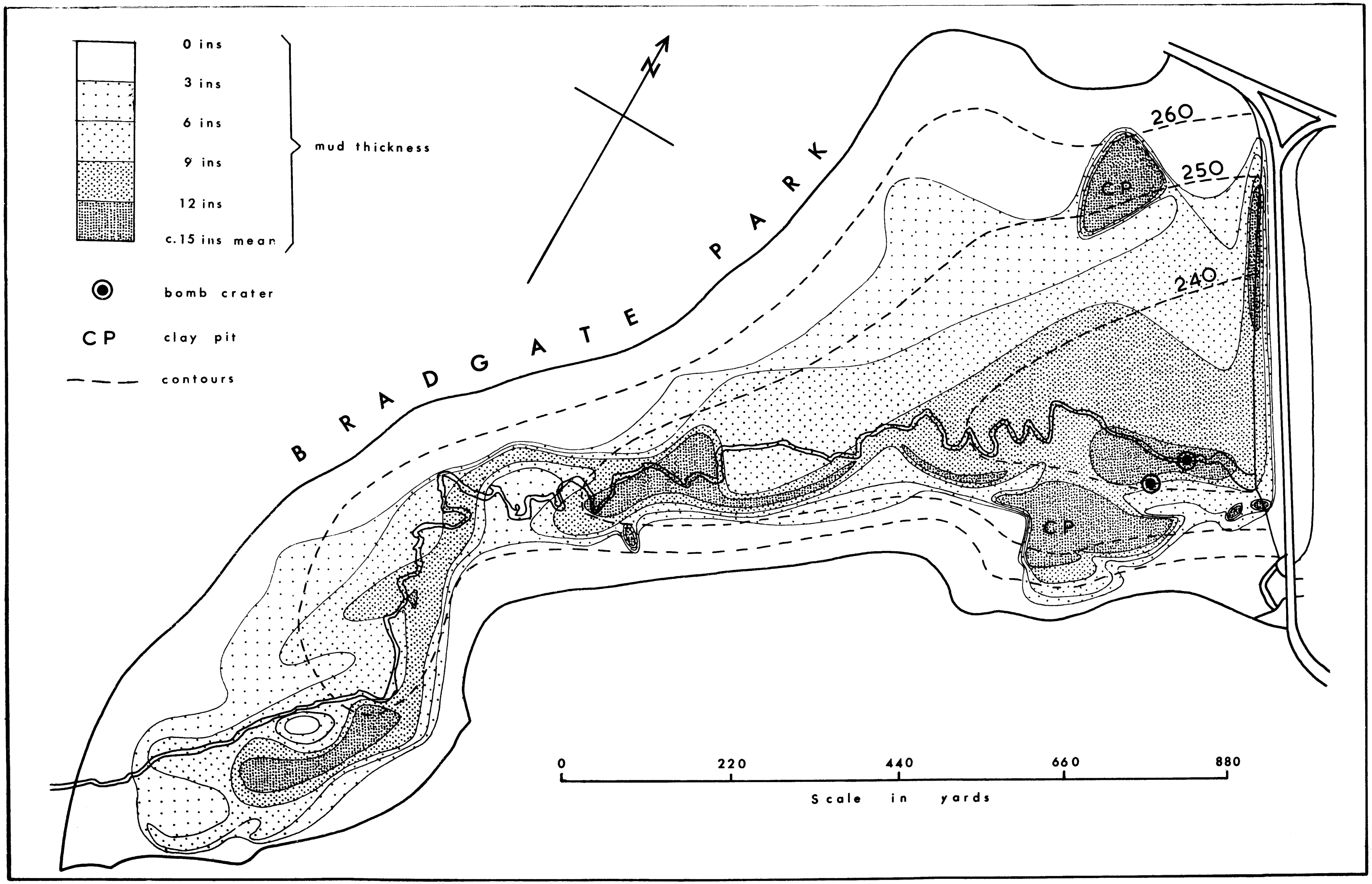
Settling ponds upstream of the reservoir were found to be trapping sediment at the rate of 1,376 cubic feet per annum. Thus the rate of erosion of sediment off the catchment area is 7,590 cubic feet per annum. This may be averaged over the whole area to give a mean annual lowering of the surface by 0.00048 inches.

## Introduction

Cropston Reservoir (SK 5410 and 5411), supplying water to the City of Leicester, was opened in 1870. It is situated at the south-eastern end of Charnwood Forest, alongside Bradgate Park. The dam at the north-eastern end carries the road (B5330) leading to the nearby village of Cropston (SK 553109). The top water level of the reservoir is 266.7 feet O.D. The highest points in the 4,400 acre catchment area are just over 800 feet O.D. The mean annual rainfall over the period from 1871 to 1964 was 28.06 inches. The main stream feeding the reservoir is Bradgate Brook. A series of five settling ponds (SK 525099 to 528101) in Bradgate Park serve to trap a good deal of the sediment load of Bradgate Brook, which would otherwise be carried on into the reservoir. These ponds are cleared about every ten years.

The catchment area is floored by Pre-Cambrian and Triassic rocks with an extensive cover of Boulder Clay (Text-fig. 4). The Triassic Keuper Marl overlies the Pre-Cambrian Charnian rocks unconformably, the junction between the two being an irregular land surface of Triassic age, which is now being re-excavated. The surface geological composition of the catchment area is as follows:-

| | |
|---|---|
| Superficial deposits | 23% |
| Keuper Marl | 48% |
| Charnian | 29% |


0 ins
3 ins
6 ins
9 ins
12 ins
c.15 ins mean
mud thickness
bomb crater
CP
clay pit
contours
N
BRADGATE PARK
260
250
240
CP
CP
0
220
440
660
880
Scale in yards

Text-Fig. 1

Text-Fig. 1. Isopach map of the sediment in Cropston Reservoir. Contours and stream course based on original site survey.

Text-Fig. 2. Data for interpretation of measured mud thicknesses (vertical scale). Each point represents one square yard sample area.

Text-Fig. 3. Top (a) Extract from field note book giving details of a square yard sample area. Bottom (b) Detailed analysis of above sample area (see text, p. 35).

Text-Fig. 4. Simplified geological map of the Cropston Reservoir catchment area.

Text-Fig. 5. Section across old field boundary, showing mud at time of observation (close stipple) and calculated underwater sediment surface (over open stipple).

The area is covered by the Geological Survey one inch sheets 155 and 156, and a general account of the geology may be found in the Geological Survey's "Regional Guide" to the Central England District.

The reservoir was emptied in April 1965 for cleaning and alteration, thus providing an opportunity for measurement of the volume of sediment accumulated over a period of 95 years, from which an estimate of the rate of erosion of the catchment area might be made.

The sediment in the reservoir is uniform black mud. The black colour is due to the presence of ferrous sulphide (c.8% dry weight). The mud also contains ten to fifteen per cent of organic matter. Thin laminae of fine sand and silt occur in the mud at shallow depths in the reservoir, and are related to periods of low water. Similar layers are found in sediment which was re-deposited at greater depths in the reservoir when it was drained. The only other noteworthy example of stratification in the mud is a layer of sand and gravel surrounding the two bomb craters in the lower part of the reservoir (see Note 1 at end).

## The isopach map

When the reservoir was emptied the stream quickly returned to its old channel and, as the mud dried and contracted, many of the old field boundaries were revealed as slight irregularities on the surface of the mud. Thus a copy of the original survey of the site made at the time of construction of the reservoir served as a useful base map for the present study.

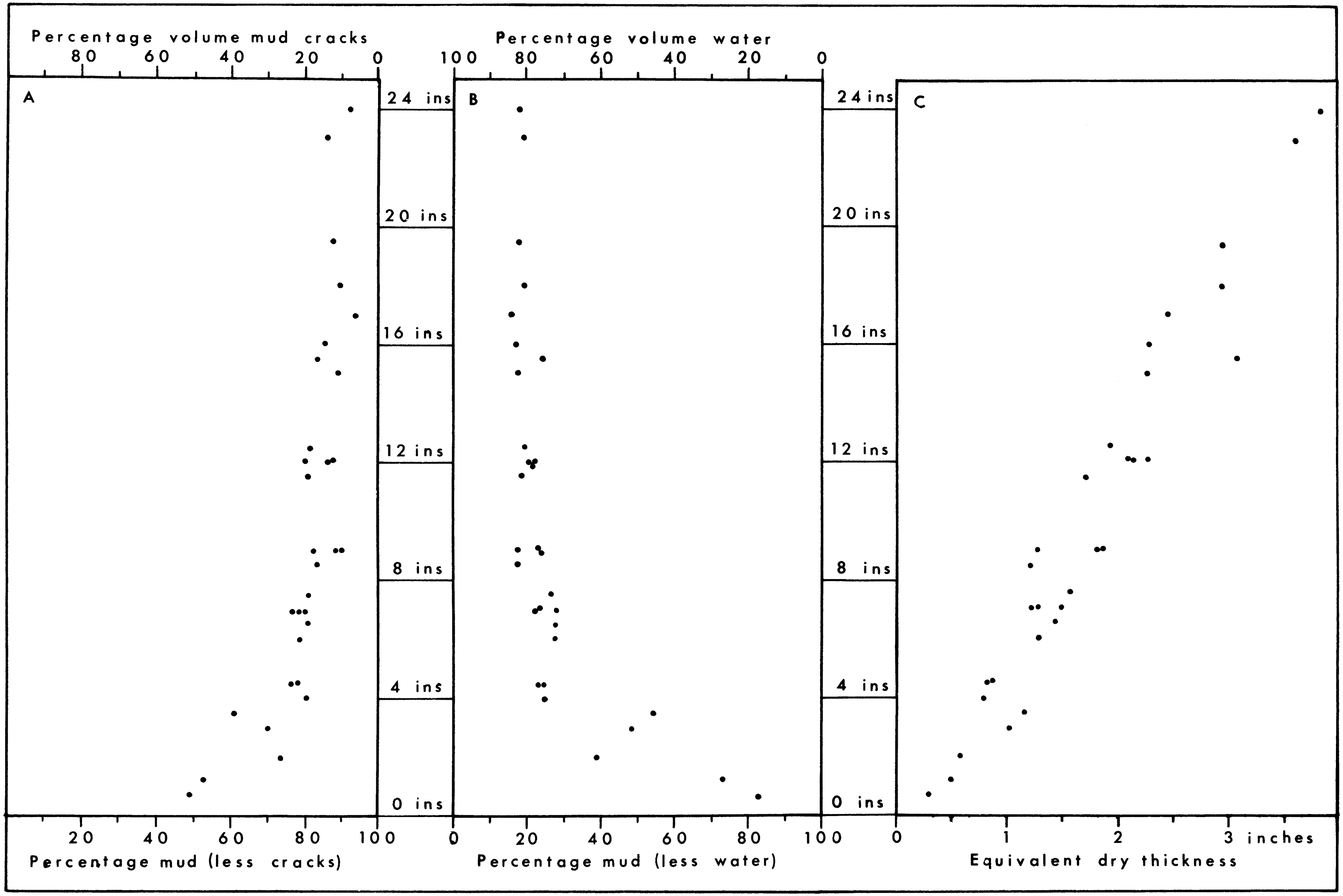
Determination of the volume of sediment in the reservoir was made from an isopach map based on measurements taken during late May and June 1965, by which time the surface of the mud had dried sufficiently to permit walking with reasonable safety over most of the area. The depth of the sediment was determined by digging and measuring with a ruler. The black cohesive mud parted readily from the substratum along the porous mat of dead roots which represented the old turf.

The isopach map (Text-fig. 1) shows a close relationship between mud thickness and topography, such that the mud is generally thicker in the deeper parts of the reservoir. Superimposed on this general pattern are areas of thick mud in local topographic depressions such as old abandoned river meander channels and the clay pits (not shown on the old map) from which boulder clay was dug for the construction of the dam. This local topographic effect is also apparent on a scale smaller than can be shown on the map. The mud is thin on banks and ridges and thick in ditches and furrows. Examples of such small scale variations are found along old field boundaries and across the ridges and furrows resulting from medieval strip cultivation, traces of which were visible over a large part of the floor of the reservoir and can also be seen in many of the fields nearby.

The variations in mud thickness, as measured in the field and shown on the map, are not necessarily directly related to variations in the amount of sediment present. Before the map can be interpreted, allowance must be made for the water content of the muds at the time of measurement, and also for the lateral contraction on drying as reflected in the pattern of mud cracks.

## Interpretation

In order to allow for the volume of mud cracks, the following procedure was devised. A square yard was marked out on the ground with string and nails. The pattern of cracks in this area, hereafter referred to as a sample area, was sketched in the field notebook (Text-fig. 3a) and the length and width of every crack measured and recorded. The surface area of the cracks was totalled and recorded as a percentage of the sample area. The percentage volume of mud cracks in the sample area was calculated, generally on the assumption that the cracks were triangular in cross-section and extended to the bottom of the mud. Where the mud was very thin and dry, the cracks were found to be rectangular or trapezoidal in cross-section and the calculation of percentage volume was adjusted accordingly. The results of these


Percentage volume mud cracks
80
60
40
20
0
A
Percentage mud (less cracks)
20
40
60
80
100
24 ins
20 ins
16 ins
12 ins
8 ins
4 ins
0 ins
Percentage volume water
100
80
60
40
20
0
B
Percentage mud (less water)
0
20
40
60
80
100
C
Equivalent dry thickness
0
1
2
3 inches

Text-Fig. 2

measurements are summarised in Text-figure 2a, in which each point represents one sample area. Over most of the thickness range there is little variation in the percentage of mud cracks, but below about six inches, there is a marked increase of mud crack volume with decreasing mud thickness.

After the mud crack measurements, part of a mud polygon was dug out for sampling. The samples, approximately inch cubes, were cut from different levels in the mud with a thin wire and placed in small self-sealing polythene bags. The water content of these samples was then determined by heating to constant weight in a drying oven. It was found that the polythene bags withstood the temperature of the oven, so the procedure was as follows:- The wet samples were weighed in the polythene bags; the bags were opened and the samples dried in the oven; they were then reweighed and the weight loss calculated as percentage water. It was found, as expected, that the upper crust of the mud was a good deal drier than the rest; and also, rather less expectedly, that the water content at the bottom was invariably less than higher up. Presumably, water was squeezed out at the bottom by the weight of the overburden (no longer supported by the reservoir water) and drained along the old turf layer. This old turf layer was an excellent example of an aquifer, and digging through the mud down to this level in a hollow generally resulted in a sudden inrush of water.

The mean water content of the mud was thus found for each sample area and converted to a mean percentage volume of water. For this purpose, a specific gravity of 2.6 was taken for dry sediment and it was assumed that the samples as collected were completely water saturated (an assumption checked in the first few sample areas by cutting cubic inch samples as accurately as possible). The results of these determinations are shown in Text-figure 2 b, in which each point represents one sample area. The percentage volume of water in the muds shows little variation down to a mud thickness of about six inches, below which the muds become drier with decreasing thickness.

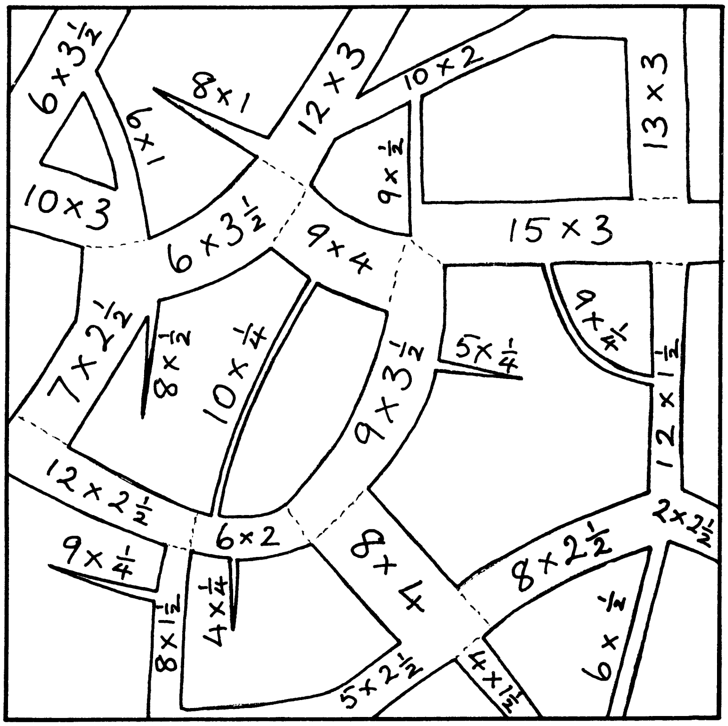
It is now possible to determine the equivalent dry thickness of the mud, that is to say the thickness of solid sediment which would spread evenly over a sample area if all the water were removed. This is given by the formula:-

$$\frac{MST}{10,000}$$

where M is the perecentage volume of mud (less cracks) in the sample area, S is the mean percentage volume of sediment (less water) in the mud, and T is the thickness of mud measured in the field.

Since the water content of the mud and the width of the mud cracks both vary with depth, a few sample areas were analysed in greater detail to check the effects of these variations. For these detailed analyses, samples were taken throughout the thickness of the mud. A cross section of such a sample area is shown diagrammatically in Text figure 3b. The blank part to the left represents the mud cracks. The first column of figures shows the percentage volume of mud (less cracks) at each sample level. The next column of figures gives the percentage volume of sediment (less water) in each mud sample. The third column gives the percentage volume of sediment (less cracks and water) for each sample level. The final column gives the equivalent dry thickness for each sample level. The sum of these gives a total equivalent dry thickness for the mud, which differs but little from the equivalent dry thickness based on the formula given in the preceding paragraph.

Time available for measurements was limited. The contractors were working on the floor of the reservoir; plants were springing up all over the place and a thick jungle of vegetation was advancing over the mud from the sides of the reservoir with surprising rapidity; finally, the condition of the mud itself was changing at an unknown rate. The general procedure adopted therefore was to take samples at intervals through the thickness of the mud in each sample area. From these a mean water content was obtained, saving much valuable time in the field and in the laboratory.




| | |
|---|---|
| Locality | 15a |
| Mud thickness | $12\frac{1}{2}$ ins. |
| Mud crack areas:- | |
| $\frac{1}{4}$ X (14, 9, 4, 10) | 9.25 |
| $\frac{1}{2}$ X (9, 6, 8) | 11.5 |
| 1 X (6, 8) | 14 |
| $1\frac{1}{2}$ X (8, 4, 12) | 36 |
| 2 X (6, 10) | 32 |
| $2\frac{1}{2}$ X (12, 7, 5, 8, 2) | 85 |
| 3 X (12, 10, 13, 15) | 150 |
| $3\frac{1}{2}$ X (6, 6, 9) | 73.5 |
| 4 X (8, 9) | 68 |
| Total mud crack area | 479.25 sq. ins. |
| Percentage area mud cracks | 37% |
| Percentage volume mud cracks | 18.5% |

| | | | |
|---|---|---|---|
| 65% mud | 28.0% solids | 18.2% of 1.25 ins. | 0.227 ins. |
| 68% - | 24.7% - | 16.8% of 1.00 ins. | 0.168 - |
| 71% - | 19.5% - | 13.9% - | 0.139 - |
| 74% - | 18.3% - | 13.5% - | 0.135 - |
| 77% - | 17.8% - | 13.7% - | 0.137 - |
| 80% - | 17.8% - | 14.3% - | 0.143 - |
| 83% - | 16.4% - | 13.6% - | 0.136 - |
| 86% - | 16.6% - | 14.3% - | 0.143 - |
| 89% - | 16.9% - | 15.0% - | 0.150 - |
| 92% - | 17.8% - | 16.4% - | 0.164 - |
| 95% - | 17.8% - | 16.9% - | 0.169 - |
| 98% - | 19.2% - | 18.8% of 1.25 ins. | 0.235 - |

Text-Fig. 3

The equivalent dry thickness is plotted against measured thickness of the mud in Text-figure 2c, in which each point represents one sample area. The two opposing factors of large crack volume and low water content in the thinner muds cancel each other out, and it can be seen that, right down to the smallest thickness measured, there is a direct linear relationship between the equivalent dry thickness and the thickness measured in the field. Thus the patterns on the isopach map reflect a real relationship between sedimentation and topography which has to be accounted for (see Note 2 at end).

## Conclusions

The total volume of sediment in the reservoir can be determined from the isopach map. The areas between the isopachs were measured, multiplied by the mean equivalent dry thickness between each one, and totalled. It was found that 590,367 cubic feet of sediment had been deposited in the reservoir in a period of 95 years. The mean annual accumulation of sediment is thus 6,214 cubic feet. This figure refers to dry sediment and is of interest in a study of erosion of the catchment area. The reservoir actually fills up with sediment at ten times this rate, because the mud which settles on the bottom incorporates about ninety per cent of water by volume. At this rate the reservoir would be completely silted up in a period of 1,433 years.

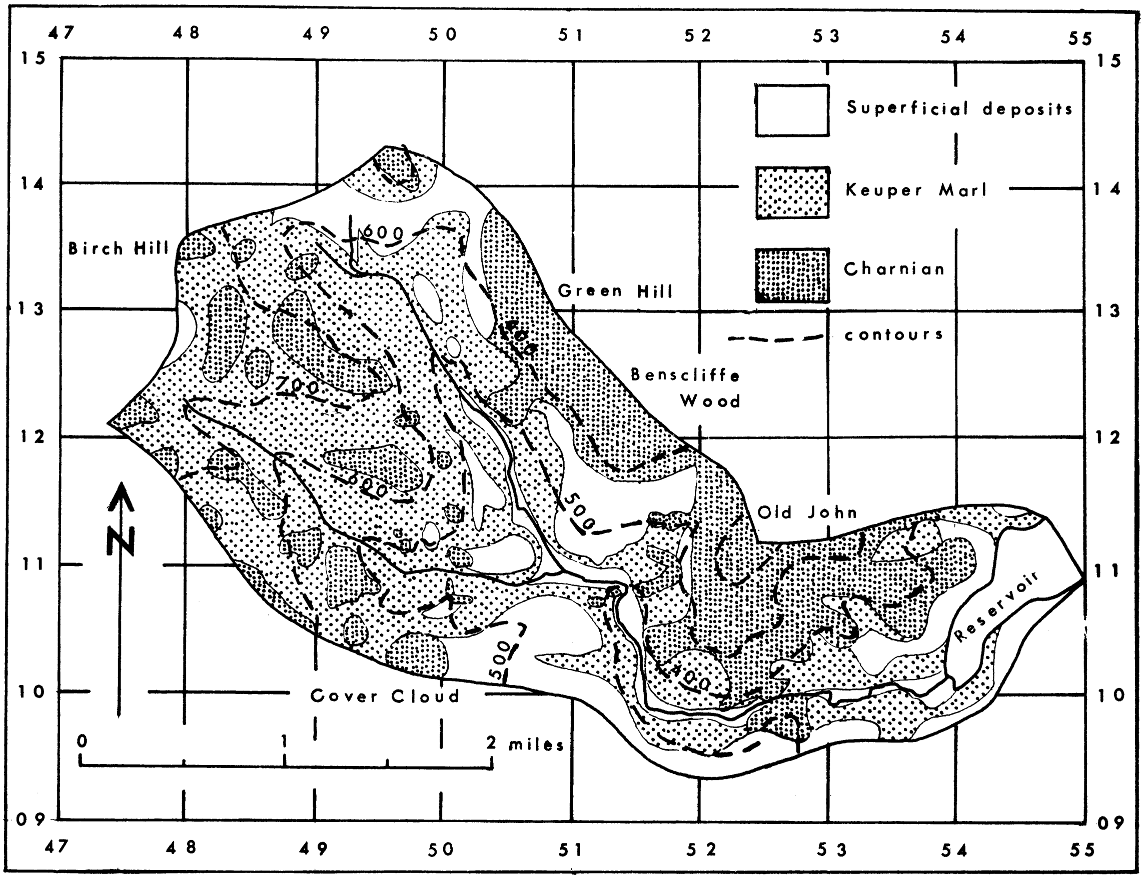
Before the rate of erosion of the catchment area can be determined, allowance must be made for the sediment which is deposited in the settling ponds in Bradgate Park. They were cleaned out during the summer of 1965 and the sediment dumped nearby. The last clearance of the ponds had been in 1955, so, assuming that the 1955 and 1965 cleanings were done in the same manner and to the same extent, the sediment in the dumps represents ten years accumulation. A rapid survey of the surface of the dumps was made; pits were dug to find the thickness of the dumped sediment; and samples were collected for water determination. The water content of the dumped sediment was considerably less than in the undisturbed reservoir muds, and dessication cracks had not developed. The total volume of dry sediment represented by the dumps from all five ponds was 13,758 cubic feet, which gives an annual rate of accumulation of 1,376 cubic feet. This is rather less than a quarter of the rate of sedimentation in the reservoir and means that the ponds are trapping 18 per cent of all the sediment coming down Bradgate Brook before it reaches the reservoir.

The rate of erosion of the catchment area, taken as the sum of the rates of accumulation in the reservoir and the settling ponds, is 7,590 cubic feet per annum. If this loss is averaged over the whole surface of the area, the annual rate of erosion may be represented as a general lowering of the surface by 0.00048 inches. Discussion of these figures and comparison with other areas will be deferred for a later publication, pending completion of research already in hand.

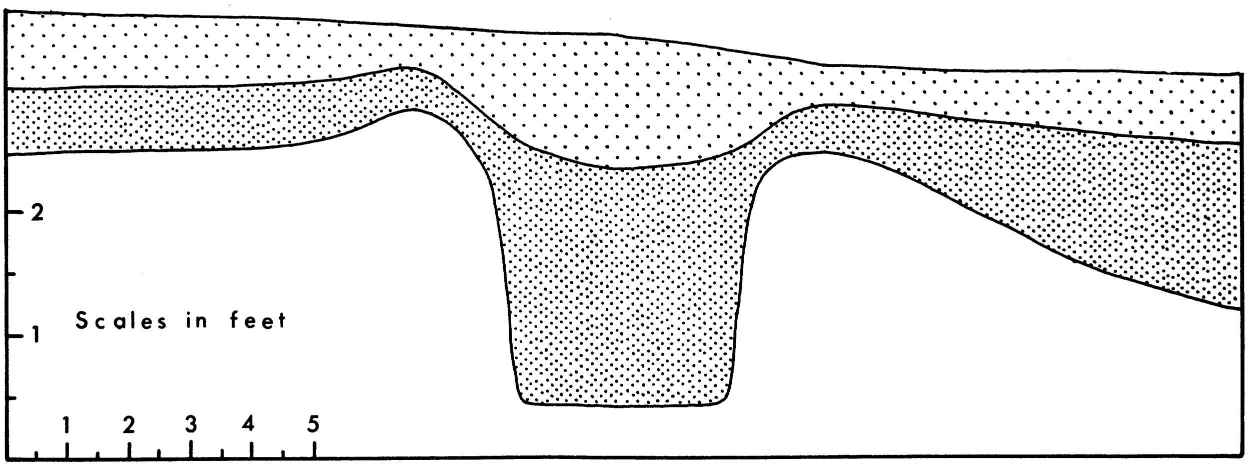
## Note 1

Two bombs fell in the reservoir during the war. One fell in the old stream course about a hundred yards from the dam and the other fell between this and the southern clay pit (Text-fig. 1). The bombs had exploded below the reservoir mud and formed circular craters, about 30 feet in diameter, with rims of upcast boulder clay. The crater of the one which had dropped in the old stream course was very imperfectly preserved. A layer of pebbly sand in the mud extended for a distance of about 30 yards from each of the craters, and the thickness and pebble content gradually decreased away from the craters. These bomb sands differed from the layers of sand associated with the emptying of the reservoir in their coarser grain size, poorer sorting, and lack of current structures such as parting lineation.

The bomb sands suggested a test for constancy of rate of sedimentation by determining the equivalent dry thickness of sediment above and below. The exact date of the bombs has not been discovered, but they must divide the history of sedimentation in the reservoir into two unequal periods, an earlier one of about 70 years and a later one of about 25 years. Two sample areas with bomb sand were analysed by the detailed method (p. 35 ). The results of both showed that the rate of sedimentation after the bombs were




Text-Fig. 4




Text-Fig. 5

dropped was apparently about fifty per cent greater than before. This anomaly is almost certainly due to an unknown thickness of mud being redeposited in this part of the reservoir when it was drained in the Spring of 1965.

## Note 2

The relationship between sedimentation and topography extends to the deepest parts of the reservoir, beyond the reach of erosion and wave action, and seems likely to have resulted from some process on the floor of the reservoir unrelated to movements in the water above. There is no evidence of sediment deposition from turbidity currents. It is suggested that the relationship has resulted from a gradual downslope flow of the watery sediment accumulating on the floor of the reservoir. Such a process would result in the accumulation of extra sediment in hollows at the expense of that on the adjacent higher ground, producing a general smoothing off of the underwater topography.

A section across an old field boundary is shown in Text-figure 5. Five sample areas were studied along this section and their relative levels measured. The equivalent dry thickness was determined for each of them and multiplied by ten to give an equivalent thickness of underwater sediment (90% water by volume for the underwater sediment is taken as being a round figure a little in excess of the highest water content of any sample collected during the present study). The underwater sediment surface, thus reconstituted, has a considerably smoother profile than either the original underlying ground surface or the surface of the mud at the time of measurement. The results of this traverse are consistent with the idea of gentle downslope flow of the watery sediment deposited on the floor of the reservoir.

## Acknowledgements

The authors wish to express their thanks to the following:- Mr. Marshall Nixon, Engineer to the Trent River Authority, and Professor W. D. Evans, Head of the Geology Department in the University of Nottingham, suggested the project to us. Facilities for working in the reservoir were given by officers of the City of Leicester Water Department, Mr. Hal Wallhouse, Engineer and Manager, Mr. R. West, Project Engineer, and Mr. A.R. Leaf, Station Superintendent of Cropston Reservoir. Analyses were carried out by Mr. D. Mather and Mr. I. Beaumont in the Geology Department.

W.A. Cummins, B.Sc., Ph.D., F.G.S.
Department of Geology,
The University,
Nottingham

H.R. Potter, Esq.,
Hydrologist,
Water Resources Section,
Trent River Authority,
West Bridgford,
Notts.
Manuscript received 19th October, 1966

# THE FIRST DETAILED GEOLOGICAL SECTIONS ACROSS ENGLAND,

# by JOHN FAREY, 1806-8

by

Trevor D. Ford

## Summary

Several years before his monumental work on the Agriculture and Minerals of Derbyshire (1811), John Farey drew what are believed to be the earliest extended geological sections of British regions. These were never published and have been overlooked in works on the history of geology. Redrawn versions are presented, with short discussions of their content and significance.

## Introduction

During the course of investigation of a collection of Derbyshire lead-mining documents in Sheffield Central Reference Library, two rolled-up hand-drawn and hand-coloured geological sections were found (catalogued as Oakes Deeds 1221 and 1224). Subsequently it was discovered that "fair copy" versions of the longer of these two sections had been donated (a) to the library of the Geological Survey by the widow of W. Topley, author of the Weald Memoir (MS 404-B); and (b) to the library of the Palaeontology Department of the British Museum (Natural History) by C. D. Sherborn. Another copy is said to have been given to the Geological Society by Greenough in 1811. Topley's section is bound with another detailed section across the Weald by Farey, and with a small section across the Derbyshire Coalfield. None of these sections was apparently ever published, in spite of their obvious important place in the foundations of British stratigraphical knowledge. Redrawn versions are presented here, with interpretations of Farey's state of knowledge compared with the facts known today. Their relationship to the rest of Farey's work is also briefly discussed.

## The Sections

1) The Ashover-Trusthorpe section (Text-fig. 1) is 9 feet long by 7½ inches wide and carries the following dedication:-

"To the Right Honourable Sir Joseph Banks President of the Royal Society this section of the principal Strata of England as the same crops out and appears between Trusthorpe near Sutton on the eastern coast of Lincolnshire passing his seat at Revesby the towns of Tattersall Sleaford and Ancaster in that County; Newark Hockerton and Mansfield in Nottinghamshire; Pleasley Temple Normanton and Ashover in

Derbyshire and extending to Sir Joseph Banks seat at Overton in the last-mentioned parish; compiled from materials collected during an extensive tour undertaken at the instance of the worthy President in the Autumn of 1807 in prosecuting the discoveries made and taught by Mr. William Smith on the arrangement of the British Strata, is most respectfully inscribed by his Obedient and very humble servant

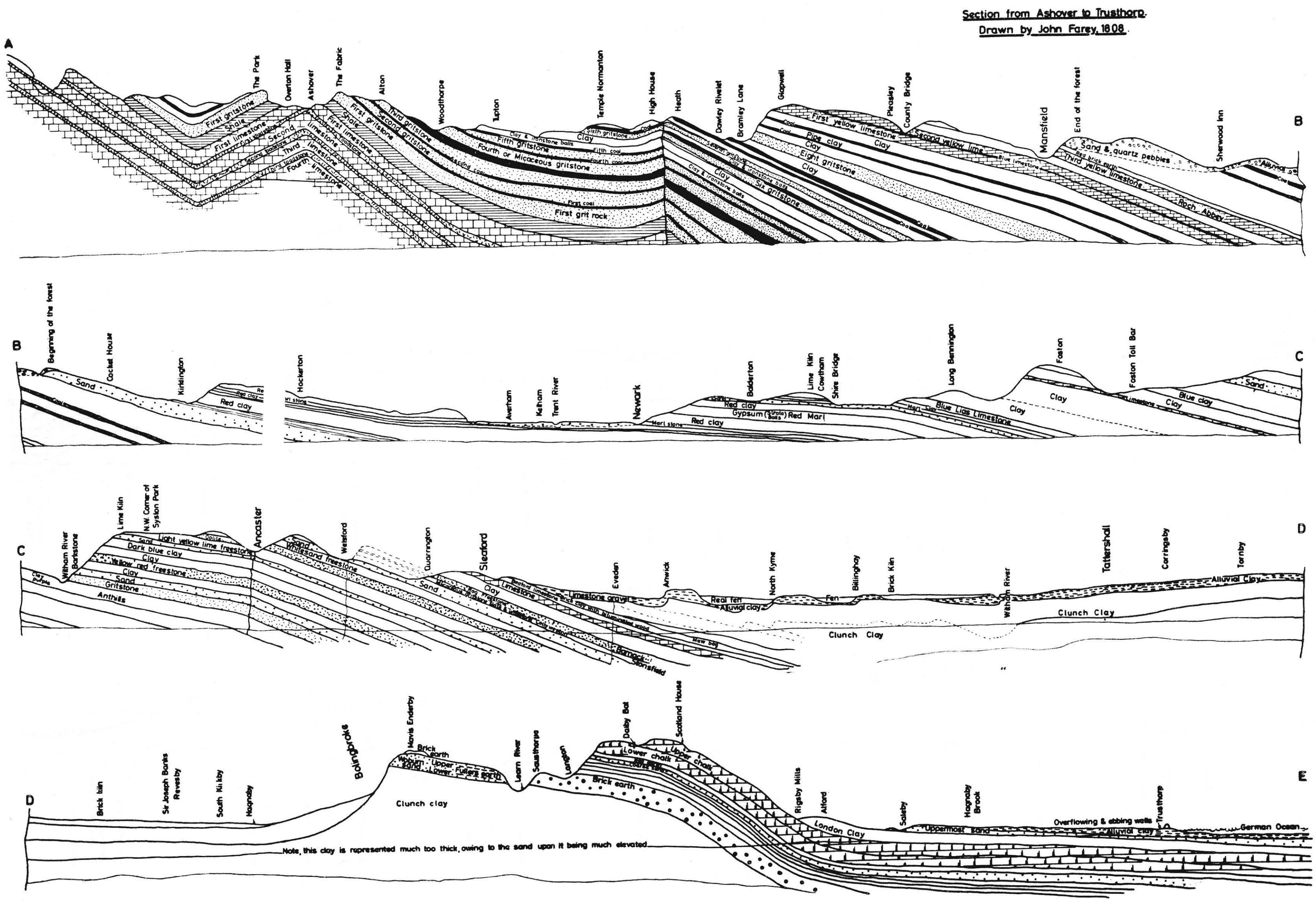
John Farey senior
Land and Mineralogical Surveyor,
12 Upper Crown St., Westminster."

The section is not dated but, as Farey is known to have made other tours in Derbyshire in 1808 and later, and as these are not mentioned in the dedication, it seems likely that the section was drawn before his 1808 tour; the Geological Survey and the British Museum (Natural History) copies are both dated 17th February 1808. This appears to be the first extended section of British strata ever drawn. Previous sections were of limited areas only, e.g. Strachey's Somerset Coalfield 1719, Whitehurst's Matlock gorge 1778 and 1786, and White Watson's Derbyshire Mountain, Ecton Mines etc. in the 1790's (see Ford 1960). Sherborn (1929) published a brief description of the section now in the British Museum (Natural History), but no published version of the section has been traced.

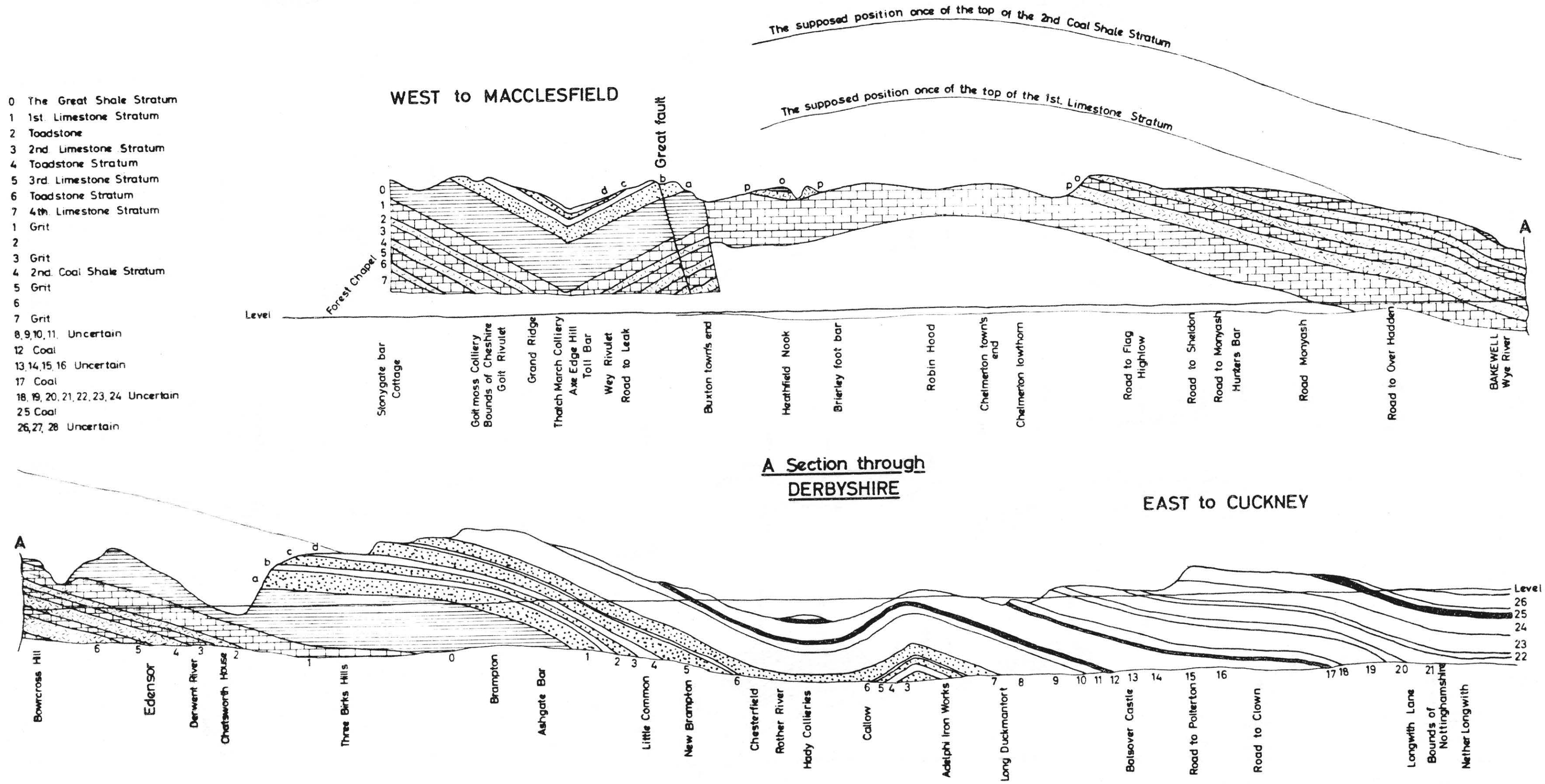
The western end of the section appears to start in the Matlock gorge and shows the correlation of limestones and toadstones (basaltic lavas etc.) beneath the Tansley syncline into the Ashover anticline, where recent boreholes appear to have penetrated a vent rather than an orderly succession (Ramsbottom et al., 1962). The limestones and toadstone are numbered downwards but the succeeding Millstone Grits and coals are numbered upwards, contrary to the practice later adopted for the Staffordshire Millstone Grit. On the British Museum (Natural History) copy the Fourth Grit is marked "Ealand Edge", which probably suggests a correlation with the Elland Flags of the West Riding. In the Derbyshire coalfield the synclinal development around Temple Normanton is clearly recognised and the faulted Brimington-Callow anticline to the east is shown by a dislocation of the strata - the only apparent fault shown on the section. The approximate position of the thicker coals is shown correctly, e.g. the High Hazles Seam which outcrops near Bramley Lane.

The Permian Magnesian Limestone escarpment at Glapwell is shown, but his subdivisions of the Magnesian Limestone are not so easily recognizable. The First and Second Yellow Limestones appear to be equivalent to the Lower and Middle Magnesian Limestone; the Third Yellow Limestone seems to be the equivalent of the Upper Magnesian Limestone, which outcrops well to the north of Mansfield but not at Mansfield itself (F.M. Taylor, personal communication). The Bunter Pebble Beds outcrop is correctly shown, but his interpretation of these as alluvial is the major error of the section. (It is perhaps excusable, in view of the wide areas of derived Bunter gravels along the Trent Valley.) His placing of coal directly beneath the Pebble Beds is less easy to understand, unless he was aware of the fact that the Permian beds are overlapped around Nottingham so that the Trias does in fact rest directly on Coal Measures. To the east, to beyond Newark, the Keuper Marl with its red clay, "marlstone", and gypsum "strata balls" is represented without major deviation from the outcrops known at present.

The Lower and Middle Lias on the section seem to be clear from Long Bennington, where the Blue Lias (hydraulic) limestones are depicted, to the River Witham at the foot of the Lincoln edge, but Farey seems to have found some difficulty in representing the alternation of clays and sands of the Upper Lias and Lower Estuarines in the escarpment. The Yellow-Red freestone is marked on the British Museum (Natural History) copy "Northampton - Uppingham" but the other Oolite Limestones are a little confused. The Collyweston and Stonesfield "Micaceous Gritstone Slate and Limestones" are wrongly correlated and are overlain by Barnack Rag Freestone; they are also wrongly placed above the Ancaster Freestone. The Oolite near Ancaster is marked in the British Museum (Natural History) copy "Ketton-Bath", again showing mistaken correlation. The Great Oolite Clay and Limestone (with its subdivision the Bedford Stone) are, however, clearly shown around Sleaford.




Text-fig. 1. Farey's section from Ashover, Derbyshire to Trusthorp, Lincolnshire, 1808




Text-fig. 2. Farey's section across the Peak District

The thickness of the Oxford and Kimmeridge Clays has been exaggerated by the scarp of the Cretaceous being made too high, but it is interesting to note that the two great clays have been separated by a broken line. The intervening Ampthill Clay has not been recognized.

The Lower Cretaceous is shown on the section as Woburn Sands with a Fullers Earth subdivision in the middle, but this also is a mistaken correlation by Farey and should be the Spilsby Sandstone Series. The overlying clays are left unnamed. The coarse sand and Red Cawk above are clearly the Carstone and Red Chalk. Two divisions of the Chalk proper are recognized. Finally, to the east, the fen clays are mistakenly labelled "London Clay" at Alford. The superficial deposits of the fens need no comment.

In this section Farey is considerably more detailed than William Smith's map, published several years later in 1815. Farey had the advantage of a larger scale, approximately 1 inch to 1 mile, whilst Smith's map was 5 miles to 1 inch. The only major error in Farey's portrayal is the position of the Bunter Pebble Beds; less important errors are in the Oolite Limestone, the Woburn Sands and the London Clays – all understandable in the state of knowledge in the early 19th century. The confusion in the Jurassic rocks at first seems surprising in view of William Smith's work in the Bath area, but the correlation of some of the equivalent beds in the Midlands is still uncertain in places.

2) The Derbyshire section (Text-fig. 2) in Sheffield library is catalogued as Farey's (Oakes Deeds 1224) and is nearly 4 feet long by 7½ inches high. Although again on a scale of about 1 inch: 1 mile, it has been taken across the Derbyshire "Dome" further to the north-west; the wider outcrops there afford more room to depict the Millstone Grits and Coal Measures in fuller detail. It has the appearance of having been drawn by a different hand (perhaps a draughtsman under Farey's instruction), with a key added in another hand. There is no inscription and it does not bear Farey's name, so there is a possibility that it is not Farey's work.

The section starts near Macclesfield and crosses the Goyt syncline, showing a thick basal Millstone Grit Shales overlain by two grits. Two faults are shown at the boundary of the Limestone at Buxton but the words "Great Fault" appear in the wrong place; the boundary here is in fact an unconformity. To the east across the Limestone "Dome", three toadstones are shown alternating with limestones in the Sheldon-Bakewell Area, though it would be difficult to place these toadstones today. The words above the "Dome" note the former extent of the top of the Limestone and the Second Coal Stratum, and clearly indicate that Farey understood that these superincumbent strata had been eroded away.

East of Chatsworth, the thick "Edale" Shales are followed by four thick grits, presumably the Kinderscout, Ashover, Chatsworth and Crawshaw horizons. In the Coalfield, a large number of horizons are shown but are labelled "uncertain" in the key, only a few important coals being specified. These show the influence of the Brimington-Callow anticline. Coal No. 12 is about the Silkstone horizon; No. 17 is either Parkgate or Deep Hard; but coal No. 25 is unidentifiable. Langwith is well within the Magnesian Limestone outcrop and this latter stratum is not indicated on the section.

Topley's Geological Survey version of this section is across the coalfield and Millstone Grit only, but has considerably better stratigraphic detail. The gritstone beds 1, 3, 5 & 7 are labelled "First, Second, Third and Sixth Grits" respectively. Bed No. 13 is labelled "Tenth Grit", No. 18 "Thirteenth Grit", and No. 22 "Twentieth Grit". Beds No. 24 upwards are labelled "First, Second, Third and Fourth Yellow Limestones" and the Coal (no. 25) is marked "Blue Limestone".

This section is drawn partly along the same line as the well-known section in White Watson's Delineation (1811).• Comparison of the two shows that the latter had a finer comprehension of the structure of the Carboniferous Limestone area, whilst Farey understood the coalfield better. It is a pity that this Derbyshire section of Farey's is undated, for it could have provided a clue as to who had more influence on the other's ideas – White Watson or Farey (see Ford 1960). It is known, however, that they disagreed over the nature of faulting, and that Watson's account of the Matlock area (1813) was written to "correct Farey's section". The limited number of faults on this section may indicate that it was drawn before Farey had fully formulated his own ideas on the subject, for his Great Peak Fault and Bakewell Fault are not shown on this section.

3) The London - Brighton section (Text-fig. 3) in the Geological Survey collection (MS 404 -B) is again on a scale of 1 inch: 1 mile and is 5 feet 3 inches long. It bears the inscription "To the Right Honourable Sir Joseph Banks, President of the Royal Society, in testimony of his zeal and liberality in promoting every inquiry connected with Natural History, this Section of the Strata of the Earth which crop out and appear on the surface in the road between London and Brighton, (made from notes taken in passing this road three times in July and August 1806 and February 1807, and applying the Principles taught by Mr. William Smith, relating to the Stratification of England), together with a Description to accompany it, is most respectfully inscribed by his most obedient and very humble servant

John Farey Senr.,
Land Surveyor and agent,
12 Upper Crown Street,
Westminster."

This section is of particular interest in showing numerous faults, in contrast to the other sections described above. They are shown as "gulfs" widening downwards, and are thus a preview of his block diagrams of faults in his book on Derbyshire(1811). A wide, but otherwise undistinguished, "gulf" is shown beneath the Thames in London; this may represent what is now known to be the buried channel.

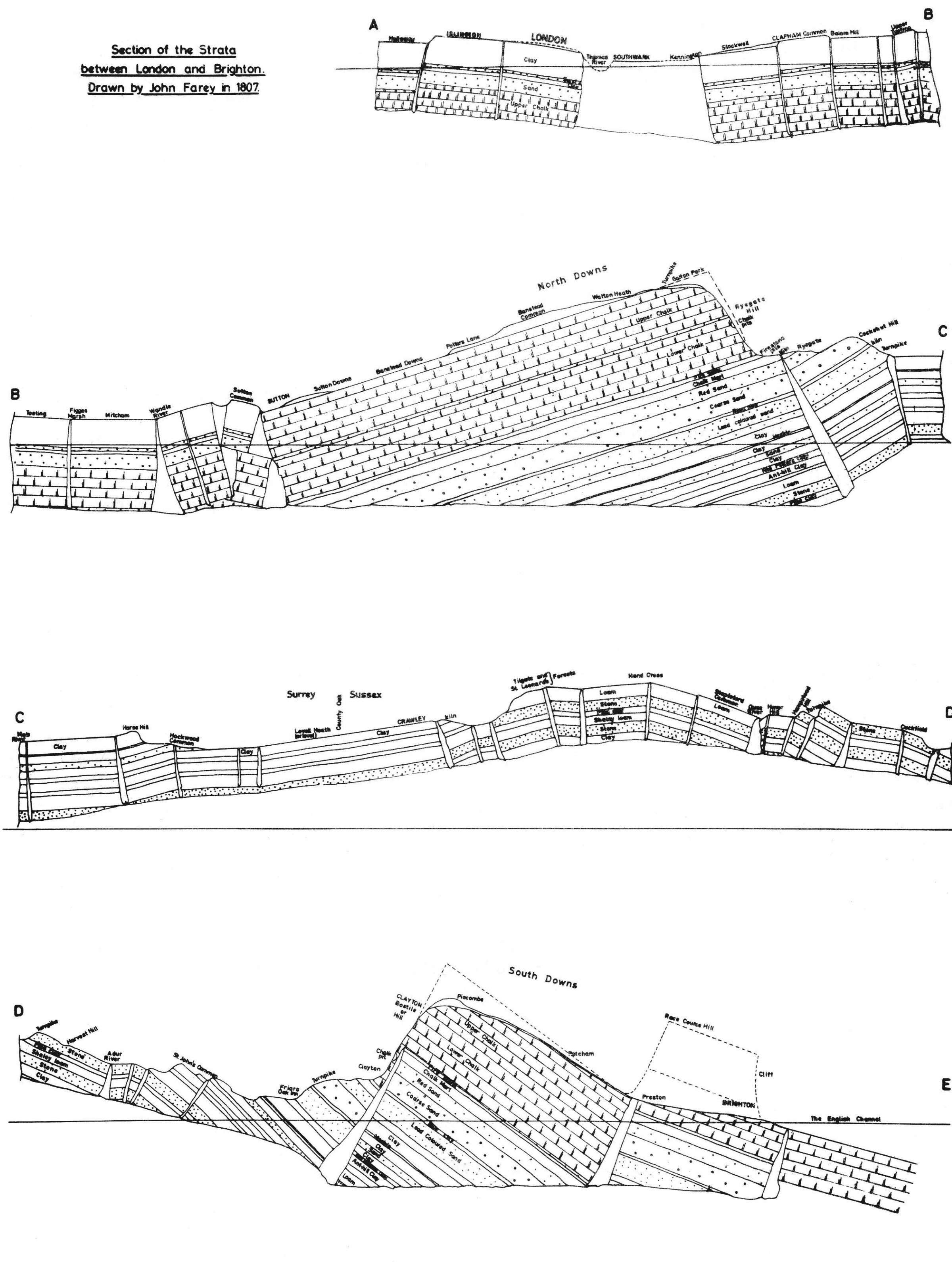
In the London area, the London Clay is shown overlying the Woolwich Beds "Sand and Clay", the Thanet Sands and the Chalk, but the veneer of Tertiaries on the North Downs around is not subdivided, probably owing to the "piping" down into the Chalk of both Lower Tertiaries and Lenham Beds. Beneath both North and South Downs the "Chalk Marl" is evidently the Gault, and the "Firestone" is the Upper Greensand, once mined as a Hearthstone in Surrey. The Folkestone and Hythe Beds follow beneath Ryegate and Cockshut Hill, being shown as "Red Sand, Coarse Sand and Lead-coloured Sand". The "Blue Clay" placed by Farey between the two latter strata is not now recognized. Horse Hill is depicted as a feature, though shown as made of clay; the feature is now known to be due to the presence of the Charlwood Sandstone,which Farey has misplaced to beneath Hockwood Common, where only Weald Clay occurs. The thin band which Farey shows beneath Horse Hill appears to represent the Sussex Marble.

In the centre of the Weald the two Tunbridge Wells Sands are clearly shown, with the "Pipe Clay" apparently the Cuckfield Clay. But to the south, around the Adur River, there seems to be some confusion with the Wivelsfield Sand in the Weald Clay. The lowest stratum shown in the central Weald appears to be the Grinstead Clay, which outcrops well to the east of the line of section and has been correctly projected in the sub-surface.

Taken as a whole this section is a remarkable achievement for only three journeys across the Weald, so that it seems likely that these were protracted journeys with plenty of time to talk to quarrymen etc.. No doubt other pioneer geologists were also consulted, but no mention is made of them.

## The Relationship of the Sections to Farey's other work

John Farey was born at Woburn, Bedfordshire,in 1766. After a common school education he went to a school in Halifax at the age of 16,to study mathematics, philosophy, drawing and surveying. At the age of 26 he was appointed steward to the Duke of Bedford at Woburn. It was there in 1802 that he met William Smith, when the latter was engaged to survey the strata of the Duke's estates. Farey became a convert and disciple of Smith; he indeed gave us the first published account of Smith's discoveries on stratification in 1806, in the first of a series of contributions to Tilloch's "Philosophical Magazine" over a period of some 10 years. From 1807 to 1810 Farey was engaged to survey the Agriculture and Minerals of




Text-fig. 3. Farey's section across the Weald from London to Brighton, 1807

Derbyshire for the Board of Agriculture. It is in the first of the three volumes of this work (published 1811) that Farey published in detail the fruits of his geological knowledge and discoveries. In the introduction to the chapter on "Soils", Farey outlined Smith's succession of strata down to the Red Marl (Keuper, as we now know it), adding his own details regarding the Carboniferous later. He discussed the significance of tracing outcrops and included a simple geological map of Derbyshire.

In this book Farey established a number of "Firsts"; these have been overlooked through being concealed under the title of what appears to be a local report of limited significance. The only recognition hitherto has been the short accounts by Mitchell (1873) and Challinor (1947). The Firsts are:-

The First published regional geological map of a part of Britain.

The First published regional descriptive memoir.

The First geometrical exposition of the nature of faulting.

The First demonstration of the significance of tracing outcrops.

The First recognition of the effects of denudation on outcrops.

The First description of a British Pre-Cambrian area (Charnwood Forest).

It is surprising, in view of the above, that the sections described herein have not previously been recognized and published. The only section in his book on Derbyshire is a very simple one across the Matlock gorge, apparently drawn to show that the "Gulf" postulated by Whitehurst (1786) was not present beneath the Derwent.

Farey's name fades from the geological scene about 1815 and it may be presumed that he was occupied as a mineral and land surveyor from then until his death in 1826 in London.

## Conclusion

No comprehensive study of Farey's works has ever been published, the longest to date being that of Challinor (1947). According to Mitchell (1873), most of his manuscripts were lost during a fire at John Farey Junior's house in 1850 (Sherborn 1929). It is thus hoped that the presentation of these sections of Farey's will help towards an understanding of one of our great pioneer geologists.

## Acknowledgements

I would like to thank my colleague H.S. Torrens for critically reading the manuscript; Mrs. Nita Farquharson for redrawing Farey's sections; and Sheffield Central Library and the Director of the Institute of Geological Sciences for their permission to reproduce their sections. Professor J.F. Kirkaldy made valuable comments on the London-Brighton section.

T.D. Ford, B.Sc., Ph.D., F.G.S.,
Department of Geology,
The University,
Leicester

REFERENCES


CHALLINOR, J. 1947. From Whitehurst's "Inquiry" to Farey's "Derbyshire", a chapter in the history of English Geology. Trans. N. Staffs. Fld. Cl., vol. 81, pp. 52-88.

FAREY, J. 1806. On the stratification of England: the intended Thames Archway etc. Phil. Mag., vol. 25, pp. 44-49.

1811. A General View of the Agriculture and Minerals of Derbyshire. Vol. 1. London, 532 pp.

FORD, T.D. 1960. White Watson (1760 - 1835) and his geological sections. Proc. Geol. Assoc., vol. 71, pp. 349-363.

MITCHELL, W.S. 1873. Biographical Notice of John Farey, Geologist. Geol. Mag., vol. 10, pp. 25-27.

RAMSBOTTOM, W.H.C., RHYS, G.H. & SMITH, E.G. 1962. Boreholes in the Carboniferous Rocks of the Ashover District, Derbyshire. Bull. Geol. Surv. G.B., No. 19, pp. 75-168.

SHERBORN, C.D. 1929. The earliest known geological section across England. The Naturalist, pp. 393-394.

SMITH, W. 1815. A Delineation of the Strata of England and Wales. (Map)

STRACHEY, J. 1719. Observations on the strata in the Somerset Coalfield. Phil. Trans. Roy. Soc., vol. 30, p. 968.

WATSON, WHITE, 1811. A Delineation of a Section of the Strata in Derbyshire. Sheffield, 76 pp.

1813. A Section of the Strata in the vicinity of Matlock Bath, from Ashover to Bonsall, to correct Farey's section. Chesterfield, 19 pp.

WHITEHURST, J. 1778. An inquiry into the original state and formation of the Earth, with observations on the strata of Derbyshire. London. 2nd edition 1786. 3rd edition 1792.


Manuscript received 8th November, 1966

# PROBLEMS IN NAMING THE PLEISTOCENE DEPOSITS OF THE NORTH-EAST CHESHIRE PLAIN

by

Peter Worsley

## Summary

The acceptance of a revised Pleistocene stratigraphy for the region has invalidated the pre-existing lithostratigraphic nomenclature. An alternative definition for the glacial sequence, based upon the American Commission's Code, is provisionally proposed and called the Stockport Formation. The general application of the code to glacigenic deposits is discussed.

## Introduction

The question of stratigraphic classification and terminology is one which is, to a certain extent, permeated with confusion and controversy. Of late some order has emerged, as a result of the application of the recommendations of the stratigraphic code (as proposed by the American Commission, 1961) in classifying lithostratigraphic sequences. In the British Islands, it has not hitherto been general practice to use a systematic code in describing Quaternary sequences. It would appear that this situation has arisen through a combination of two factors - firstly a practice, inherited from the latter half of the nineteenth century, of interpreting drift deposits in terms of a tripartite sequence; and secondly, an apparent unawareness of the need for such a code. It is the purpose of this note to illustrate the dilemma of inappropriate nomenclature which faces Quaternary stratigraphers in the Cheshire Plain region, to suggest a suitable interim measure, and to invite discussion so that general agreement may be obtained. It is hoped that the result will be to encourage research workers to state precisely what kinds of correlations they consider valid, utilising an accepted set of adequately defined terms.

## Historical Background

In a recent paper, Boulton and Worsley (1965) argued that the simple tripartite subdivision of the glacial drift succession in the Cheshire - Shropshire Basin was untenable. They demonstrated the existence of complex drift sequences overlying non-glacigenic alluvial deposits. These 'basal' alluvial beds (characterized by a very high degree of sorting, distinctive pebble lithologies and cross stratification, and the presence of an interformational organic mud bed) were designated the 'Chelford Sands'. Thus the traditional terms 'Lower Boulder Clay', 'Middle Sands' and 'Upper Boulder Clay', for so long embedded in the thinking and language of many glacial geologists, can no longer be regarded as satisfactory lithostratigraphic divisions and should be abandoned. It is therefore proposed to substitute a terminology of lithostratigraphic categories which are guided by a sound stratigraphic code (American Commission for Stratigraphic Nomenclature 1959, 1961).

Ever since Binney's (1848) pioneer study of the glacial succession in north-western England, the Manchester region has been regarded as the type locality for the tripartite succession. The most detailed recent analysis of the Pleistocene succession is that of Simpson (1959), who described an area of 100 square kilometers centred on Stockport and embracing the south western suburbs of the Manchester conurbation. Rather surprisingly perhaps, this region is not completely built over and considerable stretches of land, especially those along the major water courses, are accessible and allow inspection of the entire succession down to bedrock. In addition, several working pits and numerous constructional activities give fresh, albeit temporary, sections in the Pleistocene sequence. Thus, on grounds of both historical precedence and accessibility, this area would appear still to be suitable for providing a type locality and standard section for the deposits of the Late Weichselian glaciation in the north-east Cheshire Plain.

In his synthesis of Pleistocene events in the Irish Sea Basin, Mitchell (1960) accepted Simpson's (1959) correlations and introduced the name 'Adswood boulder clay' to denote the 'Lower Boulder Clay'. The 'Adswood boulder clay' was thought by both Simpson and Mitchell to be of early Weichsel (Würm) age. The criterion for establishing a 'Lower Boulder Clay' glaciation was solely that of lithological super-position, of till on sand on till. The meticulous analysis of their pebble composition showed no differences between the two tills (Simpson, 1960). In no instance was any evidence found which demonstrated that retreat occurred between two distinct glacial advances. Hence, accepting the reasoning and dating of Boulton and Worsley (1965) as being more consistent with known facts, the name 'Adswood boulder clay' should be discarded.

## Application of the American Code to glacial deposits

In the lithostratigraphic hierarchy, a set of divisions of <u>member</u> rank associated by some common physical attribute may be linked together as a <u>formation.</u> Normally there is an association of visible characteristics by which the formation may be recognised. However, the very nature of Quaternary deposits, especially those associated with glacial environments (i.e. a general lack of lithification, lithological variability and transient existence), does not permit the strict application of a stratigraphic procedure which was basically divised for older rocks. Accordingly a slightly modified scheme must be utilised, though the ultimate aim remains unaltered.

There are techniques which, either solely or in combination, could be utilised in confirming a given member's association with the formation. For instance, the north-east Cheshire sequence is characterized by the presence throughout of comminuted (rarely whole) molluscan shell debris in varying degrees of abundance. Theoretically this should enable a check to be made by radiocarbon assay. Alternatively, on occasion the topographic situation and lithostratigraphic type may permit determination of the depth of carbonate leaching from the land surface. Sometimes till sheets exhibit a characteristic range of size distribution and fabric similarities, but at present, in north-east Cheshire, not enough data has been obtained to arrive at any statistically valid conclusions. With these limitations in mind, the selection of a type locality may be considered.

## Proposals

For the moment, two alternative schemes will be outlined, to illustrate the application of the code to sites which appear to be suitable as type localities. The first example highlights the problem of deriving suitable geographical names and serves to emphasize the need for caution in selecting sites. The writer would stress that, ideally, no single individual should be able to determine a binding type locality and nomenclature for such an area without the consent of a central authority.

The need exists for some organisation empowered to adjudicate on all stratigraphic proposals, no matter what age the stratum in question is. To this end, the Standing Stratigraphical Committee of Council of the Geological Society of London set up a Stratigraphical Code Sub-Committee in 1965,to consider stratigraphical usage and to make recommendations. The interim report of this sub-committee was published in 1966; the proposal outlined below is in sympathy with its aims. It is anticipated that final approval for any proposed definition, or changed definition, will be referred to the Commission on Stratigraphy of the International Union of Geological Sciences.

However, the present dilemma cannot be ignored; the second of the two alternatives here outlined has already been used as an interim measure (Worsley 1966) and, as a basis for discussion, the scheme will be here formally proposed for adoption until the subject can be more fully dealt with. Indeed it may, after discussion, prove to be the most appropriate for the area. Hence some basic geological details are given, but the very nature of glacigenic materials (as already commented upon) does to some extent prohibit precise formational definition on physical parameters.

Simpson (1959, fig. 2) depicts part of the River Tame valley north of Woodley, where a small right bank tributary descends in a ravine from the gently rising upper surface developed on the drift deposits (National Grid Reference SJ 937936). The lower reaches of the stream flow over the Carboniferous bedrock and, above this datum, the ravine sides exhibit an upward sequence of till 6.6 m., sand 8.3 m. and till 3.3 m. These divisions are considered by the writer to comprise a single suite of glacigenic deposits. According to the stratigraphic code,each division, distinguished by its lithology, is technically a member and the three members together comprise a formation. Despite their tripartite arrangement, they cannot be described, in the genetic terms of the traditional interpretation, as representing two ice sheet advances with an intervening retreat stage. An inspection of the outcrop patterns, in relation to the contours on both Simpson's accompanying map and the Geological Survey's one inch Stockport sheet no. 98, clearly demonstrates the lateral impersistence of these 'members'. A stratigraphic terminology for the above locality might be:-

| | |
|---|---|
| Haughton Green Formation | Goyt Till Member<br>Mersey Sand Member<br>Tame Till Member |

The names used above for the individual members result from the lack of suitable unambiguous geographical names in the immediate vicinity. In these instances the problem is similar to that encountered in describing borehole data without a known outcrop, for obviously the geographical name of its type locality cannot be given. As such names are preferable in designating lithostratigraphic divisions and no precise name can be assigned, they ought to be derived locally,yet convey no specific locational meaning. Hence the motivation for adopting local river names.

Alternatively, the ground immediately to the north of the River Mersey at Stockport provides a suitable locality. In this case, the tripartite vertical sequence may be seen in the undercut right hand bank (National Grid Reference SJ 908915) east of Reddish. The individual members, when traced westwards, successively become the surface deposit, so that in the west the lowest member represents the entire formation. The terminology may be established as follows:

| | |
|---|---|
| Stockport Formation | Reddish Till Member<br>Heaton Moor Sand Member<br>Levenshulme Till Member |

the two tills being well exposed in local brickpits. Chronostratigraphically, the Haughton Green and Stockport Formations, as here defined, are thought by the writer to be correlatives, although correlation at member rank would not be attempted. However, it is proposed to use the term Stockport Formation in this instance, the first name suggested being of illustrative value only.

It is considered that the Stockport Formation includes the consanguineous suite of sediments, tills and fluvio-glacial sands, which were deposited as a result of the advance and decay of a lobe of the Late Weichselian Irish Sea ice sheet. Basically, this lobe moved from out of the northern Irish Sea Basin into the Cheshire Plain. Its eastern limit is defined as the zone in which the continuous drift cover ceases as the western Pennine escarpment rises above the lowland. Deposition in this zone has no marked glacial morphological expression, but southwards it passes laterally into a marked topographic feature, a bio-lobate end moraine. The end moraine swings westwards across the Cheshire Plain, turning north to follow the Welsh foothills along the borders of the Dee Lowland. Northwestwards towards the source area in the Lake District and Irish Sea Basin, no formational boundary can as yet be defined since it is likely to be under the sea and this must await the results of future research. No satisfactory statement of criteria for defining a morphological "freshness" index to delimit this advance can be made, for the degree of apparent freshness can be notoriously misleading. In Britain it has been usual practice to assign "fresh" landforms to the last glaciation; but apparently "fresh" features are known in both Poland (Galon and Roszkowna, 1961) and in Ireland (Synge, personal communication; Finch and Synge, 1966), where they can be dated with certainty as being of a pre-Eemian Interglacial age.

Where topographic situation permitted, leaching measurements made in till lithologies indicated that the average depth of carbonate removal is in the order of 1.3 m. (Boulton and Worsley, 1965). Such measurements are fraught with difficulties, arising from the need to ensure that site characteristics are constant when the results are used for comparative purposes. Details of the pebble composition found in the till members of the Stockport type area are given by Simpson (1960) and mechanical analysis of the till matrix, undertaken by the writer, revealed that the predominant particle size was silt.

## Conclusions

In view of the difficulties encountered in describing glacigenic deposits, as discussed above, it is readily apparent that, in establishing the basic glacial stratigraphy of the area, some degree of confidence in a particular worker's correlations will be necessary. If, however, future workers conform to a set of agreed definable terms, and if lithostratigraphy is clearly separated from chronostratigraphy, then the misconceptions of the past will be to a large extent eradicated. Using such terms, the communication of exact correlations will be attainable. Hence it is urged that Pleistocene stratigraphers in the area adopt a sound stratigraphic code. It is hoped that this procedure will be adopted generally for the Quaternary of the British Islands.

## Acknowledgements

I thank Professor T. G. Miller and Dr. J. B. Whittow for their friendly advice.

Peter Worsley, B.A., F.G.S.,
Quaternary Research Unit,
Department of Geography,
The University, Whiteknights Park,
Reading, Berks.

## REFERENCES


AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE
1959. Report 6 - Application of stratigraphic classification and nomenclature to the Quaternary. Bull. Amer. Assoc. Petrol. Geol., vol. 43, pp. 663-75.

1961. Code of stratigraphic nomenclature. Bull. Amer. Assoc. Petrol. Geol., vol. 45, pp. 645-65.

BINNEY, E.W. 1848. Sketch of the drift deposits of Manchester and its neighbourhood. Mem. Manchr. lit. & phil. Soc., Ser. 2, vol. 8, pp. 195-234.

BOULTON, G.S. and WORSLEY, P.
1965. Late Weichselian glaciation of the Cheshire-Shropshire Basin. Nature, Lond., vol. 207, pp. 704-6.

FINCH, T. and SYNGE, F.M. 1966. The drifts and soils of west Clare and the adjoining parts of counties Kerry and Limerick. Irish Geogr., vol. 5, pp. 161-72.

GALON, R. and ROSZKOWNA, L.
1961. Extents of the Scandinavian glaciations and of their recession stages on the territory of Poland in the light of an analysis of the marginal forms of inland ice. Przegl. geogr., vol. 33, pp. 347-64.

MILLER, T.G. 1966. Interim report (February 1966) of the Stratigraphical Code Sub-committee of the Geological Society of London. London: Geological Soc. 8 pp.

MITCHELL, G.F. 1960. The Pleistocene history of the Irish Sea. Advmt. Sci. Lond., vol. 17, pp. 107-22.

SIMPSON, I.M. 1959. The Pleistocene succession in the Stockport and south Manchester area. Q. Jl. geol. Soc. Lond., vol. 115, pp. 107-22.

1960. Stone-counts in the Pleistocene of the Manchester area. Proc. Yorks. geol. Soc., vol. 32, pp. 379-87.

WORSLEY, P. 1966. Some Weichselian fossil frost wedges from East Cheshire. Mercian Geol., vol. 1, pp. 357-65.


Revised Manuscript received 14th November, 1966

# A QUARTZ-ROCK-FILLED SINK-HOLE ON THE CARBONIFEROUS LIMESTONE NEAR CASTLETON, DERBYSHIRE

by

Trevor D. Ford

## Summary

Recent excavations west of Castleton have revealed a sink-hole filled with boulders of quartz-rock and covered by loessic soil. Its significance, in relation to the former extent of quartz-rock in the limestone and to the Pleistocene history of the area, is discussed.

## Introduction

Recent opencast workings for baryte in and around the Old Wham Vein, near the site of the Portway Mines, about 1½ miles south-west of Castleton, Derbyshire (National Grid Reference SK 128811) have uncovered an outlier of quartz rock in a depression in the Carboniferous Limestone surface. The site is marked on the Ordnance Survey 6 inches to 1 mile map SK 18 SW as "Gravel Pits". No gravel in the geological sense of the term is present, but in Derbyshire lead-mining literature "gravel" refers to ore in loose lumps; this could still be applied to the scattered lumps of galena-bearing baryte recently worked by excavator methods.

The discovery of this outlier of quartz rock and of associated boulders throws some new light on the former extent of the Pindale quartz rock of Arnold-Bemrose (1898), and also has important implications in the interpretation of Pleistocene denudational history.

## The Portway Outlier

The most obvious feature of the present exposure is the large number of blocks of a light buff coloured quartz rock lying about the spoil-heaps of the baryte workings. Many of the blocks are a foot or more in diameter; some show what appear at first to be bedding laminae about an inch apart. The laminae are of varying grain-size, but do not show any sedimentary structures. Some of the coarser grained layers show small cavities, a few of which are recognizable as casts of crinoid ossicles and other fossil fragments now dissolved away. Only one short section of the quartz rock has been seen in situ, in the present northern face of the baryte workings. This is a layer about a foot thick lying almost horizontally, with its ends near to more or less vertical walls of limestone. Although some movement has taken place due to the baryte workings, it seems clear that the layer formed part of the infilling of a cavity in the limestone surface. The rest of the fill seems to be a jumble of blocks of quartz rock, blocks of baryte, a little chert, and limestone altered to a "rottenstone" condition, all in a matrix of ochreous silty clay.

The dimensions of the infilled cavity are impossible to state in the present nature of the exposures, but it appears to have been of the order of 100 feet in diameter, and at least 12 feet deep (the depth of the baryte workings). The presence of vertical limestone walls indicates that it is some form of solution cavity into which the quartz-rock fill has subsided. Where the walls are now exposed in the workings they show a "skin" of rottenstone, which is rapidly weathering away. This "skin" is largely composed of quartz needles.

Among the scattered blocks are three variations deserving comment. The first has clearly been formed enclosing colonial Rugose corals of Lithostrotion type. These are preserved as tubular casts showing little more than the peripheral parts of the septa, so that specific identification is not possible; from their size and general appearance they would be close to L. martini. The second variety is quartz-rock with small cavities lined with amber fluorite cubes, suggesting that the quartz rock originated before at least part of the mineralization process. The third variety is quartz-rock with joints lined with goethite pseudomorphing marcasite. The significance of this last mineral is uncertain, as it is not normally present in the Derbyshire mineral veins. It may indicate the former proximity of the unconformable Edale Shale cover.

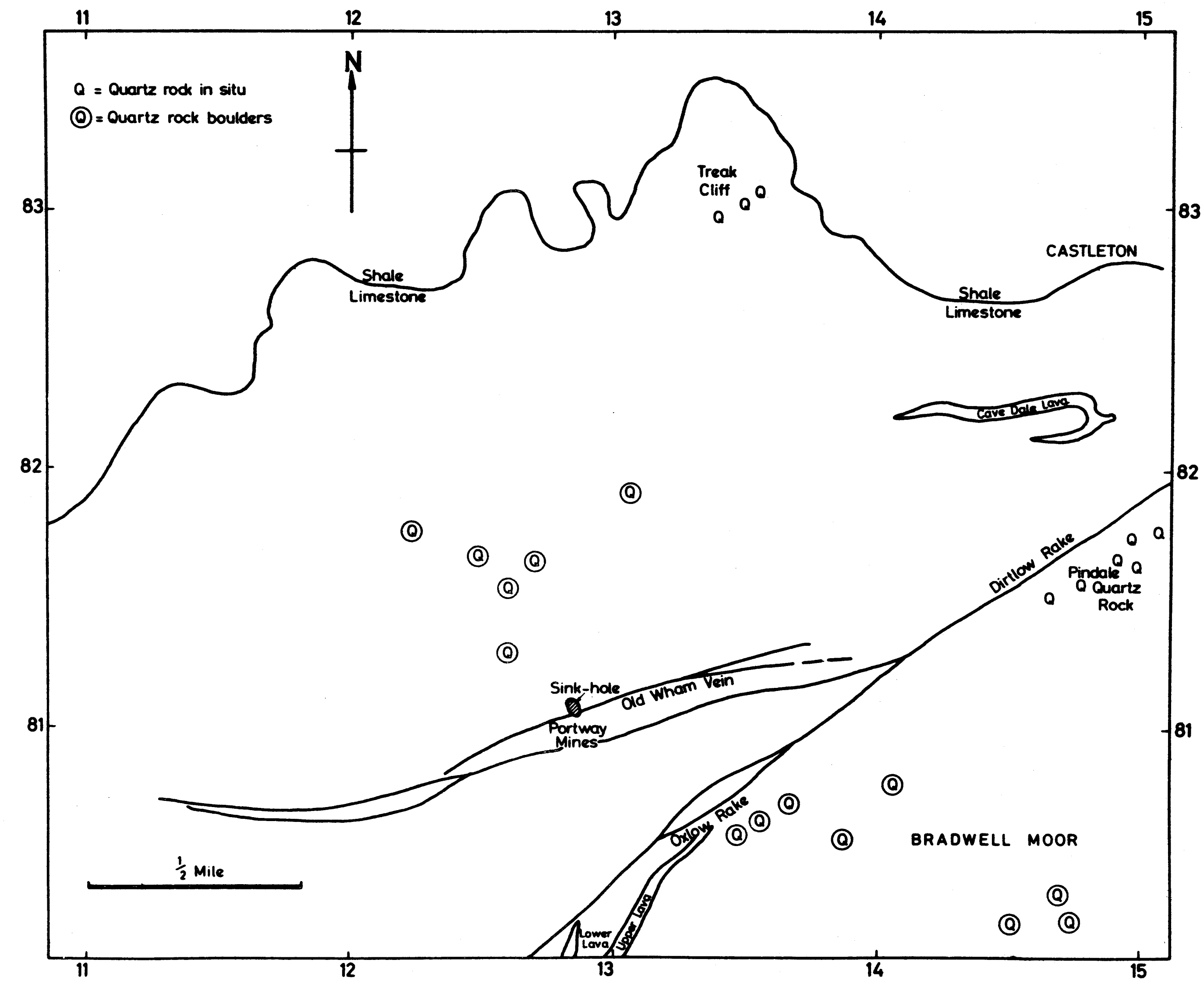
The mineral deposits which have been worked here, firstly for galena and more recently for baryte, are around the Old Wham vein, a branch of the Dirtlow Rake running WSW from Hazard Mine and lying north of Oxlow Rake. Baryte occurs typically in clusters of radiating white bladed crystals up to 3 inches long, with crusts of rather smaller crystals, and with scattered bands of galena crystals. The clusters are usually now found loose, but occasionally can be seen to have developed on what is now a rottenstone, or decalcified quartzose limestone. They are but rarely seen on the quartz rock, or in association with fluorite. Rare deeply-corroded scalenohedra of calcite have been found loose.

In thin section, the quartz-rock at Portway mines is seen to be a mesh of elongate interlocking quartz crystals identical with that described from Pindale by Arnold-Bemrose in 1898. A little fluorite baryte and a very little opaque carbonaceous material, are present interstitially.

The upper part of the working faces shows a soil profile some 3 feet thick, covering limestone and quartz rock alike. At the base of this profile is a layer of boulders of limestone, quartz rock and rare chert, up to about 6 inches in thickness. Above this the bulk of the profile is a layer of ochreous silty clay, which appears to be identical with that described by Pigott (1962) as of partly loessic origin and of Pleistocene age.

The ground surface rises gently from the outlier in both northerly and southerly directions. To the north the ground then drops away steeply towards the limestone-shale boundary, rather more than a mile away. The higher parts of the intervening hill have scattered outcrops of bare limestone suggesting, that if it ever had a cover of loessic soil, this has since been eroded. On this surface there occur occasional blocks of quartz rock, up to 3 feet in length. Some have been utilized in wall building.

Arnold-Bemrose (1898, pp. 176-178) recorded similar scattered blocks of quartz rock to the south of Oxlow Rake (approximately SK 135807) and around Bathamgate and Moss Rake on Bradwell Moor (about SK 1580). These localities have been revisited and the occurrence of the blocks is essentially similar to those north of the Portway outlier.




Text-fig. 1. Location map showing the position of the Portway outlier, the Pindale Quartz Rock and the scattered Quartz-rock boulders, to the south-west of Castleton.

## The Quartz-Rock and Mineralization

As was hinted by Arnold-Bemrose (1898), the quartz rock appears to be an authigenic replacement of limestone associated with mineralization in the Dirtlow Rake-Pindale area, a mile to the east of Portway Mines. A fact not previously recorded is that the quart-rock is clearly cut off by faulting along Dirtlow Rake (SK 151819) showing that the replacement of the limestone took place before the faulting and infilling of the vein there. The Portway outlier is situated on the Old Wham Vein, which is a branch of Dirtlow Rake. The present exposures show little of the walls of the Old Wham vein, but the visible outcrops are not silicified. The main part of the Portway outlier is a few yards off the line of the vein, to the north, and (as described above) the quartz-rock is apparently part of a sink-hole fill, indicating a former cover of quartz rock over this area. The scatter of residual blocks on the hill to the north, and on Bradwell Moor, suggests a very much wider extent of the quartz rock than has previously been recognized. The Portway outlier thus shows again that the quartz rock is older than mineralization, and it also shows that baryte and some fluorite mineralization occurred outside the actual vein, probably as some form of "flat" deposit. The outlier throws no light on the source of the mineralizing fluids or on their direction of flow.

## The Quartz Rock as a Stratigraphical Horizon

"Where the (Upper) lava does not outcrop its place is taken by silica blocks" - so said Shirley & Horsfield (1940, p. 276), implying a genetic effect between lava extrusion and the formation of the silica rock above Pindale and thus using the silic rock as an equivalent stratigraphic horizon. The Portway outlier occurs in limestone of $D_1$ age somewhat above the Cyrtina septosa horizon, i.e. at about the level of the Lower Lava. This does not outcrop in the vicinity (the nearest occurrence is about ½ mile to the south beyond the Oxlow Rake), nor is it known from mine shafts or debris. It is doubtful whether the Upper Lava did extend over this area; if it did, the solution subsidence of the Portway outlier may have let down the quartz rock to its present position. The scattered blocks to the north are in a similar stratigraphic position, but those on Bradwell Moor are at a much higher stratigraphic horizon, far above the Upper Lava, in the $D_2$ beds. These are known to have scattered way-boards of tuff - now usually in the condition of the clay.

Other occurrences of quartz rock in Derbyshire are around Bonsall (Arnold-Bemrose, 1898) where there are several lavas and tuffs nearby, and in Gratton Dale (SK 202600),again where there is the Gratton Dale lava nearby.

The correlation of these latter lavas has been discussed by Shirley (1959) and, whilst they are all in upper $D_1$ or lower $D_2$, the lavas cannot be used as stratigraphic markers from one area to another. The quartz rock is thus seen to be associated with lavas or tuffs at different horizons; whilst it may be used as a field indication of the presence of a lava in the vicinity, it is dangerous to use quartz rock as a stratigraphic marker.

## The Portway Outlier in the Pleistocene

The sink-hole outlier of quartz rock described above is in a comparable topographic position to the better-known Pocket Deposits at the southern end of the Derbyshire Limestone massif (Yorke 1961, Ford 1966 - in press), but there the resemblance ends. The Portway sink-hole is not in dolomite, nor does it contain the refractory sands and clays of the typical pocket deposits. These latter have been assigned to a Tertiary age, (Ford 1966a) and are clearly overlain by Pleistocene till.

The Portway sink-hole overlies the presumed course of the Perryfoot - Castleton underground drainage (Ford and King 1966) and it seems likely that it originated at least in part by solution collapse of a vein cavern in the Old Wham vein.

The fill of the sink-hole, as has been outlined above, is composed of blocks of quartz rock and vein minerals as solution residuals; it is covered by the silty loam soil claimed to be partly loessic origin in one of the early glacial phases (Pigott 1962). No till and no erratics have been found. The residual blocks on the hill to the north, and those on Bradwell Moor, are all of quartz rock; no erratics have been found.

In view of the occurrences of till with erratics of north-western origin (Lake District and Western Highlands) in the Bakewell and Stoney Middleton areas, in Monsal Dale, above Tunstead Quarry in Great Rocks Dale, and on the site of the Derwent Dam (Dale 1900; Jowett & Charlesworth 1929; Dalton 1945, 1953; Fearnsides 1932; Straw & Lewis 1962) the question arises as to whether the Portway outlier is evidence of an unglaciated enclave in the Castleton area. The outlier and particularly the residual blocks on the hill to the north are clear evidence of solutional weathering of the limestone, both on the surface and underground. This occurred both before and since the accumulation of the loessic soil, and it is precisely in such situations where erratics could be expected to occur. The occurrence of till between Doveholes and Bakewell (see Dalton 1945, fig. 1, for a map of the probable direction of flow of the Doveholes ice-tongue) strongly suggests the former existence of a glacier passing down the Wye valley, but in the vicinity of the Portway outlier there is no evidence of either ice erosion or of the introduction of erratics by melt-water streams. This suggests that the Portway outlier was not covered by active streaming ice and may even have been an unglaciated enclave.

## Acknowledgements

I would like to thank Mrs. Nita Farquharson for drawing the map, Dr. R.J. Rice for his critical reading of the manuscript, and Dr. G.R. Orme for the loan of notes on his work on the Pindale quartz-rock.

T.D. Ford, B.Sc., Ph.D., F.G.S.,
Department of Geology,
The University,
Leicester

## REFERENCES

ARNOLD-BEMROSE, H.H. 1898. On a quartz-rock in the Carboniferous Limestone of Derbyshire. Quart. J. Geol. Soc. Lond., vol. 54, pp. 169-183, pls. 11-12.

DALE, E. 1900. Scenery and Geology of the Peak of Derbyshire. London, 176 pp.

DALTON, A.C. 1945. Notes on Glacial Features in N.E. Derbyshire. Proc. Geol. Assoc. Lond. vol. 56, pp. 26-31.

1953. Glacial Evidences of the Sheffield Area. North Western Naturalist, vol. 24, pp. 38-54.

FEARNSIDES, W. G., et al. — 1932. The Geology of the Eastern Part of the Peak District. Proc. Geol. Assoc. Lond., vol. 43, pp. 152-191, pl. 8.

FORD, T. D. — 1966. Sand-filled solution cavities in the Carboniferous Limestone of Derbyshire. Proc. VII INQUA Cong., Boulder. Colorado. (in press)

FORD, T. D., and KING, R. J. — 1966. The Underground Drainage Systems of the Castleton area, Derbyshire, and their evolution. Cave Science, vol. 5, no. 39 (in press)

JOWETT, A and CHARLESWORTH, J. K. — 1929. The Glacial Geology of the Derbyshire Dome and the Western Slopes of the South Pennines. Quart. J. Geol. Soc. Lond., vol. 85. pp. 307-334, pl. 19.

PIGOTT, C. D. — 1962. Soil formation and development on the Carboniferous Limestone of Derbyshire. I. Parent materials. J. Ecol., vol. 50, pp. 145-156.

SHIRLEY, J., and HORSFIELD, E. L. — 1940. The Carboniferous Limestone of the Castleton-Bradwell area, North Derbyshire. Quart. J. Geol. Soc. Lond., vol. 96, pp. 271-299, pl. 18.

SHIRLEY, J. — 1958. The Carboniferous Limestone of the Monyash-Wirksworth District, Derbyshire. Quart. J. Geol. Soc. Lond. vol. 114, pp. 411-429, pl. 20.

STRAW, A, and LEWIS, G.M. — 1962. Glacial Drift in the area around Bakewell, Derbyshire. East Midlands Geog., vol. 3, no. 18, pp. 72-80.

YORKE, COURTENAY — 1961. The Pocket Deposits of Derbyshire. Private Publication, Birkenhead, 86 pp.

Manuscript received 8th November, 1966

# THE OCCURRENCE OF UPPER LIASSIC OTOLITHS AT HOLWELL, LEICESTERSHIRE

by

Adrian J. Rundle

## Summary

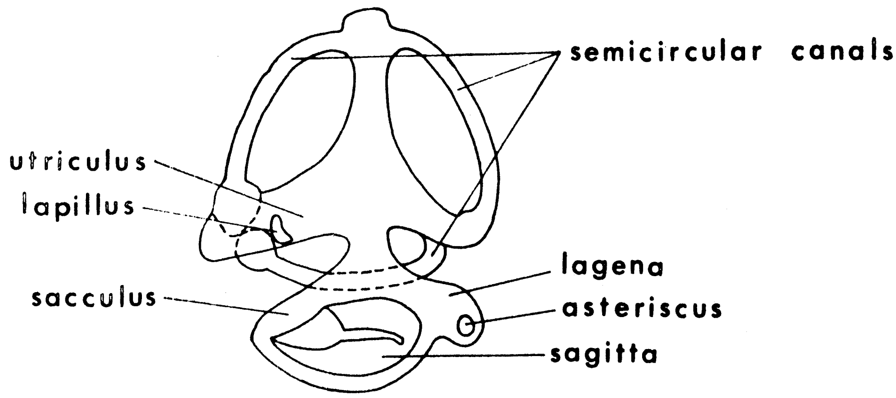
A brief summary of the literature on British Jurassic otoliths is given, together with a list of localities where they have been found. The occurrence of Upper Liassic otoliths at Holwell, Leicestershire, is put on record. Three of the forms are described, one a type of lapillus and two sagittae.

## Introduction

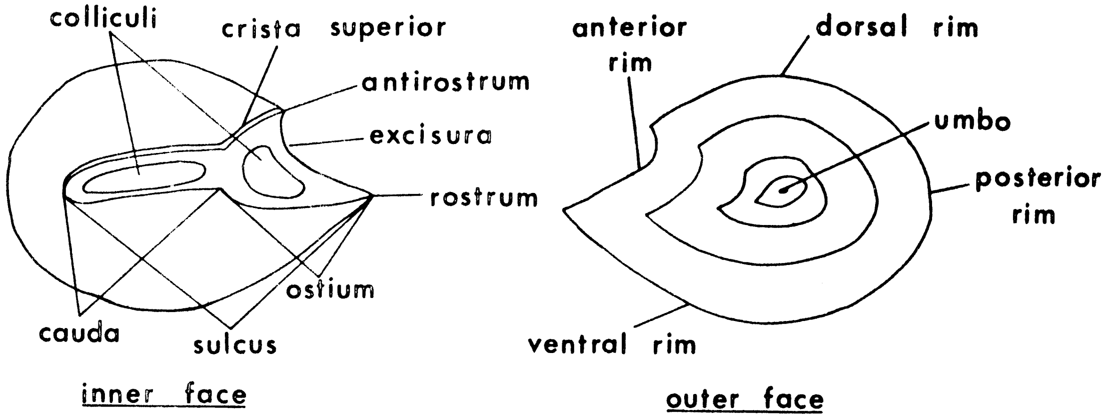
The membraneous labyrinth in Recent Actinopterygian fishes contains three discrete calcium carbonate concretions (otoliths) associated with the auditory nerve and concerned with balance. These otoliths (sagitta, asteriscus and lapillus) occur in three regions (sacculus, lagena and utriculus) of the labyrinth (Text-fig. 1). Also sometimes present in the labyrinth of Recent teleosts are small, probably pathological, calcareous particles usually associated with deformed otoliths (Frizzell and Exline, 1958). In teleost fishes the sagitta is generally the principal otolith. The orientation and terminology used in describing sagittae and lapilli is given in Text-figs. 2 and 3.

Studies on Recent teleosts have shown that the sagitta possesses characters which are relatively constant within any given species and may be used as a means of identification. It has also been found that certain groups of characters may be used in determining genera or even higher taxa. As fossil teleosts usually occur as scattered indeterminate bones, otoliths are often the only means a palaeontologist has of investigating them. This is relatively easy with Tertiary otoliths which may be compared directly with those of Recent fishes, but with Mesozoic forms this becomes hazardous because of the lack of associated otoliths and skeletons. Generic determination of these otoliths is thus rarely possible, although comparison of a contemporary fish fauna (established on skeletal evidence) with their probable Recent descendents can give a rough idea of otolith affinities.

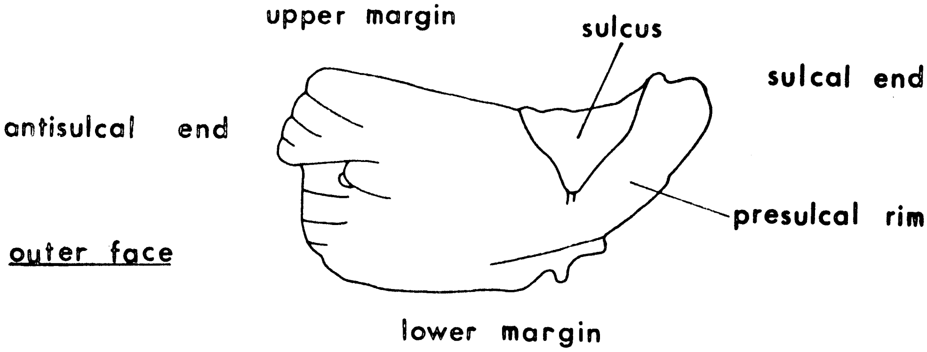
In most fossil deposits where otoliths are encountered, the otoliths are much more frequent than the skeletal remains. This was certainly evidenced in the present study, where no skeletal remains were found although more than a thousand otoliths were recovered. This phenomenon may be caused by bacteria, which are known to be able to live on phosphatic material (e.g. bone) but not on calcium carbonate (S. Rundle, personal communication, 1965).




TEXT-FIG. 1. Diagram showing the location of the otoliths in the membraneous labyrinth.




TEXT-FIG. 2. Diagram of a left sagitta showing terminology.




TEXT-FIG. 3. Diagram of a lapillus showing the terminology given by Frizzell and Dante (1965).

Teleost sagittae are also of use in fisheries research for age determination, done by counting the concentric opaque growth rings (Wimpenny, 1953, pp. 19-21). This is of especial use in studying the plaice (Pleuronectes platessa Linn.), since this fish has scales too small to be readily used and since the otoliths are more convenient than similar annual rings in bones. This is mentioned here because, with the right fossil material, a study of growth rings may be of use in elucidating some details of the ecology of fossil teleosts.

## Previous work on British Jurassic otoliths

The earliest record of Jurassic otoliths in this country appears to be that of Woodward (1893, p. 271) who stated that "Otolites of Fishes have also been found" when naming some of the fossils from the Paper Shales (Upper Lias - Tenuicostatum Zone) of Northamptonshire. The next mention they receive is by Frost (1924), who described six species from the Upper Kimmeridgian of Aylesbury and Hartwell in Buckinghamshire, one of these also being recorded from Swindon, Wiltshire. As these otoliths (sagittae) resembled those of the Recent Elopid fishes he assigned them to the "Leptolepididae" which he considered to be their forerunners. In 1926 Frost described a further six species from Hartwell, two based on sagittae and also assigned to the Leptolepidae, and four types of lapilli which he was unable to assign to any group. He also described three species based on "sagittae" of unknown affinity from the Lower Lias of Charmouth, Dorset.

The most recent work is that of Stinton and Torrens (in press), who describe ten species based on sagittae from the Bathonian of Bradford-on-Avon, Wiltshire, and Langton Herring, Dorset. These authors placed seven species into three previously established genera for skeletal remains, by means of comparison between the contemporaneous fish fauna and Recent forms. Thus Leptolepis, the presumed ancestor of the Clupeidae, was used to embrace three of the species (cf. Frost). The general morphology of the otolith was also used in placing two types of subcircular sagittae, usually characteristic of deep-bodied fishes, in the Pycnodontidae.

## British Jurassic otolith localities

As otoliths have been found at few Jurassic localities in this country, it would be worthwhile to list those at present known to the author, as a guide to their distribution and to emphasize how much they have been overlooked.

| | Horizon | Locality | Source |
|---|---|---|---|
| 1. | Lower Lias (Raricostatum Zone) | E. of Charmouth, Dorset | recorded by Frost (1926) (now in B.M. Collections) |
| 2. | Lower Lias (top of Ibex Zone) | E. of Charmouth, Dorset | recorded by Frost (1926) (now in B.M. Collections) |
| 3. | Lower Lias ("Striatum Zone" = Maculatum Subzone of Davoei Zone) (see Dean et al., 1961, p.467) | Napton-on-the-Hill, Stockton, Rugby, Warwickshire | B.M. Collections (P 37658-59). Also probably P 22806 |
| 4. | Lower Lias ("Striatum Zone") | Shearn's Quarry, 2 miles S. of Radstock, Somersetshire | B.M. Collections (P 37656) |
| 5. | Lower Lias (Davoei Zone) | 2/5 of way between Golden Cap and Seatown, Dorset | Author's personal collection |
| 6. | Lower Lias (Davoei Zone) | Waddington Brick Pit, Waddington, Lincolnshire | Author's personal collection |

| | | | |
|---|---|---|---|
| 7. | "Middle" Lias | Aston Magna, Evesham, Worcestershire | B.M. Collections (P 8573) |
| 8. | Upper Lias (Tenuicostatum Zone) | Northamptonshire | recorded by Woodward (1893) |
| 9. | Upper Lias (Cerithium Beds) | Great Brington, Northamptonshire | B.M. Collections (P 37617-23) |
| 10. | Upper Lias (Cerithium Beds) | Berry Wood, W. of Northampton | B.M. Collections (P 37625 - 47) |
| 11. | Bradford Clay (Discus Zone) | Clay Pit, Bradford-on-Avon, Wiltshire | recorded in Stinton and Torrens (in press): now in B.M. Collections (P 47394; 47406; 47800) and Leic. Univ. Mus. Collection (22725-27) |
| 12. | Fullers Earth (clay underlying the Liostrea hebridica lumachelle) | Rodden Hive Point, S.W. of Langton Herring, Dorset | recorded in Stinton and Torrens (in press): now in B.M. Collections (P 47395-402; 47404-05) and Leic. Univ. Mus. Collection (22718-24) |
| 13. | Kimmeridge Clay | Osmington Mills, Dorset | B.M. Collections (P 22766-67; 23607-09) |
| 14. | Kimmeridge Clay | Weymouth, Dorset | B.M. Collections (P 37610-14) |
| 15. | Kimmeridge Clay | Brill, Buckinghamshire | B.M. Collections (P 37673-741) |
| 16. | Kimmeridge Clay | Shotover, Oxfordshire | B.M. Collections (P 37666-68) |
| 17. | Kimmeridge Clay | Aylesbury Brickfield, Buckinghamshire | B.M. Collections (P 12630; 37669-70) (also recorded by Frost(1924) |
| 18. | Upper Kimmeridge Clay (Pallasioides Zone) | Hartwell, Buckinghamshire | recorded by Frost (1924 and 1926): now in B.M. Collections (P 22733-65; 22768-86; 22807; 37671-72) |
| 19. | Upper Kimmeridge Clay (Pallasioides Zone) | Swindon, Wiltshire | recorded by Frost (1924) |

## Occurrence at Holwell

This paper records the occurrence of abundant otoliths in the Upper Lias (Falcifer Zone) of Holwell, Leicestershire. The exposure in which they were found is at the western end of a large disused ironstone quarry, about half a mile N.E. of Holwell and three miles N. of Melton Mowbray (about SK 744241). The quarry was worked for the Marlstone Ironstone (Middle Lias - Spinatum Zone) which occupies the floor of the quarry. This is overlain in most of the pit by the lowermost Paper Shales (Upper Lias - Tenuicostatum Zone) and Boulder Clay, which yields abundant Lower Lias and Oxford Clay fossils, together with forms from other parts of the Jurassic. In the western end of the quarry the Upper Lias becomes thicker, extending up to the Falcifer Zone, and the Boulder Clay becomes very thin or absent.

Twelve samples of clay were collected at approximately one-foot intervals from a cliff section, on the south side of the end of a roadway into the quarry (built for the removal of the iron ore). The samples were taken from the top of the section down as far as possible, further sampling being prevented by the clay scree slope. If time had permitted it would have been possible to sample a lower sequence about

## TABLE 1

### Distribution of Otoliths in the section studied at Holwell, Leicestershire

Sample 1 was from the top of the section, each succeeding sample being taken at about one foot intervals downwards. The gypsum present in samples 9, 10 and 11 may have been formed by weathering.

| Lithology | Dominant associated fossils | Number of lapilli per kilo | Number of sagittae per kilo | Weight of sample studied |
|---|---|---|---|---|
| Sample 1 Grey clay made up of unorientated small discrete angular fragments of clearly bedded clay (evidently disturbed.) | No recognisable fossils | 0 | 0 | 997.7g |
| Sample 2 Less consolidated layer 4 in. below top of ironstone bed. Contains many flattened calcite ooliths up to 4 mm. Difficult to process, so otoliths may have been missed. | Few fossils (mainly bivalve fragments) | 0 | 0 | 683.0g |
| Sample 3 Varies from a non-oolitic grey clay to an oolitic, ferruginous clay | Few associated fossils | 1 | 0 | 1,109.7g |
| Sample 4 Similar to Sample 2. Base of ironstone bed | Few fossils | 0 | 0 | 930.8g |
| Sample 5 Dark grey oolitic clay with many shell fragments. | Harpoceras falcifer abundant. Bivalves abundant in concentrate | 26 | 33 | 971.5g |
| Sample 6 Grey clay with fewer shell fragments | Bivalve fragments abundant in concentrate. Otoliths poorly preserved | 21 | 35 | 1,202.7g |
| Sample 7 Dark grey clay with many shell fragments | Brachiopods and molluscs abundant in concentrate | 19 | 72 | 999.8g |
| Sample 8 Grey clay with numerous shell fragments and small (? phosphatic) nodules | Concentrate contains abundant bivalves and rather eroded otoliths | 24 | 95 | 873.4g |
| Sample 9 Grey mottled clay with many shell fragments and much gypsum | Bivalves abundant in concentrate. Otoliths poorly preserved | 25 | 37 | 877.2g |
| Sample 10 Same as Sample 9 but not mottled | Same as Sample 8 | 20 | 43 | 1,090.4g |
| Sample 11 Same as Sample 8, but with much gypsum | Concentrate contains abundant ophiuroid plates, bivalves and gastropods | 18 | 54 | 947.3g |
| Sample 12 Well-bedded grey micaceous clay | Concentrate contains abundant ophiuroid and echinoid plates and various molluscs | 45 | 336 | 902.4g |

fifty yards west of this point.

About a kilo of each sample was thoroughly dried at about 100° C and weighed. Most of the clay was then removed by successively soaking in water, wet sieving through a 30 mesh sieve and redrying, until little clay remained. The residue was finally boiled in dilute sodium carbonate (washing soda) solution and then wet-sieved in water as before. Frizzell (1965) states that sodium carbonate should not be used in the preparation of samples because it causes deterioration of the organic fibres of the otoliths. As this reagent is much used by the author for processing Eocene clays without damage to the otoliths, a few of these Liassic specimens of varying preservation were carefully examined, boiled in a 10% solution of sodium carbonate for an hour, and then re-examined. These specimens remained undamaged, so this treatment was used on all succeeding samples.

The dried, clay-free residues obtained were then graded using a 10 mesh sieve, the coarser fraction being sorted by eye and the finer fraction by means of a binocular microscope on a gridded tray, all the otoliths being removed and eventually counted. All the otoliths were found in the finer fraction, none being large enough to be retained by the 10 mesh sieve.

All the samples examined were from the Falcifer Zone, Harpoceras falcifer (J. Sowerby) being found from the top of the Lias in the section to within three feet of the bottom. No specimens of Harpoceras were found in these lower three feet of section, but the occurrence of H. cf. exaratum (Young & Bird) well below this in the Paper Shales in a nearby section proves them to be within the Falcifer Zone.

It was found that the otoliths were most abundant and better preserved in the lowermost sample studied, becoming increasingly scarce higher up (Table 1). As so few otoliths were found within the ironstone bed, it is presumed that the conditions of its deposition were unfavourable to the fishes yielding them. The sorting action of currents cannot have caused this scarcity, since many of the ooliths present are of similar form and size to the otoliths. Solution and attrition may also be dismissed owing to the reasonably good preservation of the otoliths found.

## Taxonomy

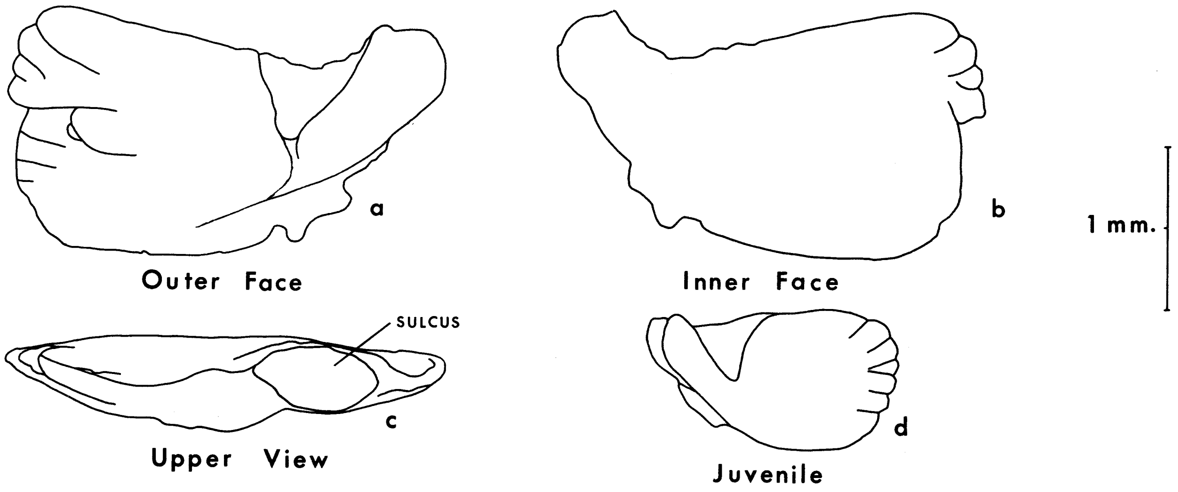
Most works on fossil otoliths have used a trinomial system of nomenclature first established by Koken (1884), in which Otolithus was designated for all fossil otolith-based species. This was followed by a name indicating the probable generic or familial affinities of the species in parenthesis. The use of such a trinomial system is not in accordance with the provisions of the Zoological Code.

An alternative procedure, now adopted by Stinton, Frizzell, and others, is to use conventional generic names where affinities can be demonstrated. There is little difficulty in applying this to Tertiary forms where direct comparision with Recent fishes can usually be made, but with Mesozoic forms this implies a certainty not existing at present and it can therefore be misleading. In cases where the assignment to a genus is somewhat tentative, the insertion of a question mark after the generic name is advisable.

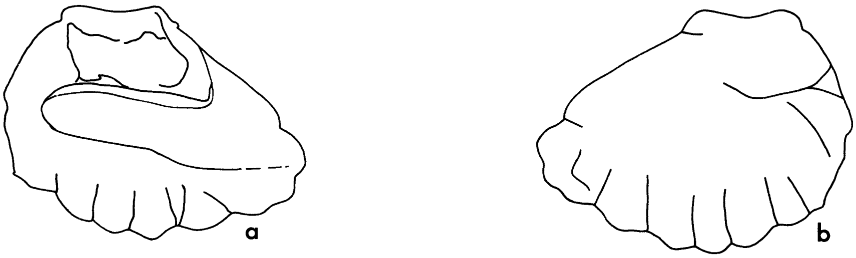
All the lapilli found were of the same type and probably worthy of specific rank; the sagittae, however, belong to many species and would require a great deal of research to elucidate what forms are present and to determine their affinities. It is therefore considered unwise to establish any new species at the present time, but worthwhile to describe the lapilli and two of the sagittae which resemble forms described by Weiler (1953, 1965).

The figured specimens, excepting the sagitta lost in transit, have been deposited in the British Museum (Natural History), the numbers being those of the Department of Palaeontology.

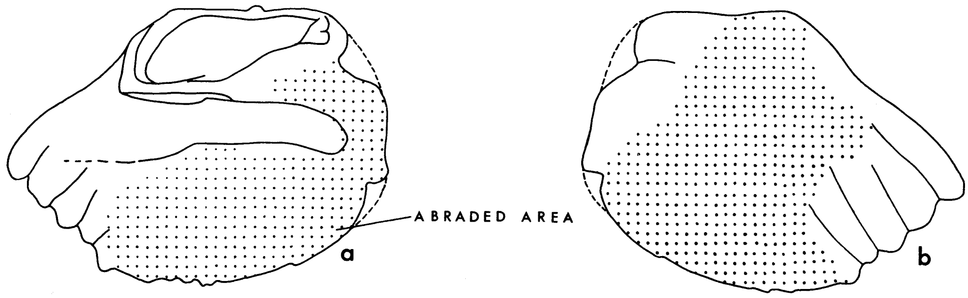
### Semionotidae (?) gen. indet.
(Text-figs. 4a, b, c, d)




**TEXT-FIG. 4.** Semionotidae (?) gen. undet.




**TEXT-FIG. 5.** cf. Lycopteroidarum? brevis Weiler




**TEXT-FIG. 6.** cf. Lycopteroidarum? ornatus Weiler

**CAMERA LUCIDA DRAWINGS OF UPPER LIASSIC OTOLITHS.**

Figured specimens: P 48683 (Text-figs. 4a, b, c): P 48684 (Text-fig. 4d).

Dimensions: P 48683 Length 2.7 mm. Width 1.5 mm. Length/Width 1.8

P 48684 Length 1.5 mm. Width 0.9 mm. Length/Width 1.7

Description: An elongate lapillus with a concave outer face and a convex inner face. Antisulcal half of otolith roughly rectangular, sulcal half tapering towards the sulcal end. Sulcus restricted to triangular region in sulcal half of otolith, opening widely on upper margin and extending half way towards lower margin. Presulcal rim wide and curved outwards. Upper margin relatively smooth, lower margin smooth except for two projections about one third of length from sulcal end, antisulcal end crenulate, divided into two by notch making upper half project over lower half. Outer face smooth.

The juvenile (Text-fig. 4d) differs from the adult in lacking notch on antisulcal margin, although the position where the notch will develop is distinct owing to two crenulation directions, the lower set being approximately horizontal and the upper set directed downwards, as in the adult.

Discussion: These lapilli are referred to the Semionotidae because this order is thought to be the forerunner of Lepisosteus in which the major otolith, the lapillus, is very similar to this form (Stinton, personal communication).

The specimen closely resembles the lapillus from the Lower Lias of Charmouth, Dorset, figured by Frost (1926) as Otolithus (incertae sedis) curvatus. His specimen differs, however, in lacking the crenulate antisulcal margin characteristic of this form. Lapillus Typus a and b figured by Neth and Weiler (1953), although appearing to be somewhat abraded, are also similar to this specimen; Typus a differs in lacking any crenulations and Typus b in that the crenulations present are not divisible into two well defined zones.

cf. Lycopteroidarum ? brevis Weiler
(Text-figs. 5a, b)

(The specimen figured here was unfortunately lost in transit.)

Dimensions:- Length 1.9 mm. Width 1.4 mm. Length/Width 1.4

Description: A thin, rather elliptical left sagitta. Dorsal rim horizontal, slightly concave owing to two feeble lobes; rounded, slightly uneven posterior rim; rounded, crenulate ventral rim; and long, oblique, uneven anterior rim. Outer face slightly concave and ornamented with radiating ribs in the ventral and posterior regions. Umbo indistinct, approximately central. Inner face slightly convex, with a medium sulcus opening widely on the anterior rim and terminating near the posterior rim. Sulcus consists of a short, triangular, shallow ostium and a long, wide, slightly curved cauda. Crista superior recurving at the ostial end to form an acute angle and coalescing with the dorsal rim: it is accentuated by a depression above. Marked rostrum; no exisura, antirostrum or colliculi.

Discussion: Stinton (personal communication, 1965) states that he is not in favour of Weiler's group Lycopteroidarum, partly because the genus Lycoptera is freshwater, not marine, and partly owing to the presence of a large asteriscus in this genus, which is presumed to be ancestral to the Cyprinidae whose sagittae do not resemble these.

cf. Lycopteroidarum ? ornatus Weiler
(Text-figs. 6a, b)

Figured specimen: P 48685

Dimensions: Length 2.3 mm. Width 1.7 mm. Length/Width 1.35

Description: A thin, rather elliptical right sagitta. Dorsal rim horizontal, slightly concave; posterior rim notched in two places owing to corrosion, probably bevelled; evenly rounded, crenulate ventral rim, corroded posteriorly; and oblique anterior rim. Outer face flat, ornamented with radiating ribs in the ventral region (absent posteriorly due to abrasion). Flat inner face, with a median sulcus opening widely on the anterior rim and terminating near the postero-ventral corner. Sulcus consists of a wide shallow ostium, with an indistinct lower margin, and a long, narrow, relatively deep cauda, slightly downturned near its posterior end. There is an indistinct angle between the ostium and the cauda on the lower rim. Crista superior recurving at the ostial end to form an acute angle and coalescing with the dorsal rim: it is accentuated by a depression above. Marked rostrum and shallow excisura; no antirostrum or colliculi.

Discussion: Although much abraded, most of the diagnostic features are still discernible on this specimen.

## Conclusions

It is evident that Jurassic otoliths are not such rare fossils as was previously supposed and, if a careful and systematic search is made in the clay strata at other localities, there is little doubt that otoliths will come to light. The fauna includes a possible Semionotid represented by numerous lapilli, and several forms of sagittae similar to those grouped as Lycopteroidarum? by Weiler, probably not true Lycopterids.

## Acknowledgements

The author would like to thank Mr. F.C. Stinton for identifying the specimens figured and for his help and encouragement over the past few years; the Keeper of Palaeontology, British Museum (Natural History), for permission to study museum material; Mr. H.A. Toombs for help with literature, etc.; Dr. C.H. Rochester for help in the field; Stewarts and Lloyds Minerals Ltd. for permission to visit the Holwell Quarry; and members of the Department of Geology, Nottingham University, for their help and advice.

## REFERENCES

DEAN, W.T., DONOVAN, D.T. and HOWARTH, M.K.
1961. The Liassic Ammonite Zones and Subzones of the North-West European Province. Bull. Brit. Mus. (Nat. Hist.) Geol., Vol. 4, pp. 435-506, Pls. 63-75.

FRIZZELL, D.L. 1965. General Procedures and Techniques applicable to Major Fossil Groups - Otoliths. In KUMMEL, B. and RAUP, D., "Handbook of Paleontological Techniques", San Francisco: Freeman, pp. 125-127.

FRIZZELL, D.L. and DANTE, J.H.
1965. Otoliths of some lower Cenozoic fishes of the Gulf Coast. J. Paleont., Vol. 39, No. 4, pp. 687-718, Pls. 86-88, 2 text-figs.

FRIZZELL, D.L. and EXLINE, H. 1958. Fish ossiculiths; unrecognized microfossils. Micropaleontology, Vol. 4, No. 3, pp. 281-285, text-figs. 1-7.

FROST, G.A. 1924. Otoliths of fishes from the Upper Kimmeridgean of Buckinghamshire and Wiltshire. Ann. Mag. Nat. Hist., London, Ser. 9, Vol. 14, pp. 139-143, Pl. 5

1926. Otoliths of fishes from the Jurassic of Buckinghamshire and Dorset. Ann. Mag. Nat. Hist., London, Ser. 9, Vol. 18, pp. 81-85, Pl. 4.

KOKEN, E. 1884. Ueber Fisch-Otolithen, insbesondere über diejenigen der norddeutschen Oligocän-Ablagerungen. Z. dtsch. geol. Ges., Berlin, Vol. 36, pp. 500-565, Pls. 9-12, 3 text-figs.

MARTIN, G.P.R., and WEILER, W. 1965. Neue Untersuchungen an Fisch-Otolithen aus dem älteren Jura NW-Deutschlands. Senck. leth., Vol. 46, pp. 35-72, Pls. 2-4, 4 tabs.

NETH, U. and WEILER, W. 1953. Untersuchungen an Fisch-Otolithen aus dem deutschen Dogger. Paläont. Z., Vol. 27, pp. 113-121, 1 Tab.

STINTON, F.C. and TORRENS, H.S. (in press). Fish Otoliths from the Bathonian of Southern England. Palaeontology.

WIMPENNY, R.S. 1953. The Plaice. London: Arnold, 145 pp., figs. 1-27.

WOODWARD, H.B. 1893. The Jurassic Rocks of Britain. Vol. III. The Lias of England and Wales (Yorkshire excepted). Mem. Geol. Surv., U.K.


Manuscript received 28th November, 1966

# A GLACIAL CHANNEL AT SPROXTON, LEICESTERSHIRE

by

Peter Charles Stevenson

## Summary

A channel, incised into the solid rocks and first encountered during the working of an ironstone pit, is described, and an account given of the contents. A plan and measured sections of the channel are presented; recognition of the channel by a resistivity anomaly is established; its topographic setting is summarized and some suggestions are made as to its origin.

## Introduction

In 1961, the opencast working of the Northampton Sand ironstone at Sproxton in Leicestershire intersected a channel filled with unconsolidated sand, gravel, and clay. The pit ceased working but remained open until 1965, when it was backfilled and the land reinstated. While it was open, the visible parts of the channel were mapped by a project party of the East Midlands Geological Society led by the author; samples were taken, and sketches and some geophysical measurements were made, mostly during the summer of 1964. This paper assembles the information on the channel, partly on the basis of observations made by the quarry owners at the time of excavation, and partly from observations made by the project party.

## Location and Solid Geology

The site of the channel lies in Sheet SK 82 of the 1:25,000 map of the Ordance Survey. Map references of the known ends of the channel are 854255 and 874254, between which it follows a slightly sinuous course. The village of Sproxton (pronounced to rhyme with 'roasten') lies about 1 km. to the south of the site and Saltby about 1 km. north-west of it.

The solid geology of the site is as indicated in the following table:

| | | |
|---|---|---|
| Lincolnshire Limestone, mostly below the horizon of the Crossi Bed | | 34 - 36 ft. |
| Lower Deltaic clays and silts | | 22 ft. |
| Northampton Sand ironstone | about | 25 ft. |
| | (base not seen) | |

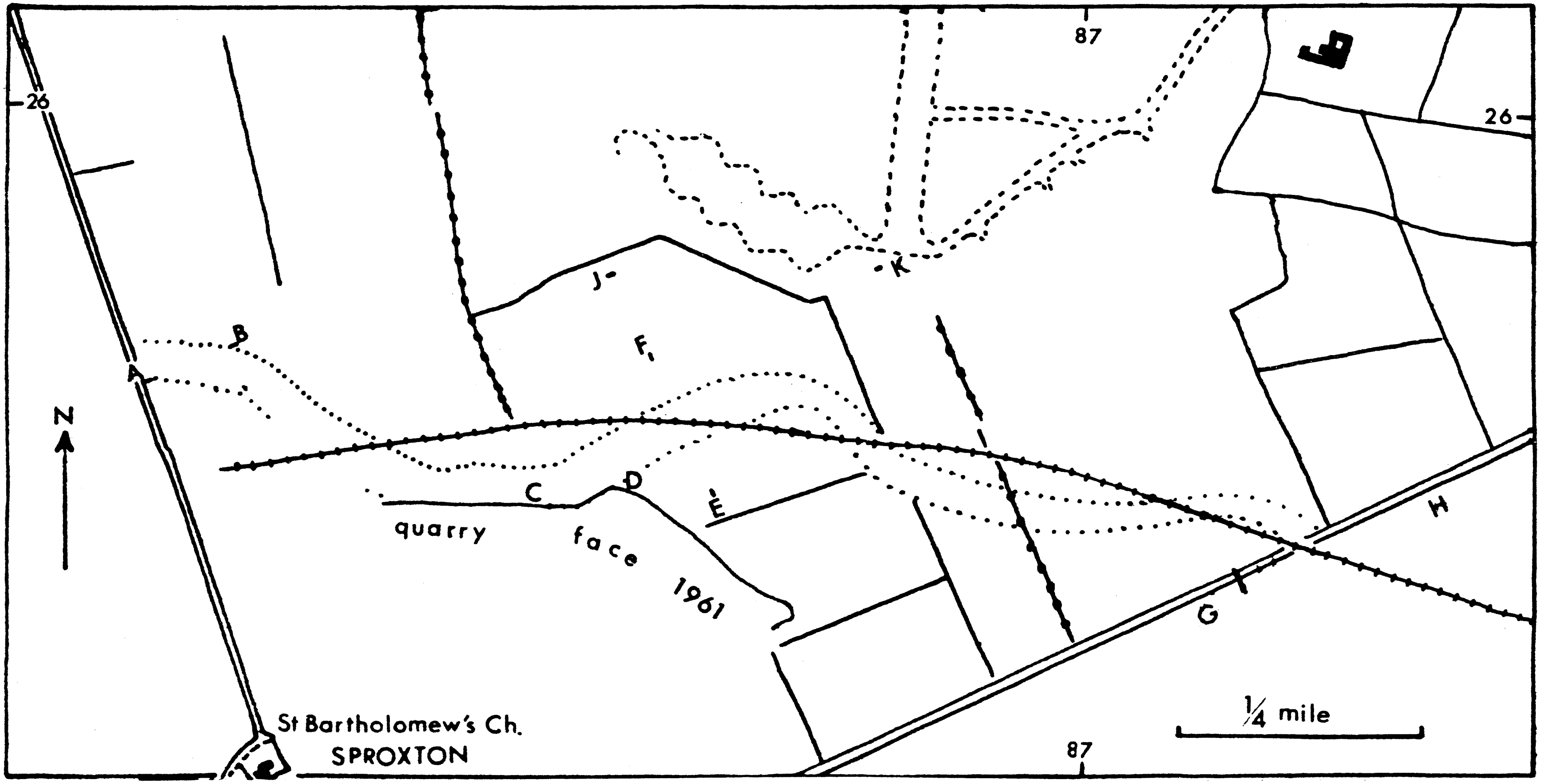



Fig. 1. Plan of the Sproxton channel, showing positions of Sections A–B, C–D, and Geophysical Traverses E–F, G–H, and J–K

These rocks are patchily covered by spreads of brown and grey boulder clay, and form a plateau departing little from 500 feet.

The solid rocks dip east at a low angle; some normal faulting, of a few feet throw, has both been encountered in the quarries and mapped by the Geological Survey.

## The Channel in Plan

When first encountered, the channel was located by the quarry owners by means of a large number of boreholes; its course, as plotted in Text-fig. 1, is derived from their maps. The normally well-bedded Lincolnshire Limestone was seen to be replaced by a poorly-bedded sequence of coarse sand, rounded limestone pebbles and boulders, and a cover of grey and brown boulder clay. A line of boreholes about 10 metres apart was drilled along a hedge line, on a bearing of about 080 deg. True, from 855255 to and beyond the site of the old Sproxton windmill. The hedge line and the mill no longer exist, but are shown on old maps. The smaller section (A-B) in Text-fig. 3 has been constructed from the borehole records, which, though indefinite and incomplete, indicate the possible depth and width of the channel.

The channel then appears to pass under the existing office and workshop buildings and was next seen in a small access cutting to the north of the western end of the 1961 quarry face, indicated in Text-fig. 1. Here the visible channel filling consists of about 10 ft. of brown crumbly clay with patches of grey clay, groups of rounded limestone boulders and irregular beds of coarse sand. Because both sides of the channel, where the filling is in contact with undisturbed limestone, are obscured or have been removed, the exact width is not measurable, but it is not much in excess of 200 ft. The south side of the channel was exposed in the quarry face from C to D as shown in Text-figs. 1, 2, and 3. The line of trees shown in the sketch (Text-fig. 2) and in the Plate also appears on Text-fig. 1. In 1964, the section C-D, then considerably deteriorated, was measured and sampled, and appeared as in Text-fig. 3 C-D. The course of the channel from here to the East was traced by shallow boreholes drilled by the quarry owners. Its course was apparent to the 1964 party because the normally angular Lincolnshire Limestone 'brash' was replaced above the course of the channel by rounded stones.

The channel was also located crossing the two electrical resistivity traverse lines E-F and G-H in Text-fig. 1. Along these lines, a series of electrical depth probes was taken, using electrode separations up to 90 ft. in the Wenner four-electrode configuration, and read on an Evershed 'Megger' Earth Resistivity meter. The anomalies discovered on traverse E-F are illustrated in Text-fig. 4. The disturbed ground that they represent lies in the position postulated for the channel. Similar anomalies were observed in the channel position between G and H. Traversing between J and K to the north of the channel showed no such anomalies, and, at least in this direction, the channel appears unbranched.

The project party was able to show that rounded boulders of limestone outcrop in fields near 852256, where the ground falls away rapidly towards the Eye Brook; no continuation of the channel on the west side of this stream, where a thick cover of boulder clay is present, could be found. The far east end of the channel similarly runs out into falling ground near 874252, and it cannot be located beyond this point.

## The Channel in Section

The oblique cross-section at A-B (Text-fig. 3) gives the general dimensions of the channel, i.e. from 150 to 200 ft. wide and with its floor more than 50 ft. below the present ground surface. It would appear from this section that the margins of the channel are quite steep and that the limestone close to the channel sides is shattered.

The part of the channel exposed by quarrying (between C and D in Text-fig. 1 and figured in Text-figs. 2 and 3 and in the Plate) was the only part available to general examination; as can be seen

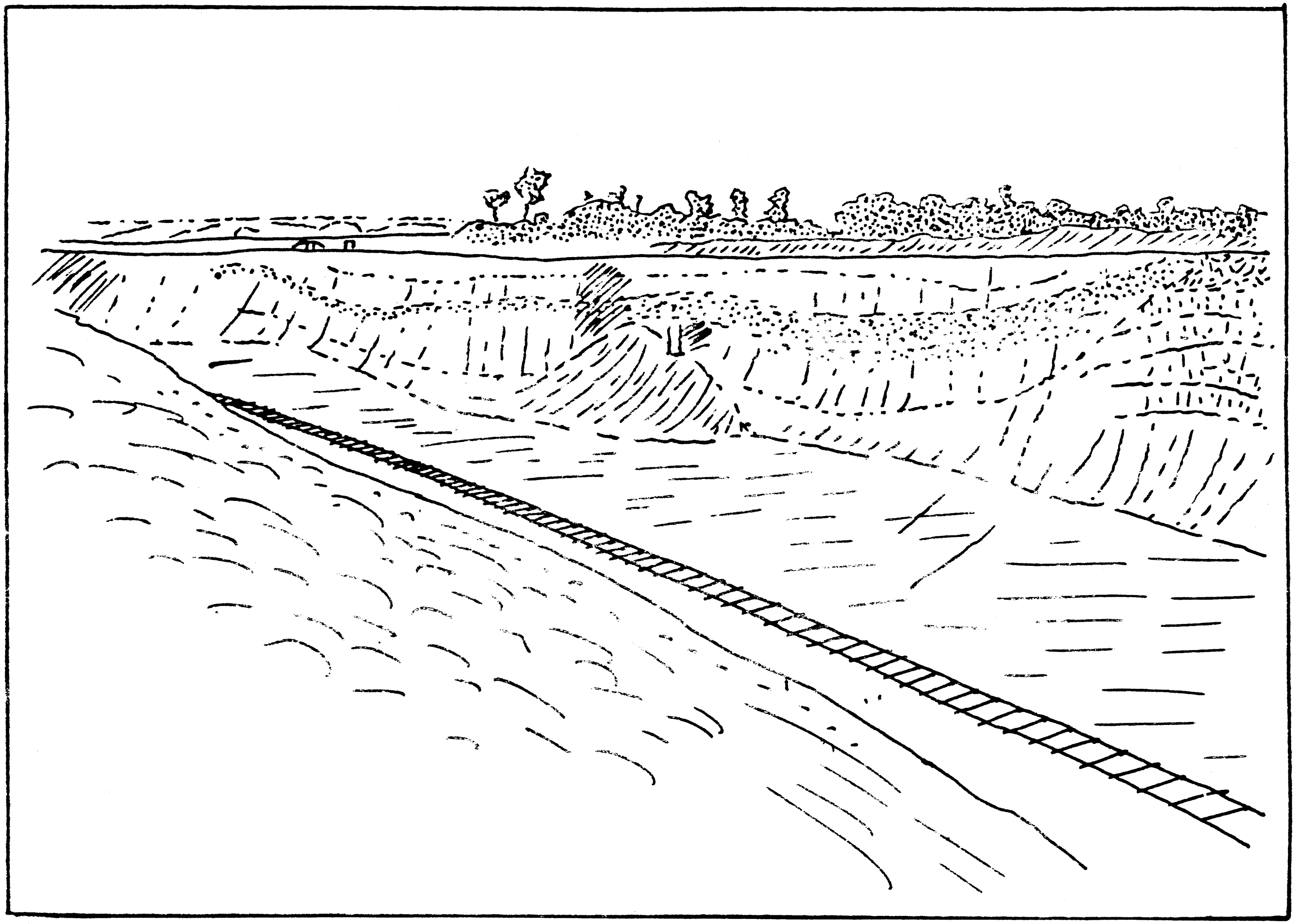


Fig. 2. View of the Section C-D in 1961, compiled from the photographs shown in the Plate. Compare Fig. 3

from Text-fig. 1, it was a section almost parallel with the channel length. The deposits presumably lie in sheets along the length of the channel and slightly concave upward. Any section almost parallel with the channel length will encounter the edges of beds, the apparent height of which will be dependent on the relative positions of the face and the channel centre. The rises and falls in the beds may therefore be due to sinuosities in the face or in the channel rather than to actual longitudinal inclinations in the beds.

In 1964, the lowest exposed part of the section, about 44 ft. below ground surface, consisted of rather ill-sorted rounded gravel and sand, the gravel not being over 3 ins. in diameter. The 1961 view shows material below this level which does not appear substantially different; but clays, possibly varved, have been mentioned to the writer in this position. The gravel and sand continued upward for about 16 ft. with little change in character, when they were replaced by a bed of soft sand without pebbles about 2 ft. thick. Above this band, which appeared discontinuous, about 6 ft. of gravel was again seen, becoming very coarse with particles up to 18 inches in diameter and, for the uppermost three or four feet, firmly cemented with calcite. This cemented band could be followed along the exposed section for nearly 350 ft. Its apparent change in level could be accounted for by the oblique section of the channel, as indicated above.

Above the cemented gravel, there follows up to 12 ft. of grey boulder clay and then from 4 to 8 ft. of brown clay. Little or no soil is seen on this section since it was removed before the face was opened.

At D, where the channel deposits were seen in oblique contact with the limestone, a zone of shattering from 2 to 8 ft. in thickness was seen intervening between them. The solid limestone was itself cambered slightly towards the channel.

## The Channel Sediments

The gravel and sand sample from the C-D section shows a range of grain sizes and its grading curve is shown in Text-fig. 5. The coarser parts of the gravel show a predominant oblate or equant shape, bladed shapes amounting to only 15%. Considerable variations in angularity were noted.

The fraction of the gravel above ½ inch in least dimension consists very largely (about 97% by weight) of material which matches very well with the local succession. A small part of this fraction consists of dark brown or reddish ferruginous sandstone which may be taken to represent the Northampton Sand, while the rest is Lincolnshire Limestone. The remaining 3%, mostly in the ½ inch to 1 inch fraction, consists of foreign material. Of this 3%, 2½% is not difficult to match amongst the Bunter Pebbles of the Midlands, brown and yellow ironstained vein quartz and banded brown quartzites being present. The last ½% consists of dark grey, fine-grained, hard, compact limestone for which a Carboniferous Limestone origin is suggested.

The Lincolnshire Limestone contribution appears in all shapes from very angular to well rounded, while the materials of more distant origin are now uniformly well rounded.

The cemented band in the gravel does not appear to differ in composition from the uncemented, the cementing being entirely secondary and possibly representing a period when the gravel formed the surface of the deposit.

The grey boulder clay of Text-fig. 3 is a hard, light-grey, compact material when dug, which tends to crumble into equidimensional grains from 1 to 10 mm. in diameter. The material is light grey on freshly broken surfaces, but older surfaces running through the mass and dividing the grains are light brown in colour.

Rather few large stones, up to 3 inch in diameter, form about 10% by weight of the boulder

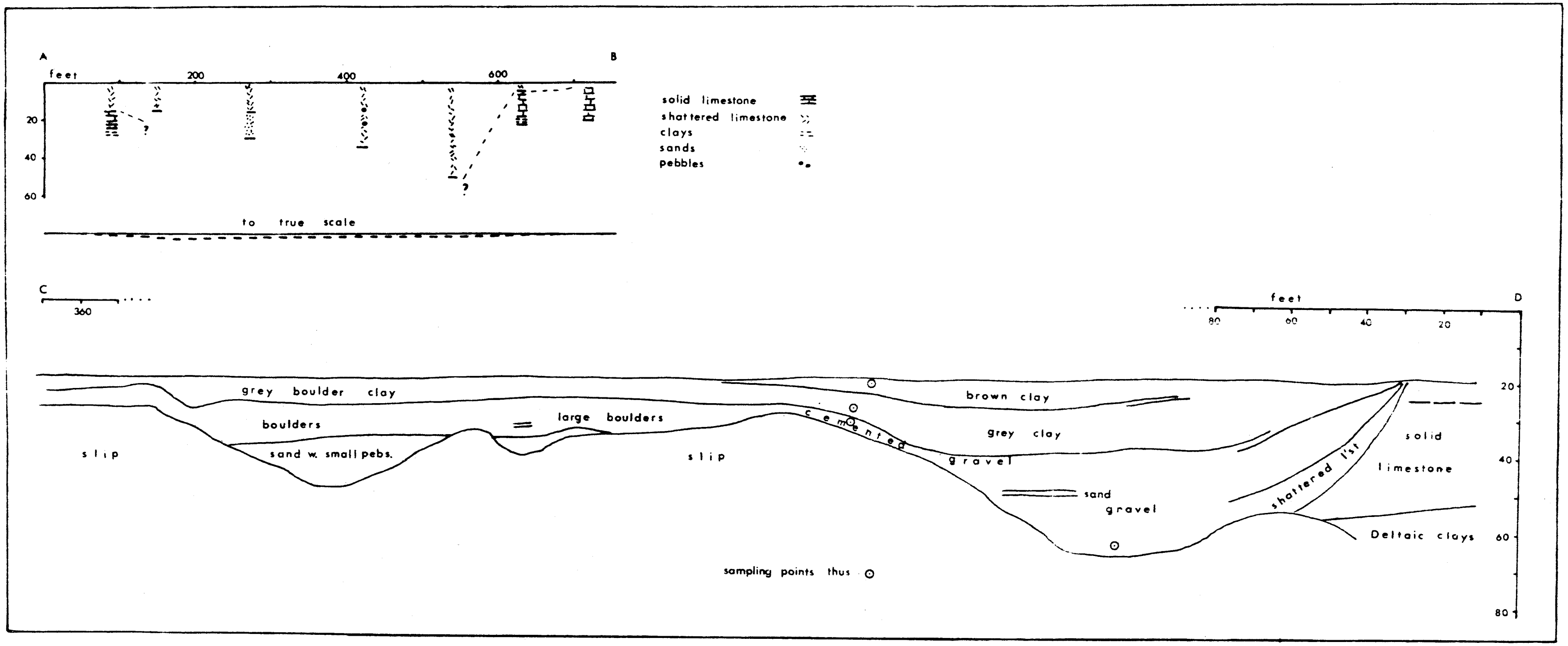



Fig. 3. Sections of the Spraxton Channel. A–B from boreholes; C–D from measurement in 1964

clay. The stones consist of fine grained limestones of Lias aspect, micaceous sandstones and broken fossils (*Gryphaea* sp.).

Smaller stones no larger than $\frac{3}{4}$ in. are contained in the clay, forming perhaps 5%. Of these, the most obvious are particles of chalk, but soft ferruginous sandstone, small limestone pebbles,and small iron-stained quartzes,comparable with those in the gravel, are present. No materials related to the Lincolnshire Limestone are seen, although the clay contains a considerable fine carbonate content,as is evident from the effervescence with dilute hydrochloric acid.

The brown boulder clay overlies the grey clay and is divided from it by a well defined line. The clay shows a similar granular structure when dry and grades up into the surface soil. It is differentiated from the grey clay by a different suite of contained stones, and a complete absence of any carbonate material, fine or otherwise.

The contained stones constitute about 10% by weight of the whole; they divide almost equally into Bunter material and rocks for which no immediate origin is obvious. These consist of medium grained, iron-and silica-cemented sandstones reminiscent of Millstone Grit, white cherts, yellow siliceous siltstones, pink cherts, and occasional igneous rocks. Some of these stones are notably angular when compared with either the Bunter material contained in the brown clay, or with the stones contained in the grey clay. The brown clay has a higher sand content than the grey clay.

The boulder clays only exist within the channel in the immediate neighbourhood. The 'banks' of the channel consist of Lincolnshire Limestone not covered by clay.

## The Topographic Setting

As the channel was seen to end both ways in falling ground, its topographic setting suggested itself as an additional study.

This is summarized in Text-fig. 6, where areas over 500 ft. are shown dotted and the modern watershed lines separating the Wreake, Trent, and Witham drainages are drawn in. That the position of the Sproxton channel is anomalous is very apparent, if it were taken to have any close connection with the modern drainage, since a modern col lies about a mile to the south and almost 100 ft. lower. It can only be supposed that the channel predates the modern pattern of drainage; this supposition is confirmed by the position of the channel deposits, lying under a local representative of the Gipping or Great Chalky Boulder Clay.

## Conclusions

The general nature of the Sproxton channel reminds one of the Thistleton channel described by Rice (1962), but on closer examination significant differences are apparent. The Thistleton channel is much larger, its length being measured in miles rather than hundreds of yards; and, unlike the Sproxton channel, it is covered by a spread of clay wider than the channel. Its deposits also seem to consist largely of clay, gravels and sand being poorly represented. The Sproxton channel is reasonably straight and certainly far from showing a meander pattern, as is shown for a small stream in Rice (1965). Equally, it gives rise to little or no surface relief,whereas both the Thistleton channel and smaller drift-filled valleys mentioned by Lamplugh (1909) are still represented by notches or low ground. The Sproxton channel cuts across the watershed,not at a col, but at one of the highest points in the area.

Its waterlaid deposits, in spite of their rounding, do not appear to have travelled far; they owe their rounding to violent transport rather than distance. The foreign stones in the gravel can be related to the nearby presence of boulder clays. The channel gravels were later overrun by ice which laid down

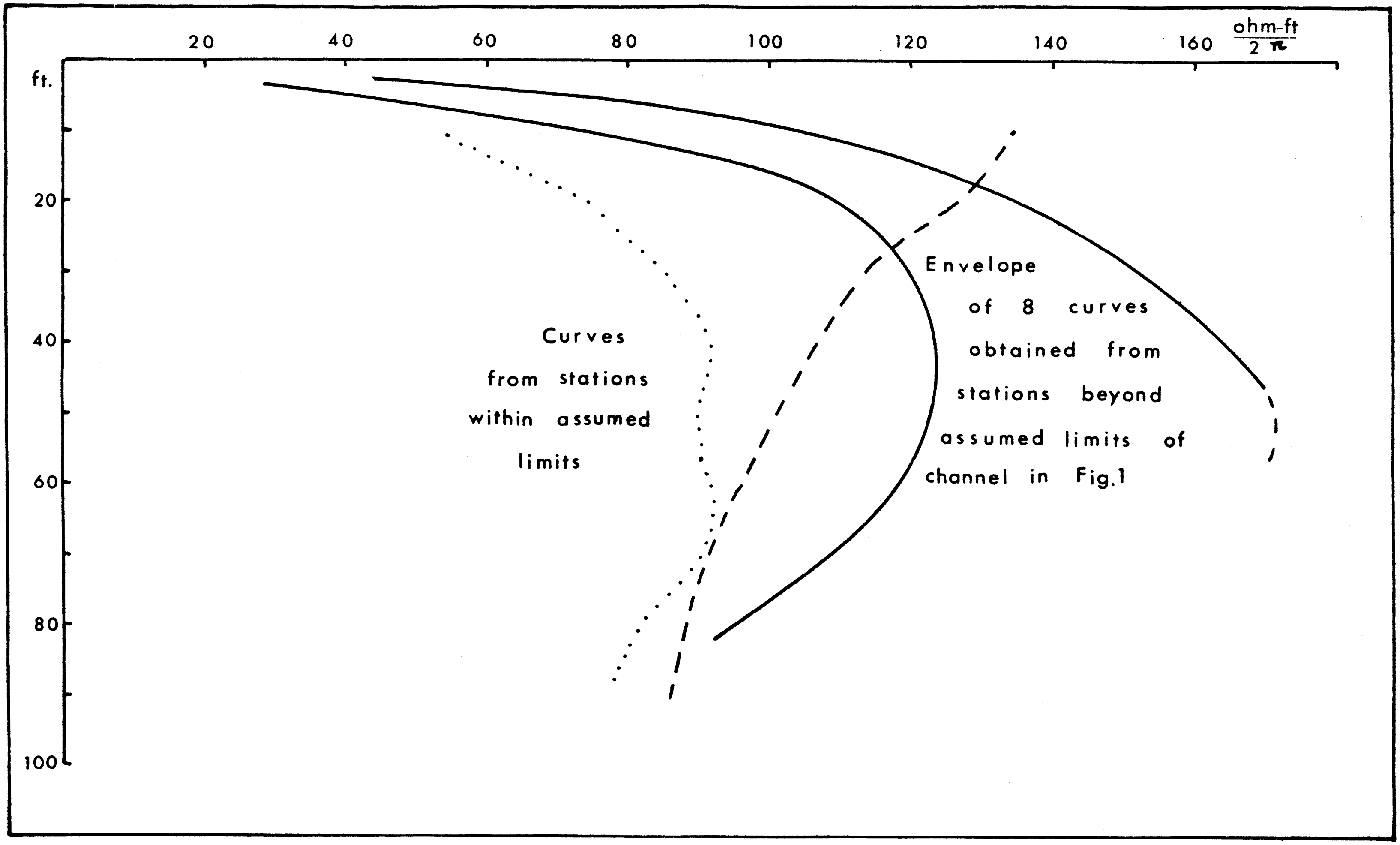



Fig. 4. Curves of Apparent Resistivity v. Electrode Separation obtained from stations along Traverse E-F

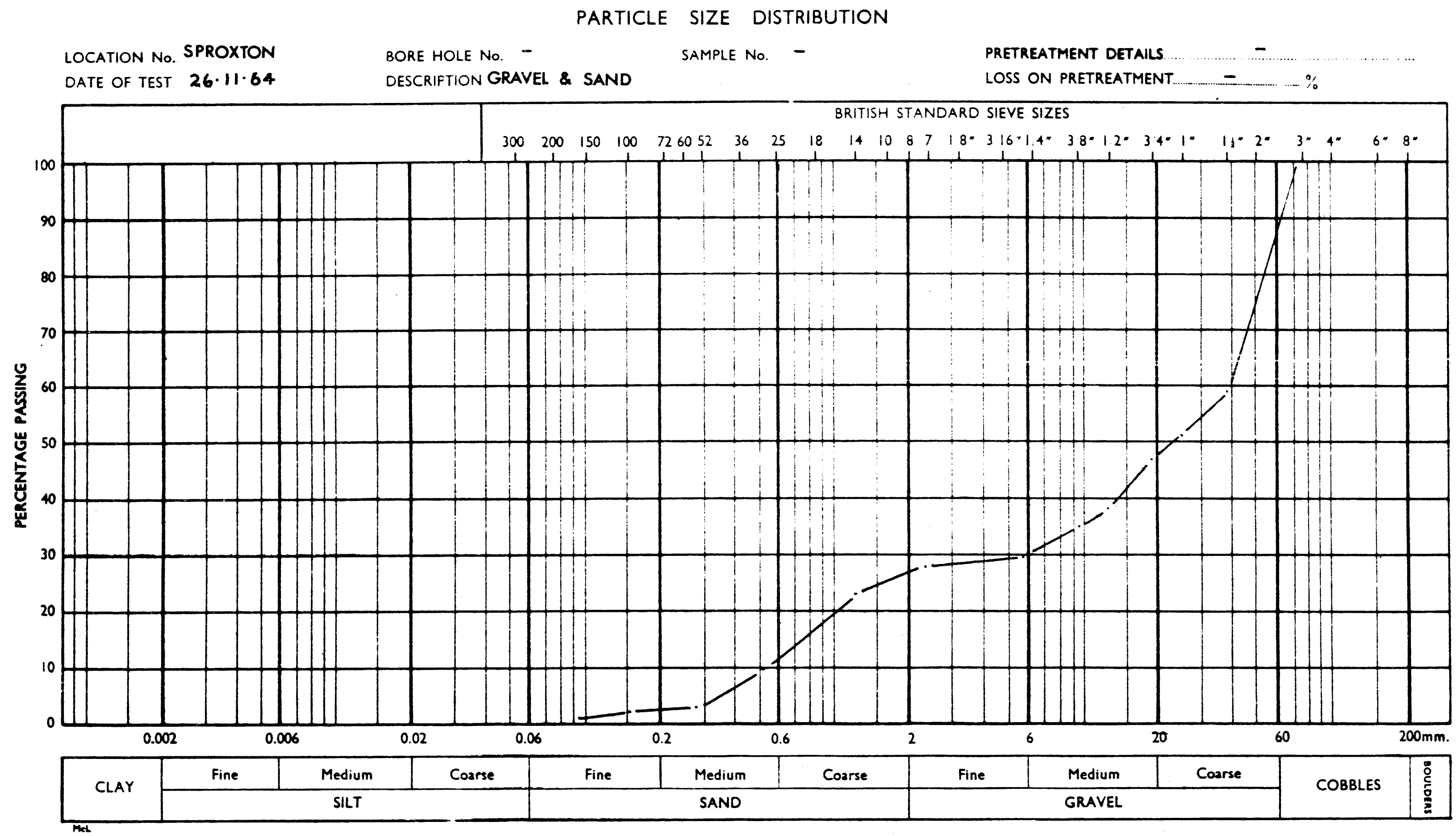



Fig. 5. Grading curve of the gravel and sand of the Sproxton channel

the grey and brown boulder clays, though these latter do not differ much in their state of weathering and therefore not much in age. Between these two events, the channel gravels had become strongly cemented at the top, indicating the occurrence of a temporarily warmer climate.

A tentative suggestion may therefore be made of the history of the channel. The channel was cut by the violent release of water from local melting ice, as if by the rupture of an ice dam. The hill-top position of the channel today may mean little in terms of subglacial topography; the channel might have been cut subglacially, though this was not necessarily the case. The channel filling is therefore mainly of local material, with a slight contamination of material introduced by the ice. A warmer interval would cause the cementing of the gravels; the hollow left by the channel would trap some of the subsequent thin boulder clay cover, which has otherwise been almost entirely removed from the immediately surrounding plateau.

The channel bears no relation to the modern drainage, but was a feature controlled by the presence of ice and was abandoned as soon as lower levels were exposed by the melting. Any continuation it had at either end was cut either through into ice or into topography which has since been removed by modern erosion.

The writer feels sure that other channels remain to be discovered in the Lincolnshire limestone plateau, for instance at Hungerton, where possibly a similar feature exists in an ironstone pit. Until a greater number are known, their nature will remain unclear.

## Acknowledgements

The writer would like to acknowledge the assistance of the following members of the East Midlands Geological Society who cooperated in the work on the channel: Mr. R.S. Jackson, Mr. F. Golshani, Mr. D. Salt, Mr. D. Beach, Mr. R.W. Morrell and Mr. R. Draper.

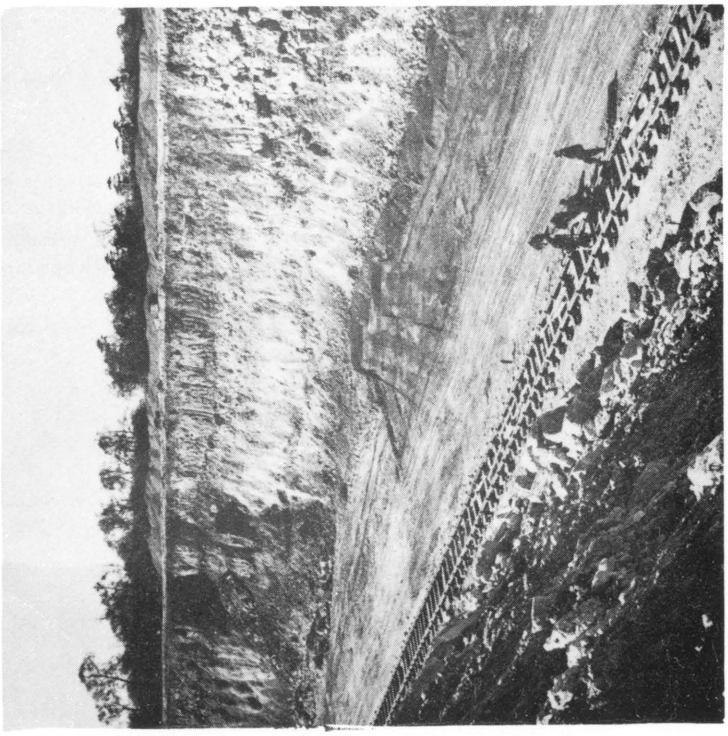
He would also like to thank Mr. D.H. Newman of the Park Gate Iron and Steel Company Limited, and the Company itself,for the use of maps and photographs and for allowing the party access to the quarry on numerous occasions.

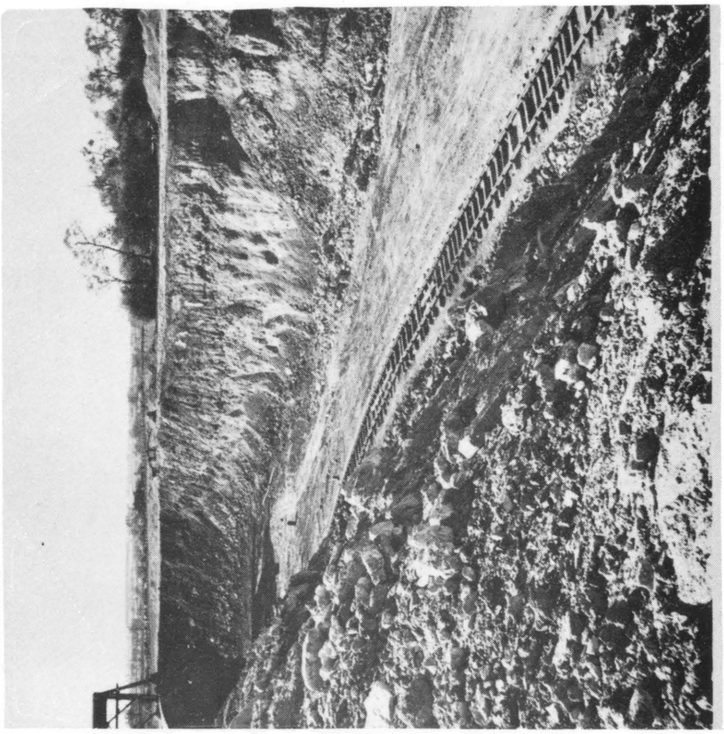
Further assistance in the project was given by Mr. J.H. Ball, Mr. L.H. Waring, Mr. D. Creswell and Mr. J.P. Withers of the Nottingham Regional College of Technology.

P.C. Stevenson, M.Sc., B.Sc., F.G.S.
Geological Survey, Department of Mines,
Government of Tasmania, Hobart,
Tasmania, Australia

(late of:- Department of Mining,
Nottingham Regional College of Technology,
Burton Street,
Nottingham).

Plate 1.





Views of the Sproxton Channel as excavated in 1961

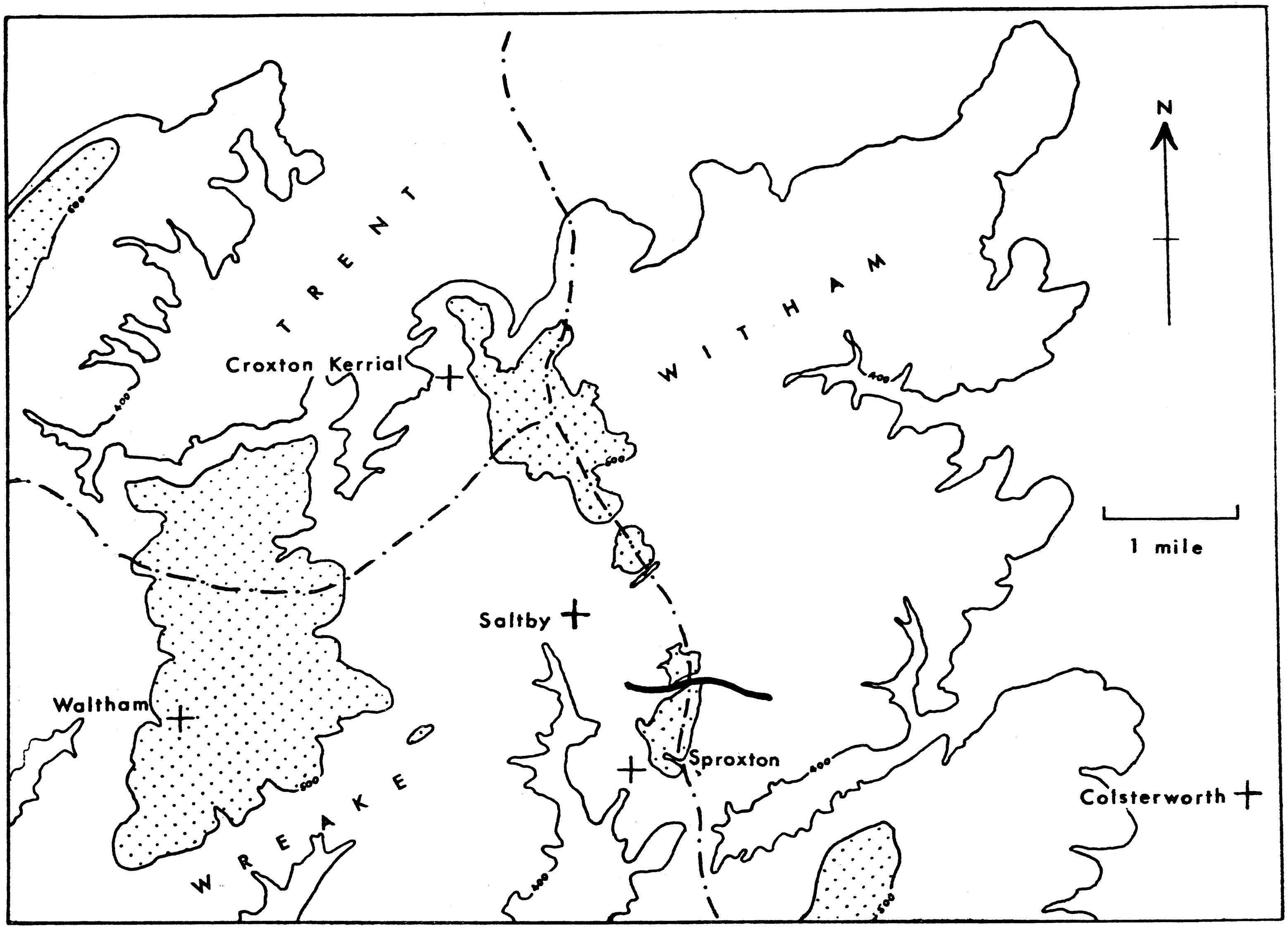



Fig. 6. The topographic setting of the Sproxton channel

REFERENCES

LAMPLUGH, G.W. and others 1909. Geology of the Melton Mowbray District and south-east Nottinghamshire. Mem. Geol. Surv., Gt. Br.

RICE, R.J. 1962. A drift filled valley at Thistleton on the Rutland-Lincolnshire border. Geol. Mag. vol. 99, pp. 468-74.

1965. The early Pleistocene Evolution of North-Eastern Leicestershire Trans. Inst. Brit. Geog., vol. 37, pp. 101 - 110, 8 figs.

Manuscript received 23rd November, 1966

# FIBROUS CHLORITES IN THE VOLCANIC ROCKS OF DERBYSHIRE

by

William Antony S. Sarjeant

## Summary

Records of chlorites and of presumed asbestos minerals from Derbyshire are reviewed. It is shown that fibrous minerals from three Derbyshire localities (Calton Hill, Tideswell Dale and Waterswallows) are chlorites, variously weathered to montmorillonoids or amesite, and that the dominant fibrous mineral at a fourth locality (Ible) is calcite. There is found to be no evidence of any asbestiform mineral from Derbyshire.

## Introduction

The chlorites are a group of hydrous silicates of magnesium and aluminium, containing variable quantities of ferrous or ferric iron, chromium or manganese. They are typically green in colour, but this varies,according to composition and the presence of impurities, to brown or even black.

The chlorite molecules form two-dimensional sheet-like structures of $SiO_4$ tetrahedra, linked by three of their corners. Crystallisation is in the monoclinic system, crystals being sometimes pseudo-hexagonal; a perfect basal cleavage (parallel to the $SiO_4$ sheets) causes splitting into flakes. The chlorites are very soft, hardness averaging about 2 on Moh's Scale, and can thus be scratched with the finger-nail. In all these properties, they resemble the micas: they differ, however, in composition, in the fact that the flakes are flexible but not elastic, and in certain optical properties. (The micas are also somewhat harder, averaging 2.5).

Many different varieties of chlorite have been named,primarily on the basis of chemical analysis, supported by optical measurements. The variation in composition results from isomorphous replacement of the electropositive atoms within the same general structural framework; under X-ray examination, it is found therefore that there is very little difference in molecular structure between the chemically different varieties, only the secondary characteristics of the X-ray diffraction pattern being altered (see Brindley and Robinson, 1951).

The chemical composition is extremely variable in detail; there is complete gradation between the different named types of chlorite, the names being merely employed to indicate that a specimen lies within certain compositional limits. The first classification put forward was by G. Tschermak (1890,1891), who recognised two basic groups: the ortho-chlorites, with compositions between $(Mg,Fe'')_2\ Al_2\ SiO_5\ (OH)_4$ and $(Mg,\ Fe'')_3\ Si_2\ O_5\ (OH)_4$, and the leptochlorites, with compositions not considered explicable on this basis and generally richer in trivalent ions (especially $Fe'''$) relative to silicon and divalent ions. The two presumed end-members of the orthochlorite series were amesite and serpentine; but it is now known that neither of these minerals has a true chlorite structure.

Later work by A. N. Winchell (1926, 1936) and others showed the leptochlorites to contain considerable amounts of ferric iron: a recomputation of their analyses with this iron in the ferrous state brings them into line, structurally speaking, with the orthochlorites. The leptochlorites are therefore simply oxidised chlorites.

The classification now generally adopted was proposed by M.H. Hey (1954). A basic division is made between the normal, or orthochlorite, series, and the oxidised chlorites (the "leptochlorites" of Tschermak), an arbitrary figure of 4% $Fe_2O_3$ being taken as the dividing line. The two series are further subdivided into mineral species on the basis of proportions of iron and magnesium. Eleven species of orthochlorite are thus recognised (corundophilite, pseudothuringite, sheridanite, ripidolite, daphnite, clinochlore, pycnochlorite, brunsvigite, penninite, talc-chlorite and diabantite) and three species of oxidised chlorites (thuringite, chamosite and delessite). (See Hey, 1954, Text-fig. 1; Deer, Howie and Zussman, 1962, Text-fig. 35). Chlorites also exist in which the magnesium has been partially, or wholly, replaced by manganese:- manganese-penninite and grängesite (manganiferous brunsvigite) contain small percentages of MnO; pennantite is a thuringite in which almost all the magnesium has been replaced by manganese; and gonyerite approximates to serpentine in composition, whilst retaining a chlorite structure. There are, in addition, chlorites containing chromium:kämmererite (a variety of penninite) and two varieties of clinochlore - chrome - clinochlore (less than 4% $Cr_2O_3$) and kochubeite (more than 4% $Cr_2O_3$).

Chlorites may be formed in a variety of different ways. In igneous rocks, they occur principally as products of the hydrothermal alteration of pyroxenes, amphiboles, and biotite mica, their composition being dependent on the composition of the mineral they are replacing. Frequently the chlorite pseudomorphs the mineral it is replacing. They are commonly found in amygdales in lavas or as lamellar coatings, often slickensided, in joint planes and fissures. Chlorites are widespread as products of the low-grade metamorphism of igneous and sedimentary rocks, being the most characteristic minerals of the green-schist facies; they disappear in higher grades of metamorphism. In sediments, they occur both as detrital and as authigenic minerals in argillaceous rocks; and chamosites, in the form of ooliths, are important constituents of sedimentary iron formations, such as the Northampton Ironstone.

## Previous Records of Chlorites from Derbyshire

The first mention of a chlorite from Derbyshire was by Woodward and Mello (1881, p. 185), who record "viridite", here used as a synonym of chlorite, from dolerites at Matlock, Millers Dale and Castleton.

Green, Strahan et al. (1887, p. 136) recorded delessite, coating calcite in toadstone vesicles at Mill Dam Mine, Great Hucklow (National Grid Reference SK 177780).

Sargent, in a discussion of spilitic lavas from various localities in Derbyshire, noted "chloritic minerals" in the lavas at Tideswell Dale (1917, p. 12); chlorites in lavas at Salters Lane, Matlock (SK 276593) and in the waste-heaps of Seven Rakes Mine, Masson Hill, Matlock (p. 14: SK 285590); and a "fibrous green chloritic substance" lining the margins (the fibres "standing out well from the walls of the cavity") and occupying the centres of vesicles in the lava of Worm Wood, near Bakewell (p. 16: SK 211694). The most abundant of these latter chlorites was stated to be "helminth", an old name for ripidolite; and a yellowish-brown chlorite, near delessite, was noted as also present.

Garnett (1920, 1923b) recorded diabantite from Millclose Mine, Darley Dale (SK 259625), as dark green, radiated spherical aggregates, up to 2 cm. in diameter, in amygdales in weathered dolerite: a yellowish-green chlorite (unspecified) was noted as present in the groundmass. Subsequently (1923a) he recorded a chlorite occurring in a well defined stratum and as fibrous veins in the Ible Sill; this occurrence will be discussed more fully in a later section.

Tomkeieff (1926) described the presence of green chlorite (determined on analysis to be near delessite) in vesicles in decomposed basalt at Calton Hill, near Buxton. He also records chlorite in the groundmass of, and filling vesicles in, the lavas of Knot Low, Millers Dale (SK 135735) - not analysed, but stated to be near chlorophaeite, a mineral species described originally from similar situations in the Western Isles. [The name "chlorophaeite" seems to have fallen into disuse in Western literature and is not mentioned by either Hey, 1956, or Deer, Howie and Zussman, 1962; it remains current among Russian mineralogists, e.g. Ivanov, 1958. In absence of an analysis by Tomkeieff, no alternative name can be suggested for the Derbyshire chlorite.] Tomkeieff reviewed the earlier work of Garnett and Sargent, and concluded that the Derbyshire chlorites were of three types:-

i) Primary chlorite, present in the glassy material (palagonite) of lavas

ii) Chlorite of a post-volcanic phase, filling vesicles

iii) Secondary chlorite produced by atmospheric weathering, found in the weathering-crust of lavas and in the green clays produced from such weathering

Later (1928, p. 709), in a fuller account of the geology of Calton Hill, Tomkeieff referred again to the chlorite amygdales and assigned them to the delessite-diabantite group.

Cope (1933), in a description of a tholeiite dyke in Great Rocks Dale, near Buxton (SK 103737), records greenish yellow chlorites, forming rounded or six- to eight-sided bodies, as visible in thin section in the tholeiite; he also notes chlorites to be present in xenoliths of sedimentary rock from the dyke margins.

Hamad (1963, p. 485), in a note on olivine nodules in the Calton Hill basalts, mentioned a dark green chlorite as occurring as aggregates of fibrous spherulites in the basalt. He gave analyses of the basalt and commented that the high water content revealed might be attributed to the presence of the chlorite (p. 487).

Finally, Ford and Sarjeant (1964, p. 137) brought together earlier references to chlorites in the "Peak District Mineral Index" and quoted, in addition, the occurrence of delessite in Lathkill Dale (SK 184658).

## The Supposed Derbyshire "Asbestos"

A number of minerals occur naturally in the form of very long, fine, flexible crystals, easily separated by the fingers and capable of being spun into a yarn. These are of commercial importance because of their resistance to heat and (to a lesser degree) to acids; they are employed in the manufacture of fire-proof clothing and paints, roofing-tiles, boiler covers, insulating cements, etc. Asbestiform minerals include various amphiboles (actinolite, anthophyllite, amosite, crocidolite) and one form of serpentine (chrysotile).

There is a long-standing tradition among Derbyshire mineralogists that asbestos is to be found in the volcanic rocks of the Peak District. Garnett (1923, p. 62) notes that the fibrous chlorites of the Ible Sill had been supposed to be chrysotile; he does not cite a reference for this supposition, but it is likely that this is the first echo in geological literature of the "Derbyshire asbestos".

A mineral supposed to be asbestos was collected by a Sheffield University party, led by Mr. W.H. Wilcockson, M.A., from the Calton Hill road metal quarry around 1950. The specimens (which were accompanied by a sketch illustrating the form of occurrence) survive in the Sheffield University collections and were examined by the present author in 1956. During a series of visits to Calton Hill Quarry, similar fibres were found forming bands within the weathered basalt. These were described in a short note (Sarjeant, 1957); the asbestiform nature of the mineral was not contradicted by the brief examination made, and it was tentatively suggested that the mineral might be either chrysotile or amthophyllite. Specimens of the Calton Hill mineral were exhibited at the 1956 meeting of the British Association in Sheffield and attracted a fair measure of interest.

Subsequently, after a joint expedition to Calton Hill Quarry with the author, Dr. W. Eric Addison, of the Department of Chemistry, University of Nottingham, prepared X-ray powder photographs of the mineral, suggesting a mixture of calcite + chrysotile. Agreement was not perfect, the weaker chrysotile lines not being observed; Dr. Addison emphasized that the result was "not too convincing" (personal communication).

In the "Peak District Mineral Index", it is noted that "many of the obscure notes of asbestos in Derbyshire may well be Chrysotile" (Ford and Sarjeant 1964, p. 137) and that "an asbestiform mineral occurs in the toadstones of Calton Hill, Tideswell Dale and Ible" (p. 138).

The present author has therefore done much, inadvertently, to bolster the tradition of Derbyshire asbestos. However, studies subsequent to 1964 indicate that the supposed "asbestos" of Calton Hill, Tideswell Dale and Ible is, in fact, simply a very impure, fibrous chlorite, altered in varying measure to clay minerals. The results of these studies are presented in the following section.

## Fibrous Chlorites by Locality

### CALTON HILL

The Calton Hill roadmetal quarry, operated by Derbyshire Stone Co. Ltd., is situated south of the Buxton-Bakewell road, about 4 miles east of Buxton (SK 117715). Volcanic rocks were first noted from Calton Hill by Arnold-Bemrose (1894, 1910): the opening of the quarry, in the early 1920's, afforded opportunity for a fuller study by Tomkeieff (1928). He noted three principle groups of rocks:-

i) Stratified volcanic agglomerate and tuff

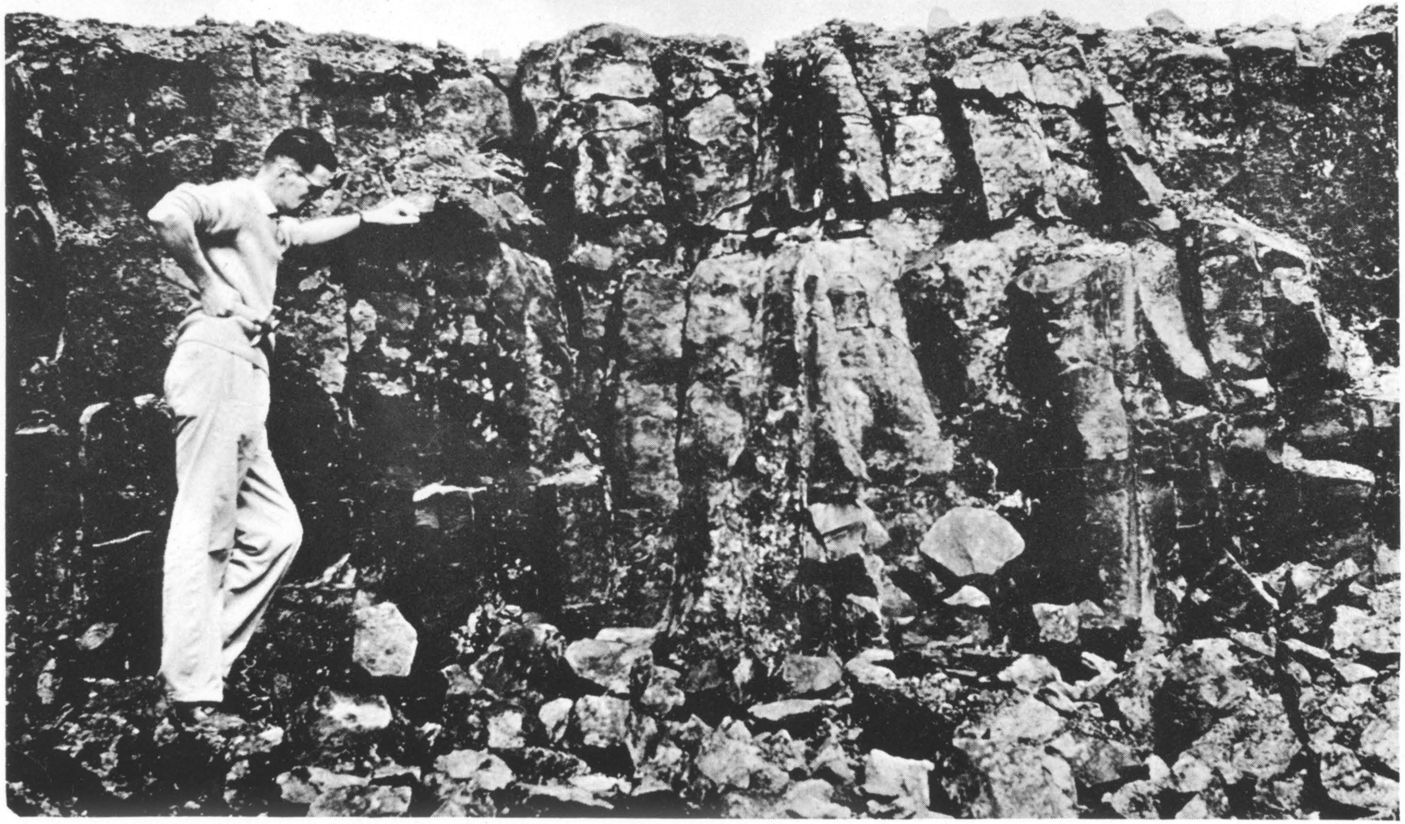
ii) Greatly decomposed vesicular lava ("toadstone")

iii) Fresh, compact analcite-basalt with peridotite inclusions

He concluded that the first two groups represented an extrusive phase of eruption, and the latter an instrusive phase. Although the enormous extension of quarrying since 1928 has revealed a greater complexity of structure than Tomkeieff visualised, so that his maps and sections are now difficult to apply, his conclusions remain sound. The lowest levels now exposed, at the southern end of the quarry, show an impressive development of columnar jointing in the basalt intrusion (Plate 2 ).

The fibrous minerals were located in a deeply-weathered surface of analcite basalt, in deep workings near the centre of the quarry. They were arranged in bands around relatively unweathered cores (see Sarjeant, 1957, Text-figs. 2-3), the fibres being usually perpendicular to the vein margins, but sometimes at an angle when a block had slipped. (This part of the quarry has now been filled in). Subsequently, bands of fibres were found also in a crag of vesicular lava towards the southern end of the quarry.

The length of the fibres ranged from about 6mm to about 45 mm and the colour varied from yellowish-brown through greenish to grey-black, the darker fibres sometimes exhibiting a resinous to silky lustre. The lighter fibres are very brittle, splitting to form flat, columnar aggregates and readily breaking down to a powder; the darker fibres are more flexible but would not be capable of weaving.



Columnar basalt in the lower levels Calton Hill Roadmetal Quarry, nr. Buxton, being examined by Mr. Leslie O. Ford. The photograph was taken on Sunday 30th July, 1961, when the exposure was still fresh: it is now much decayed.

(Photo: W. A. S. Sarjeant)

A number of X-ray powder photographs have been made at different times from fibres taken from various bands. The earliest of these, prepared by Dr. W.E. Addison, have been already discussed. Subsequent films consistently show the strong 14 Å line typical of chlorites and montmorillonoids; its presence rules out the possibility that the mineral is a serpentine. (The lowest lines were apparently missing from Dr. Addison's film; his higher lines accord well with subsequent observations). The X-ray patterns indicate that the fibres are chlorites, showing a parallel intergrowth with calcite and sometimes with quartz, and weathering to form clay minerals (montmorillonoids).

A chemical analysis of the fibres from veins in the analcite basalt is here presented and compared with Tomkeieff's (1926) analysis of the green chlorite from vesicles in the decomposed lava:-

| % Weight | Fibrous chlorites (Howie, in litt., 1964) | Chlorite in vesicles (Tomkeieff, 1926) |
|---|---|---|
| $SiO_2$ | 35.42 | 35.92 |
| $TiO_2$ | 0.09 | 0.00 |
| $Al_2O_3$ | 7.86 | 12.20 |
| $Fe_2O_3$ | 12.99 | 7.59 |
| FeO | 2.53 | 4.66 |
| MnO | 0.08 | - |
| MgO | 18.57 | 21.82 |
| CaO | 0.84 | 1.82 |
| $Na_2O$ | 0.03 | - |
| $K_2O$ | 0.01 | - |
| $H_2O+$ | 8.01 | 9.20 |
| $H_2O-$ | 13.28 | 6.50 |
| $CO_2$ | - | 0.13 |
| Total | 99.71 | 99.84 |

Howie's analysis, recalculated on the basis of 28 oxygens, gives the following result:-

$$(Si_{7.609}Al_{0.391})\ (Al_{1.600}Ti_{0.014}\ Fe^{+3}_{2.101}\ Fe^{+2}_{0.454}\ Mn_{0.014}\ Mg_{5.945}\ Ca_{0.193}\ Na_{0.001})\ O_{28}$$

The value of $Fe^{+3} + Fe^{+2}/Fe^{+3} + Fe^{+2} + Mg$ is thus 0.300 and the Si/Al ratio puts it in the delessite group.

A second analysis was made of fibres from the decomposed lava by Mr. D.J. Mather, under the direction of Dr. R.J. Firman. The result was somewhat different. (see Table on following page).

Firman's analysis suggests the presence of free quartz intimately admixed with the chlorite. Assuming $SiO_2$ percentage to be 35%, recalculation on the basis of 28 oxygen atoms still fails to fit the chlorite formula. This suggests that the chlorite is highly altered to a montmorillonoid, so that the original character of the chlorite can no longer be determined.

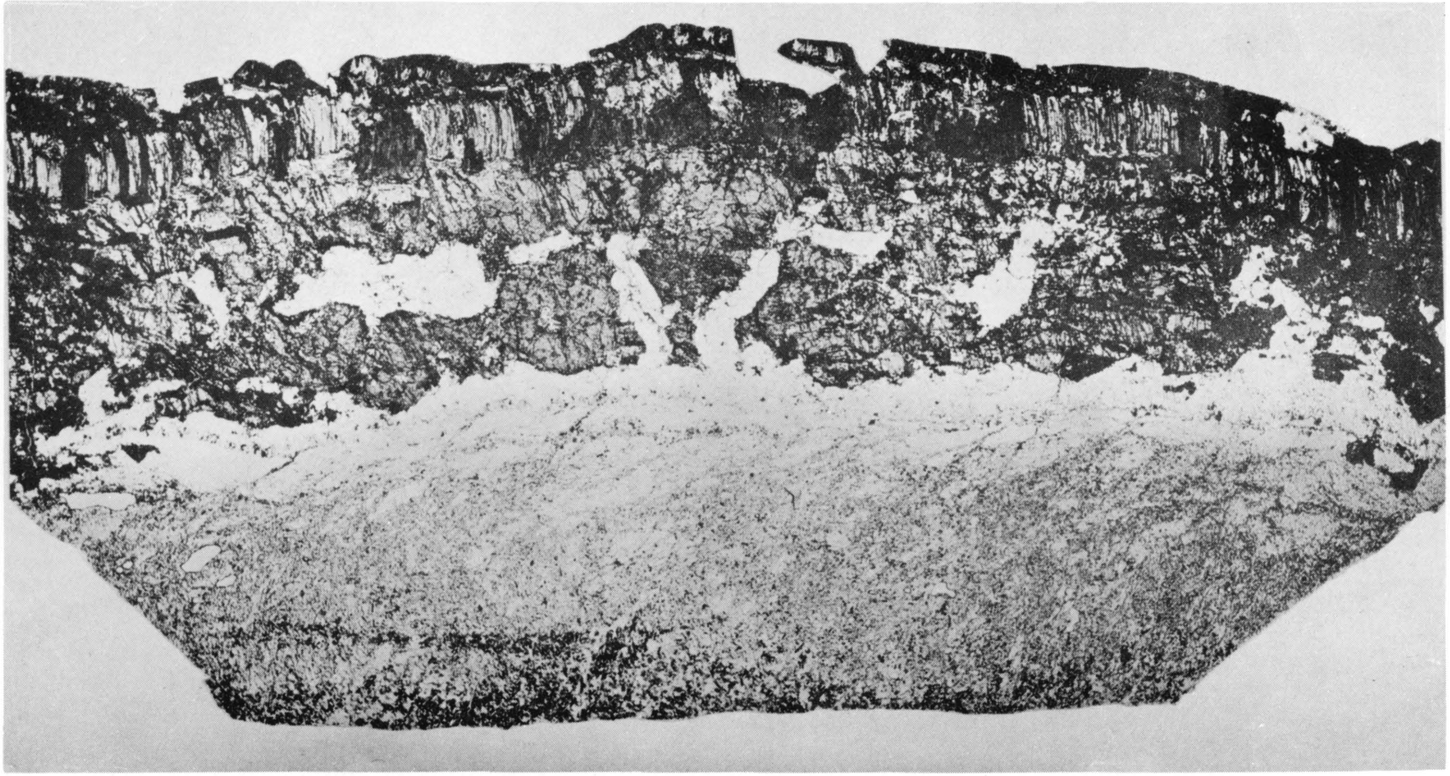
| % Weight | Fibrous chlorites (Firman, personal communication, 1966) | Fibrous chlorites (Howie, in litt., 1964) |
|---|---|---|
| $SiO_2$ | 42.58 | 35.42 |
| $TiO_2$ | 0.01 | 0.09 |
| $Al_2O_3$ | 7.69 | 7.86 |
| $Fe_2O_3$ | 9.50 | 12.99 |
| Fe O | 1.95 | 2.53 |
| MnO | 0.01 | 0.08 |
| MgO | 17.52 | 18.57 |
| CaO | 1.74 | 0.84 |
| $Na_2O$ | 0.03 | 0.03 |
| $K_2O$ | 0.01 | 0.15 |
| $H_2O+$ } $H_2O-$ } $CO_2$ } | 18.44 | 21.29 |
| $P_2O_5$ | 0.01 | - |
| Total | 99.61 | 99.71 |

IBLE

The Ible Sill is exposed in a small quarry, abandoned before 1920, which is situated immediately to the south-east of the village of Ible (SK 253568). It was first described by Arnold-Bemrose (1907, p. 275) and subsequently by Garnett (1923a). It consists of an ophitic olivine-dolerite, containing (in the quarry - lateral extent unknown) a 4 - foot chlorite-rich horizon, apparently produced by hydrothermal alteration of the dolerite; the chlorite is dark olive-green in colour and is in the form of a confused mass of intergrown lamellar and foliated aggregates.

Traversing both dolerite and chlorite-rock are numerous small veins of fibrous to columnar minerals. The veins are at their largest and most numerous in the upper parts of the metamorphosed horizon and immediately above it; they range in thickness from about 5 mm. to over 100 mm. The vein material consists very largely of fibrous to columnar calcite, white to yellowish in colour; amongst this were patches of yellow-brown to dark olive-green fibres, with a resinous to dull lustre, superficially similar to the material from Calton Hill. The long axes of the fibres are always vertical, regardless ot the attitude of the veins (except at the tips, which meet the vein margins at right-angles). Thus the fibre axes are perpendicular to the margins of horizontal veins and at varying angles to the margins of all other veins - unlike the fibrous minerals of Calton Hill, whose axes were consistently perpendicular to vein margins, regardless of vein attitude (except where a block had slipped). A section, prepared from the darker material, showed that the fibres were uniformly of calcite, the colour being caused by patches of another mineral in among the calcite fibres (Plate 3).

X-ray powder photographs of the darker mineral proved unsatisfactory; in all films prepared, strong calcite or quartz lines were present, masking other lines. A 14 Å line, suggestive of chlorites or montmorillonoids, was, however, consistently present. A chemical analysis of calcite-free vein material was made by Mr. D. J. Mather, under the direction of Dr. R. J. Firman; the result is given below and



Thin section of a vein in the chlorite rock of Ible, Derbyshire. The ground mass, seen at bottom, is dominantly of calcite and opaline silica where it approaches the vein margins. Opaline silica (white) forms the lower vein margin and irregular patches within the vein. The calcite fibres form two layers: a lower, imperfectly fibrous layer containing much opaline silica, and an upper, more perfectly fibrous layer, containing a little quartz and opaline silica and more numerous darker patches, interpreted as chlorites and/or montmorillonoids. Magnification X 6 approx.

Photo: J. Eyett

compared with analyses made by Garnett (1923a, p. 63):-

| % Weight | Vein material (Firman, personal communication 1966) | Fibrous chlorite (Garnett, 1923) | Chlorite from aggregates in the chlorite-rock (Garnett, 1923) |
|---|---|---|---|
| $SiO_2$ | 44.90 | 42.7 | 37.5 |
| $TiO_2$ | 0.01 | - | - |
| $Al_2O_3$ | 8.04 | 8.2 | 10.4 |
| $Fe_2O_3$ | 8.21 | 13.6 | 8.8 |
| FeO | 1.83 | 2.8 | 10.8 |
| MnO | 0.01 | - | - |
| MgO | 18.40 | 20.7 | 20.8 |
| CaO | 1.77 | 0.0 | 0.0 |
| $Na_2O$ | 0.01 | - | - |
| $K_2O$ | 0.60 | | |
| $H_2O+$ | } 15.93 | } 11.7 | } 9.6 |
| $H_2O-$ | | 0.0 | 0.0 |
| $CO_2$ | | | |
| $P_2O_5$ | 0.01 | - | - |
| Total | 99.71 | 99.7 | 100.3 |

The vein mineral partially dissolved in hydrochloric acid (as do chlorites); the insoluble residue consisted of over 75% $SiO_2$, suggesting the possible presence of an admixture of free silica in the vein mineral.

Garnett compared his analyses with analyses of epichlorite, given by Zincken and Rammelsberg (1849, quoted in Garnett, 1923, p. 63) in their original description of that mineral from the Harz Mountains, Germany. Epichlorite is described as a fibrous or columnar mineral, occurring in thin veins; the characters are said to be intermediate between chlorite and bastite serpentine. Hey (1954, p. 280) includes epichlorite among a group of mineral species about which he states "... if they are really chlorites and the analyses are trustworthy, they form a third division of true leptochlorites, in which the total cations are less than 10 per 14 oxygen cations (anhydrous basis)".

Comment on Garnett's conclusions is doubly difficult, in view of the doubtful status of epichlorite and the fact that, in the specimens collected by the present author, the darker mineral was never itself fibrous, but merely intergrown with fibrous calcite (Garnett notes also the presence of quartz in the veins as "more or less fibrous aggregates" [1923a, p. 62] ). Neither the X-ray powder photographs nor the analyses permit of any firm conclusions. All that can be said is that, at the present, the fibrous mineral occupying the veins is almost wholly calcite; and that within the veins, quartz and another mineral or association of minerals (chlorites or clay minerals belonging to the montmorillonoid group) form a relatively minor component.

## TIDESWELL DALE

The Tideswell Dale igneous body is well exposed in an abandoned quarry about ½ mile south of Tideswell (SK 155737). It was originally worked around 1850 for the marble underlying the sill, but quickly abandoned owing to the high cost of removing the toadstone. Subsequently the toadstone itself was worked for road-metal; the rusting crushing-plant, a considerable eyesore, was recently removed through the intervention of the Peak Park Planning Board. Arnold-Bemrose (1899) considered the igneous body to represent lava-flows of olivine-dolerite, into which a sill of the same material had been intruded, the rocks above and below the intrusion being markedly vesicular. He comments:-

> "The rock in the quarry is traversed by numerous small veins of a mineral that is probably chrysotile. It is of a golden yellow and consists of prisms or bundles of parallel fibres arranged perpendicular to the walls of the cracks in which it occurs. When wet it is soft and easily rubbed into a waxy material between the fingers, but when dried becomes tougher and slightly brittle."

The latter part of this description suggests a clay mineral rather than chrysotile.

Garnett (1923, pp. 64-5) was unable to collect this material, owing to the poor condition of the quarry at that time, but he noted its similarity to the chlorites of the Ible Sill.

The veins of fibrous material now to be seen are high at the northern end of the existing quarry face. The fibres range in colour from olive brown to greyish black and have a resinous to silky lustre: they are thus closely comparable with the Calton Hill materials. The fibres range in length from about 5 to 15 mm.

X-ray powder photographs show a considerable admixture of quartz, whose strong pattern masked all weaker lines; however, the 14 Å line could be recognised. The one quartz-free film obtained indicated a mixture of the mineral amesite (a mineral related to the chlorites but differing in molecular structure: see Deer, Howie and Zussman, 1962, pp. 166-7) with montmorillonoids. The Tideswell Dale fibres therefore appear to comprise chlorites, highly altered to amesite and to montmorillonoids and intimately admixed with quartz. It is probable that Arnold-Bemrose saw, and described, them when in much fresher condition and it is regrettable that no analyses are available from that period.

## WATERSWALLOWS

The Waterswallows roadmetal quarry, operated by Messrs. Hughes Bros., is situated about 1 mile northwest of Buxton (SK 085750). Arnold-Bemrose (1907, p. 273) considered it to be a sill, on the basis of the slight exposures then available. The structure is now well exposed by quarrying and is undoubtedly a vent (see Moseley, 1966).

Specimens of a grey-black, fibrous mineral were collected here by the author in 1956, from slipped material (briefly referred to in Sarjeant, 1957, p. 217). The fibres, too thick to be taken for asbestos, have a greasy feel and resinous lustre. X-ray powder photographs again indicated a chlorite-montmorillonoid mixture, with a strong admixture of calcite.

## Conclusions

Examination of fibrous minerals from four localities in Derbyshire provides no support for the supposition that asbestos occurs in the county. The fibres from Calton Hill, Tideswell Dale and Waterswallows were found to be chlorites, weathered to montmorillonoids and/or amesite; a varying admixture of calcite or quartz, sometimes showing parallel growth, was present. The results of study of fibres from Ible were less satisfactory: the dominant (possibly the only) fibrous mineral present is calcite, but varying proportions of quartz and a darker mineral (chlorite or a clay mineral, or a mixture of both) are present among the calcite fibres. The fibrous chlorite of Calton Hill was found by chemical analysis to be, at least in part, delessite; recognition of the chlorite species elsewhere did not prove possible.

## Acknowledgements

Studies of the Derbyshire fibrous chlorites have been carried out intermittently over a period of ten years and at four different Universities. During this time, advice, encouragement and assistance have been received from the following:- Mr. W.H. Wilcockson and Mr. Peter Wilkinson, of the Department of Geology, University of Sheffield; Mr. Leslie O. Ford, now of Dartmouth; Mr. Harold Sarjeant and Mr. Michael E. Smith, of Sheffield; Dr. W.E. Addison of the Department of Chemistry, University of Nottingham; Mr. John E. Thomas, formerly of the Department of Geology, University College of North Staffordshire, and now of the University of Reading; Dr. R.A. Howie, formerly of the Department of Geology, University of Manchester, and now of King's College, London; and Dr. T.D. Ford and Mr. R.J. King, of the Department of Geology, University of Leicester. In the closing stages, Dr. R.J. Firman gave the author a great deal of encouragement and assistance and critically read the manuscript. Sincere thanks are offered to all the above.

W.A.S. Sarjeant, B.Sc., Ph.D., F.G.S., Mem.Soc. Géol. Fr.,
Department of Geology,
The University,
Nottingham

## REFERENCES

ARNOLD-BEMROSE, H.H.

1894. On the microscopical structure of the Carboniferous dolerites and tuffs of Derbyshire. Quart. J. Geol. Soc. Lond., vol. 50, pp. 603-44, pls. 24-5, 2 tabs.

1899. On a sill and faulted inlier in Tideswell Dale (Derbyshire). Quart. J. Geol. Soc. Lond., vol. 55, pp. 239-250, pls. 19-20, text-fig. 1.

1907. The toadstones of Derbyshire; their field-relations and petrography. Quart. J. Geol. Soc. Lond., vol. 63, pp. 241-81, pls. 19-22, 1 text-fig.

1910. On olivine nodules in the basalt of Calton Hill, Derbyshire. Geol. Mag., new ser., decade 5, vol. 7, pp. 1-4, pls. 1-2.

BRINDLEY, G.W., and ROBINSON, K.

1951. The chlorite minerals, in X-ray identification and crystal structures of clay minerals. London: The Mineralogical Soc., 345 pp., 15 tabs.

COPE, F.W.

1933. A tholeiite dyke near Buxton, Derbyshire. Geol. Mag., vol. 70, pp. 414-22, text-figs. 1-3, tabs. 1-2.

DEER, W.A., HOWIE, R.A., and ZUSSMAN, J.

1962. Rock-forming minerals, vol. 3, Sheet Silicates. London: Longmans, 270 pp., 44 tabs.

FORD, T.D., and SARJEANT, W.A.S.
1964. The Peak District mineral index. Bull. Peak District Mines Hist. Soc., vol. 2, pp. 122-150.

GARNETT, C.S. 1920. Minerals hitherto unknown in Derbyshire. Nature, vol. 106, no. 2657, p. 148.

1923a. On a peculiar chlorite-rock at Ible, Derbyshire. Min. Mag., vol. 20, pp. 60-4.

1923b. The 'toadstone-clays' of Derbyshire. Min. Mag., vol. 20, pp. 151-7.

GREEN, A.H., STRAHAN, A., et al.
1887. Geology of the Carboniferous Limestone, Yoredale Rocks and Millstone Grit of North Derbyshire. Mem. Geol. Surv., 2nd edit., 212 pp.

GRIM, R.E. 1953. Clay mineralogy. London & New York: McGraw-Hill, 384 pp.

HAMAD, S. EL D. 1963. The chemistry and mineralogy of the olivine nodules of Calton Hill, Derbyshire. Min. Mag., vol. 33, pp. 483-97.

HEY, M.H. 1954. A new review of the chlorites. Min. Mag., vol. 30, pp. 277-92, text-figs. 1-4.

IVANOV, K.P. 1958. On chlorophaeite from the Lower Mesozoic basalts and dolerites of the eastern slope of the Urals (in Russian). Doklad. Akad. Nauk. S.S.S.R., vol. 120, pp. 1338-1340, 1 pl.

MOSELEY, F. 1966. The volcanic vents and pocket deposits of Derbyshire. E.M.G.S excursion, Sunday 5th Sept. 1965. The Mercian Geologist, vol. 1 no. 3, pp. 283-5, text-fig. 1.

SARGENT, H.C. 1917. On a spilitic facies of Lower Carboniferous lava-flows in Derbyshire. Quart. J. Geol. Soc., Lond., vol. 73, pp. 11-25.

SARJEANT, W.A.S. 1957. On the asbestos of Calton Hill. J. Univ. Sheffield Geol. Soc., vol. 2, pp. 215-7, text-figs. 1-3.

TOMKEIEFF, S.I. 1926. On some chloritic minerals associated with the basaltic Carboniferous rocks of Derbyshire. Min. Mag., vol. 21, pp. 73-82, text-figs. 1-4.

1928. The volcanic complex of Calton Hill (Derbyshire). Quart. J. Geol. Soc. Lond., vol. 84, pp. 703-18, text-figs. 1-4, tab. 1.

TSCHERMAK, G. 1890. Die Chloritgruppe. Sitzber. Akad. Wiss. Wien, vol. 99, p. 174 et seq.

1891. Die Chloritgruppe. Sitzber. Akad. Wiss. Wien, vol. 100, p. 29 et seq.

WINCHELL, A. N. 1926. Chlorite as a polycomponent system. Amer. J. Sci., ser. 5, vol. 11, pp. 283-300, text-figs. 1-4.

1936. A third study of chlorite. Amer. Min., vol. 21, pp. 642-51, text-figs. 1-4.

WOODWARD, C. J. and MELLO, Rev. J. M.
1881. The minerals of the Midlands: List of the minerals of Derbyshire. Midland Naturalist, vol. 4, pp. 183-6.

# XENUSION - ONYCHOPHORAN OR COELENTERATE?

by

L. B. Halstead Tarlo

## Summary

The affinities of the Pre-Cambrian problematical fossil Xenusion auerswaldae, from a presumed Pre-Cambrian boulder from Sweden, are discussed; it is shown to be comparable with the Pre-Cambrian genera Rangea, from South-West Africa, and Charnia, from Charnwood Forest, Leicestershire. These organisms are considered to be probably colonial coelenterates.

## Introduction

Following the recent discovery of Pre-Cambrian fossils in Charnwood Forest (Ford 1958, 1962, 1963) and in the Ediacara Hills in South Australia (Glaessner & Daily 1959, Glaessner 1961, 1963), there has been a revival of interest in Pre-Cambrian faunas in general. For example, the fossils described by Gürich (1930, 1933) from the Nama Formation of South West Africa have received further attention. In contrast, the fossil Xenusion auerswaldae, described by Pompeckj (1927) has received only passing mention. The purpose of this short note is to discuss Xenusion in the light of our present knowledge of Pre-Cambrian fossils.

## Description and Discussion

Xenusion is preserved as a natural mould in a quartzite erratic of Cambrian or Pre-Cambrian age from Sweden. It has achieved a degree of fame as a result of being interpreted as an onychophoran, and thus possibly a connecting link between the two major phyla Arthropoda and Annelida. The living onychophorans are found under the barks of trees in tropical forests of Africa, Asia and South and Central America; they are rather caterpillar-like in appearance, being two to three inches long, but they show no external segmentation apart from their legs or parapodia. These latter are not jointed but bear claws. The Middle Cambrian Burgess Shale from British Columbia has produced a fossil onychophoran, Aysheaia pedunculata Walcott; this is reasonably similar to the living Peripatus apart from the segmental appearance of the body, which gives it a more worm-like aspect. Aysheaia is preserved as a carbonaceous film, as is appropriate for such a soft bodied organism.

In marked contrast to the Burgess Shale fossil, Xenusion is preserved as an impression in a quartzite with the structures in high relief (see Plate 4 ). Furthermore the dimensions of Xenusion are approximately four times those of all known onychophorans. The perfect bilateral symmetry of the fossil suggests that the organism in question was comparatively rigid and somewhat frond-like. It seems reasonable to conclude that Xenusion is unlikely to have been an onychophoran.

The solution to the affinities of Xenusion are to be found among the material described by Gürich as Rangea schneiderhoehni, from the Pre-Cambrian Nama Formation of South-west Africa. This fossil is preserved in the same manner as Xenusion; its structures are of the same size and, to my mind, cannot be distinguished in any significant detail. In both Rangea and Xenusion there is a central axis that narrows distally and from which there arise, at either side, a series of distally diminishing branches which are themselves subdivided into short segments. The two genera differ in the nature of the axis; this, in Xenusion, bears a row of paired nodes, which are not present in Rangea. The segmented branches in Rangea appear to be confined by an outer lateral border, whereas they are free in Xenusion. Glaessner (1961) has compared Rangea to the living sea-pens, a group of coelenterates, but these differ from Rangea in exactly the same way that Xenusion does. The branches are not rigidly confined by any lateral structure.

The discoveries of Ford (1958, 1963) throw further light on this question. It is now evident that the original material of Charnia (a fossil from the Pre-Cambrian Woodhouse Beds of Charnwood Forest, Leicestershire, first described by Ford, 1958) represented the opposite surface of a Rangea. The 'ventral' surface shows no sign of a median axis, with the segmented branches meeting each other in the midline to form a zig-zag line. The new material of Charnia (Ford, 1963), showing the 'dorsal' surface, reveals the central axis.

It now appears that Rangea and Xenusion represent the 'dorsal' surface of an organism and Charnia the 'ventral'. In fact these three genera clearly belong to the same group of organisms. Indeed, had the 'ventral' surface of Xenusion been preserved, rather than the 'dorsal', it would never have been placed anywhere near the onychophorans.

## Affinities

Glaessner (1961) and Ford (1963) have discussed the possible affinities of the Rangea-Charnia group, suggesting coelenterate and algal affinities respectively. On balance, the arguments for some type of colonial coelenterate seem marginally stronger and hence I would now tentatively assign Xenusion to such a position in the animal kingdom.

## Age

The recognition of the relationship of Xenusion to Rangea-Charnia now enables the age of the erratic block concerned to be determined with a certain degree of confidence. This group of organisms appears to be characteristic of the uppermost Pre-Cambrian, which is now placed in the Varangian period. These animals can thus be considered as stratigraphical markers for the Varangian. In view of this it can be suggested that the erratic block containing Xenusion must be of Varangian age, rather than Cambrian.

## Acknowledgements

My thanks are due to Professor W. Gross, formerly Director, Geological-Palaeontological Institute of Humboldt University, Berlin, for permission to examine the type specimen of Xenusion and to take casts of it. Photograph (Plate 4 ) by Mr. J. Watkins.

L. B. Halstead Tarlo, D. Sc., Ph. D., F. G. S.,
Department of Geology,
The University,
Reading

Plate 4.

Cast of holotype of Xenusion aeurswaldae Pompeckj, x $1\frac{1}{2}$.
Geol.-Palaont. Inst. Humboldt University, Berlin, N.4

## REFERENCES


FORD, T.D. 1958. Pre-Cambrian fossils from Charnwood Forest. Proc. Yorks. geol. Soc., vol. 31, pp. 211-217, pl. 13.

1962. The oldest fossils. New Scientist, vol. 15, pp. 191-194.

1963. The Pre-Cambrian fossils of Charnwood Forest. Trans. Leic. Lit. Phil. Soc., vol. 58, pp. 57-62, pl. 1.

GLAESSNER, M.F. 1961. Pre-Cambrian animals. Sci. Amer., vol. 204, pp. 72-78.

1963. Pre-Cambrian fossils. Biol. Rev., vol. 37, pp. 467-494.

GLAESSNER, M.F. and DAILY, B. 1959. The geology and late Pre-Cambrian fauna of the Ediacara Fossil Reserve. Rec. Sth. Austral. Mus., vol. 13, pp. 369-401

GÜRICH, G. 1930. Die bislang ältesten Spuren von Organismen in Südafrika. C.R. Int. geol. Congr. XV. S. Africa (1929), vol. 2, pp. 670-680.

1933. Die Kuibis-Fossilien der Nama-Formation von Südwestafrika. Paläont. Z., vol. 15, pp. 137-154.

POMPECKJ, J.F. 1927. Ein neues Zeugnis uralten Lebens. Paläont. Z., vol. 9, pp. 287-313.


Manuscript received 1st December, 1966

# SOURCES OF INFORMATION FOR THE AMATEUR GEOLOGIST

by

David A.E. Spalding

## Summary

Possible sources of information and assistance for the amateur geologist are listed, with notes as to the best use of libraries, museums and other bodies. The amateur is encouraged to reciprocate by helping in return where possible.

## Introduction

The amateur geologist, even more than most naturalists, must often find himself out on a limb. In his exploration of the countryside, particularly when visiting quarries and collecting minerals and fossils, he must often feel that his activities are of no interest to anyone but himself. Conversely, when he is in need of information about the history and significance of the sites he visits, or the identification and conservation of the specimens he acquires, he may be at a loss to know where to turn for assistance. When on occasion he makes an important find or discovery, it may well not come to the attention of the appropriate authorities, or it may take so long to do so that significant details are forgotten. His personal collection, which may often represent sites not normally accessible to the professional and include specimens of considerable scientific significance, is perhaps not fully labelled for want of the necessary advice. On the owners' loss of interest, eventual demise, or surrender to uxorial pressure, the collection may fail to reach the repository where it may be most useful, or, if it does so, it may be without the essential field note-books and manuscript catalogues which would make it useful.

At the editor's suggestion, therefore, these note have been put together to assist the amateur geologist in dealing with some of these difficulties.

## SOURCES OF INFORMATION

### 1. Local Libraries

An immense amount of geological information is to be found in books, maps, and scientific papers at various levels of technicality, but, even if every geologist were possessed of unlimited funds, few of the relevant works would be found to be still in print or even available second-hand. The library is therefore the key to obtaining the necessary books.

Everyone is within reach of at least a small branch lending library, and most people live in larger towns and cities with access to specialised reference facilities. Even the smallest library has links with local and national networks: these include many specialist libraries and the National Lending Library, from which books may be obtained through the local branch. There is usually no charge other than postage: the only difficulties involved are the time lag and often a proviso that the book shall only be studied in the library - this may well cause difficulty when many fossils are to be identified.

Apart from basic geological works, normally available on the library shelves, the geologist is likely to require books for two purposes. The first is for the identification of collected material and the second is for detailed local information. If he knows which books or papers are required (and here the advice of a professional geologist is often of assistance), then it is relatively simple to obtain them, provided author, date of publication, and publisher or reference are known. If this information is not available, likely books can usually be traced through the index systems of larger libraries. Sometimes one of the library staff will be able to offer advice, though of course few general libraries employ specialists in all the fields covered by their books. Otherwise, the more help the librarian can be given, the sooner a useful book can be found; and it is therefore well worth keeping a note of suitable books and papers in different fields. A recent paper on any aspect of the subject may often refer to the last published summary of the subject as a whole.

Local information is much more difficult to find easily than books for identification. A few large firms employ geologists and keep careful records, but many do not. Almost every quarry and cutting in the country has been visited and studied at some time, and the results of the investigation may well have been published. But to find at short notice all the information relating to a particular site may be extremely difficult, unless there is a bibliography of the subject available. It is well worth enquiring about the existence of such a bibliography; there may be one already in print, in a county volume, a more specialized regional memoir, or in the journals of the local geological or natural history Society. Many have been prepared to assist private research projects or by various institutions; these are often not in print. As an example, a bibliography of the area twenty miles round Sheffield is being prepared at Sheffield City Museum, and it is now being cross-indexed for localities. A bibliography of Peak District geology is likewise under preparation at Leicester University (this is shortly to be published in the "Mercian Geologist"), and new publications are often noticed in the North Midlands Bibliography.

## 2. Specialist Local Libraries

Many institutions concerned with geology, such as Museums, University and Technical College Departments, may have specialist libraries in the subject. The older established these are, the more likely they are to contain the older and rarer local works and long runs of journals.

Often these libraries are part of the library inter-loan schemes, and their books may be accessible through ordinary public libraries. This is however not always so. Although access to such specialist libraries is restricted, it is usually possible to obtain at least reading privileges, providing a reasonable case can be made or a sponsor on the staff of the institution can be found.

## 3. National Libraries

A number of specialist national libraries are often open to consultation. The libraries of the British Museum, the Geological Museum, and the Natural History Museum are available (with permission) to those wishing to consult them. Members of National Societies (particularly the Geological Society of London and the Geologists' Association) have access to the libraries of their Societies. Some provide a rapid postal lending service, and there may also be photocopying facilities of the type that many public libraries provide.

## 4. Local Museums

Local Museums perform many functions; their role in geology has been summarized in an earlier paper (Spalding, 1964). They are often able to be helpful to the amateur; many regard the building of links with amateurs as of particular importance, affording plenty of opportunities for mutual assistance. Any or all of the following services may be available in a local Museum to the amateur geologist:

a) Specialist library, with local works and maps.

b) Reference collections, usually with a local bias, which may be consulted for identification of material.

c) Extensive local information, either in the Curator's memory (useful but not of long-term value!) or in the form of site indexes, bibliographies, etc.

d) Specialist publications of the Museum, and other bodies, on sale.

e) An identification service (often using specialist referees in other Museums and, where necessary, national museums and University specialists), which can name and give information about specimens.

In return, the amateur geologist may well be able to assist the Museum, by keeping the Curator informed of his work, by helping to prepare and keep up to date site indexes and bibliographies, and even (if the amateur is expert and the Museum very small) by overhauling collections and assisting with the identification of simple specimens.

It is worth remembering that many smaller Museums are (unaccountably) run by librarians and therefore cannot normally be of much assistance; and that, even where a geologist is on the staff, he must often be responsible for many other things besides geology. Museum professionals work, nominally, a five day week (even if they do spend the weekends catching up on fieldwork) and so are not normally available for consultation at weekends, though specimens may always be left for attention. If a visit is likely to involve numerous identifications or much time, it is worth writing to make an appointment.

It is worth remembering too that Museums are, like all institutions, responsive to pressure. Even the most unsympathetic librarian, who is subjected to a flood of geological enquiries, may contemplate the appointment of professional staff; and a similar stimulus may well help a willing curator to convince an unsympathetic committee.

## 5. National Museums

Two National Museums are concerned with geology. The Natural History Museum has world-wide collections of fossils and minerals, and the Geological Museum is primarily interested in the geology of this country. Both welcome enquiries, but if the more straightforward enquiries are tried locally first, it may save the valuable time of specialist staff.

In addition to specialist libraries and collections, both have some extremely useful publications of which lists are published, and the latter has, available for reference, many unpublished maps and site records. The Geological Museum is particularly interested in information about temporary exposures; this, however, is often collected by local Museums until required in the revision of maps.

## 6. University and Technical College Departments

Geology departments in Universities and Technical Colleges are primarily concerned with teaching and research, and, as such, have little direct contact with the general public. Many of the professional geologists employed in these institutions, however, take a keen interest in encouraging the study of their subject by amateurs, are willing lecturers, and often provide the core of officers for local Societies, which help them to make wide contact with amateurs in the area. Although the special library and collections are not normally available, access may sometimes be obtained by serious enquirers who seek permission.

## 7. Societies

Quite a number of Societies may be of interest to the geologist. Many local natural history societies have geological sections, or may have special library or museum facilities which will repay joining. There are a few local Societies of special geological interest (e.g. the Hull Geological Society) and several regional ones, such as the East Midlands Geological Society. National Societies include the Geologists' Association and Palaeontological Association; more advanced amateurs may attain membership of the Geological Society of London and Mineralogical Society. Other national bodies with an interest in geology include the British Association for the Advancement of Science and the recently-formed Council for Nature, an 'umbrella' body which is not yet perhaps adequately representative of geological interests.

## 8. Private Collections

The amateur may well have access to existing collections in private hands, which are of direct utility as far as they are adequately labelled and preserved.

His own specimens may well come in time to achieve the status of a 'collection', and it is worth taking pains with this to make it achieve maximum usefulness. There is not room here for detailed notes on collection and care of specimens, but a few comments may well be useful.

Full data about the locality and stratum of collection should be kept, preferably in a field note book as well as attached to the specimen. Each specimen, when cleaned and prepared for the cabinet, should have a number firmly attached referring to a catalogue, and, if possible without spoiling the specimen, the data may be written directly onto it (not in a code known only to the collector). After treatment for pyrites disease where necessary, specimens may be stored in trays, card or wooden boxes, or a cabinet with separate labels.

When a geological collection is disposed of, its permanent preservation should be seriously considered. Any type, or otherwise unique, specimen, in particular, should be safe-guarded, but almost all categories of geological material may be of value for some scientific or educational purpose.

The collection may sometimes be transferred to another amateur geologist, but this is in general undesirable. If this does happen, a Museum near the main collecting area should be informed about the collection and its whereabouts. Otherwise the collection should ideally be put in the hands of the nearest Museum or University department that has adequate curatorial staff. Under no circumstances should a collection be deposited in a school, where (although there may at the time be a qualified geologist), the material will be of only limited utility and has no future guarantee of safety. Many important collections have been ruined in this way.

## 9. Geological Institute

In addition to its London headquarters at the Geological Museum, the Institute of Geological Sciences (formerly the Geological Survey) has regional headquarters in various provincial cities. Its maps and publications may be purchased directly from the Museum, together with photographs and slides; lists of these are available. Maps and memoirs are also available through Her Majesty's Stationery Office and its official outlets.

10. Slides and Photographs

Geological slides and photographs are now available from a number of Museums, and lists may be had from the Museum and the Slide Centre. Most Museums will arrange to take photographs of geological specimens on request, or allow facilities for photography.

11. Mineral Suppliers

Most geologists prefer to build up collections from their own field work, but some may wish to buy at least occasional specimens to fill gaps. There are a number of suppliers who may be able to assist.

12. Conservation of Sites

Geologists, whose sites are often quarries much in demand for tipping, are often not aware that mechanisms exist for preservation of the more important sites. Some may be scheduled by the Nature Conservancy as Sites of Special Scientific Interest ('S.S.S.I's'), or exceptionally as National Nature Reserves. Their work is often supplemented by Naturalists' Trusts in each County. Any threats to geological sites of importance should be notified to these authorities, and it is wise to try and schedule sites well in advance of any possible threats.

## Conclusions

This list of possible sources of information and assistance includes the main ones known to the writer, but it is not intended to be exhaustive. All the institutions concerned have limited resources and staff, but are nonetheless usually anxious to help as much as possible; the amateur geologist will find it useful to develop a personal relationship with secretaries, curators and librarians. If he is in turn able, and willing, to assist the institutions in their work, a relationship of real value to all parties can often be developed.

D.A.E. Spalding, B.Sc., F.G.S., A.M.A.,
Deputy Director, The City Museum,
Sheffield.

## REFERENCE

SPALDING, D.A.E. 1964. Geology in provincial museums. Mercian Geologist, vol. 1, no. 1, pp. 11-13.

## APPENDIX: USEFUL ADDRESSES

| | |
|---|---|
| British Association for the Advance of Science : | 3 Sanctuary Buildings, 20 Great Smith Street, London, S.W.1. |
| Gregory Bottley & Co. (Mineral Suppliers): | 30 Old Church Street, London, S.W.3. |
| Council for Nature: | 41 Queen's Gate, London, S.W.7. |
| Geologists' Association: | Dr. F.H. Moore (Hon. Sec.), 178 Fir Tree Road, Epsom Downs, Surrey. |
| Geological Society of London: | Burlington House, Piccadilly, London, W.1. |
| Institute and Museum of Geological Sciences: | Exhibition Road., London, S.W.7. |
| Mineralogical Society: | 41 Queens Gate, London, S.W.7. |
| Natural History Museum: | Cromwell Road, London, S.W.7. |
| Nature Conservancy (Midland Region) : | Attingham Park, Shrewsbury, Shropshire. |
| North Midlands Bibliography: | Editor: Mr. R.A.H. O'Neal, Derby & District College of Technology, Kedleston Road, Derby. |
| Palaeontological Association: | Professor C.H. Holland, Department of Geology, Trinity College, Dublin 2, Ireland. |
| R.F.D. Parkinson (Mineral Suppliers): | Cranmore, Shepton Mallet, Somerset. |
| Slide Centre: | Portman House, 17 Brodrick Road, London, S.W.17. |

Manuscript received 3rd December, 1966

## EXCURSION TO RUTLAND, NORTHAMPTON, THE FENS, AND THE WASH: - THE TRIAS, JURASSIC, CRETACEOUS AND QUATERNARY ROCKS TO THE SOUTH AND EAST OF NOTTINGHAM

Leader:- P. C. Stevenson

Sunday, 1st May 1966

The party of about 40 persons left Shakespeare Street at 09.45 and took the A606 to Melton Mowbray. Much of this part of the journey was over familiar ground, but the leader pointed out the Keuper Marl plain near Edwalton (600340) and the escarpment formed by the Rhaetic (635315). The recent road works at Widmerpool cross-roads (653290) had shown that the Lias rocks here were covered by boulder clay, but the exposures were no longer open. The hilly country near the Broughtons (685265) appeared to be due both to boulder clay and to sandstone bands in the Lower Lias. As demonstrated on a previous excursion, the sharp rise of Broughton Hill (713214) was caused by the Middle Lias Marlstone, but because of the southerly dip, no corresponding escarpment is found on the generally declining road to Melton Mowbray, which lies on the Lower Lias.

The next stage of the journey showed rolling country, with the road passing up again over the Middle Lias on which Oakham stands (860090). Then taking the A 6003 up through the Upper Lias, the excursion passed into country between Manton (880046) and Uppingham (865000), where outliers of Inferior Oolite lie on a plateau of Upper Lias.

The Welland valley has been cut down deeply into the Upper Lias and is floored by thick alluvium. On its south side, the strong escarpment formed by the Inferior Oolite was seen, and the route climbed it at Rockingham (868910). After the beauty of this village, a prospect of Corby administered an unpleasant shock. A brief halt enabled an ironstone pit on the north side of the road (876908) to be viewed from the bus. The leader explained that the Northampton Sand was about 25 ft. thick, the upper fifteen feet being worked as ore, and that it was covered by up to 20 ft. of Lower Deltaic clays and sands: in this case, it is further overlain by about 30 ft. of Lincolnshire Limestone. A diversion was then made around Corby to a point near Kirby Lodge, where the party left the bus to examine a disused pit (915920). The succession here was sensibly the same as at the previous pit and typical of the succession seen in most of the Northampton Sand ironstone pits of the area.

The journey then continued via Little and Great Weldon (927895) on to the A 427. An appreciable rise in the ground surface (935891) marked the presence of the Great Oolite Limestone, and this cream coloured stone was noted in buildings hereabouts. The journey to Oundle was over a very smooth surface formed by the limestone, with here and there a thin skin of Cornbrash and clays. The Nene at Oundle (046889) has cut down into the Upper Lias, but this is generally unexposed and covered by a wide spread of valley alluvium. The A 605 road from Oundle was found to rise on to a shelf near Tansor Lodge (055899) because of the presence of the Cornbrash, and the brash in neighbouring fields was noted. From Elton (090939), the leader pointed out the way in which the topography, hitherto fairly well marked, became more and more subdued as the Oxford Clay, itself a soft formation, became enshrouded by the Quaternary gravels, clays and peats of the Fens.

The A 605 was held to through Peterborough and a brief stop was made at King's Dyke (245971) so that a brick pit on the north side of the road could be seen from the bus, showing a thick Oxford Clay with an overburden of gravels. The leader remarked that the pits were not easy to visit because of the unsympathetic attitude of the brick companies.

From Whittlesey, the B 1097 was followed to March, and the true fen country was seen. Mr. Taylor remarked that the name "The Turves" seen on a sign was, he believed, one of the few Celtic survivals in an otherwise Scandinavian area. The leader pointed out how March stands on a gravel 'island' appreciably above the fen level, and then called a halt for lunch to be taken in the town.

After lunch, the party took the B 1099, and turned left on to the B 1098 at Bedlam Bridge (468949). At 485977 the bus was stopped and the party got out. The leader described the fen deposits and explained the nature of the fen roddons. He then pointed out that the place where the party was standing was on such a roddon, a ridge running across country about 250 ft. wide and perhaps 6 ft. above the surrounding fens. The roddon, as is often the case, is occupied by a Roman road and by a line of farms; it was quite apparent to careful observation, running approximately East-West through the place where the party stood. After about fifteen minutes, the party rejoined the bus and followed the roddon along the B 1094, which crossed it several times. From Nordelph (555010) the journey continued uneventfully by A 1122 and A 1101 to Wisbech, and by A 47 to King's Lynn.

The next exposure seen was in the Cretaceous Sandringham Sands, in a quarry showing a face about 18 ft. high (682295). The Sands were white and cream in colour, ironshot, weakly cemented, and current-bedded. The pleasant warm weather now caused the tourist traffic to increase so much that the excursion was jeopardized, but by taking back roads through Shernborn (714324) and Fring (736347), the bus got to the Lighthouse at Old Hunstanton (675420). From here the party walked down to the beach and examined the classic section of the Carstone, overlain by the Red Chalk and the white Chalk. This concluded the field work for the day. After a short wait, the bus reappeared from the holiday crowds. The long journey back to Nottingham was broken briefly at Spalding for refreshment. Mr. Taylor proposed a vote of thanks, to which the leader replied. The party reached Nottingham at about 21.40.

P.C.S.

## REFERENCES


ORDNANCE SURVEY 1" SHEETS
122 Melton Mowbray
133 Northampton
134 Huntingdon and Peterborough
135 Cambridge and Ely
124 King's Lynn

JENNINGS, J.N. 1950. The origin of the Fenland meres. Geol. Mag., vol. 87, pp. 217-225.

TAYLOR, J.H. 1949. Petrology of the Northampton Sand Ironstone Formation Mem. Geol. Surv., 112 pp., 6 pls.

# THE GEOLOGY OF EDALE, DERBYSHIRE

Leader:- Mr. W.H. Wilcockson, M.A. Sunday, 5th June 1966

The party assembled at Edale about 10.30 a.m. Before moving off, the leader gave a short general account of the geology of the area. Edale is situated in the valley of the River Noe,which rises at Edale Head and is fed principally by streams flowing from the southern slopes of the Kinder Plateau. The rocks exposed all belong to the Namurian and the succession is as follows:-

| | |
|---|---|
| Kinder Scout Grit | 250 feet |
| Grindslow Shales | 300 feet |
| Shale Grit and Mam Tor Sandstones | 600 to 800 feet |
| Edale Shales | 650 to 750 feet |

The Kinder Scout Grit is a coarse massive rock. It underlies the Kinder Plateau to the north of Edale,where it forms the striking crags of the Edges. The Grindslow Shales are fine grained and sandy shales devoid of fossils. The Shale Grit and Mam Tor Sandstones are a series of sandstones, sometimes massive with shale bands in the upper part and becoming more flaggy, with more frequent shale partings, in the lower portion. The Edale Shales are fine grained dark shales, often carbonaceous, with thin bands of nodular earthy limestone. They have many thin beds containing marine fossils, notably goniatites. The upper shales belong to the R1 zone while the lower contain fossils of the H and E1 zones.

Geologically the Edale valley is a broad anticline with its axis trending roughly ENE-WSW and along the axis the River Noe has exposed the lower beds of the Edale Shales as far down as the E1 zone. It was in the core of the anticline, between Upper Booth and Barber Booth,that a trial boring for oil was made some years ago. To the north, the Kinder Scout Grit lies in a very shallow syncline forming the plateau; to the south is a similar syncline,in the core of which the Shale Grits are preserved as a narrow ridge extending from Lose Hill, through Mam Tor to Rushup Edge. To the south the syncline is bounded by the northern limb of the Derbyshire Dome, bringing up the Carboniferous Limestone of Castleton. From the work of Jackson, Hudson and Cotton,numerous fossil localities are known along the River Noe and its tributaries but, since groups of people crossing the fields are not welcomed by the farmers (especially on Sundays in the summer), it was decided to omit the shale exposures and to concentrate on the higher ground, where the harder rocks are exposed and views of the country can be had.

First,therefore,the party set off along the Castleton footpath that crosses the southerly sandstone ridge at Hollins Cross (National Grid reference SK 136845). From here the ridge was followed westwards to the summit of Mam Tor (SK 128836). Here, on the south face, the cliff exhibits an excellent section of the thin bedded Mam Tor Sandstones from which fragments are continually falling, giving the hill its local name of "Shivering Mountain". The cliff is the back of the great "scoup" whence have come the landslips for which Mam Tor is famous and which give so much trouble in the maintenance of the road from Castleton to Chapel-en-le-Frith. From the top of the hill, a wide view is obtained over the limestone country to the south and of the Edale Valley and the Kinder Plateau to the north. On the south-facing slope of the plateau, the horizontal attitude of the strata can be seen very clearly and also the typical form of the escarpments of this region. Here, as elsewhere, there is the summit edge of the Kinder Scout Grit and below it, separated by the Grindslow Shales, the underscarp of the Shale Grit Series. The massive Kinder Scout Grit often makes sharp outstanding crags,while the softer Shale Grit Series gives rounded shoulders with little or no rock showing,except where the sandstones have been exposed as a result of landslips, as on Mam Tor and Back Tor (on the south side of the Edale Valley between the former hill and Lose Hill - SK 147850).

From Mam Tor, the descent was made past extensive but less spectacular landslips to Edale, where lunch was taken. After lunch the destination was Kinder Scout by way of the valley of the Grindsbrook (approx. SK 122861 to SK 110872). After leaving the north end of the village, the stream is crossed by the "log" bridge where, in the banks, there are good exposures of the Edale Shales (black in colour, with much ochreous deposit from the oxidation of pyrites). The path proceeds through the Grindsbrook Meadows with no further exposures till, after passing a small wood, outcrops of Shale Grits are seen in the banks of the stream below. These show alternations of harder and softer rocks giving a number of small waterfalls. Nearer the edge of the plateau, the valley narrows and a good exposure of the Grindslow Shales can be seen in the bank and bed of the stream. A little further on, the crags of the Kinder Scout Grit tower above the valley; from the base of this grit, springs are thrown out. Through the edge the stream has cut a narrow gorge where the Grit is exposed in high cliffs. Here it is a very massive thick bedded variety.

Higher up, where the gorge widens, it can be seen to cut down into an underlying thin-bedded grit, which suggests that the massive grit is situated in a channel eroded into an earlier grit. In confirmation of this it can be seen that the massive grit extends as a narrow belt for more than two miles along the southern edge of the plateau, where it gives rise to many curiously shaped weathered rocks.

The plateau is covered with a thick deposit of peat, up to ten or more feet in places. Near the top of the Grindsbrook gorge, the stratification of the peat was examined in one of the deep channels that have been cut through it.

Return was then made to Edale over Grindslow Knoll (SK 109868) and along the "Peat Road", a track made by bringing down peat which, until the coming of the railway, was the only fuel available in the village.

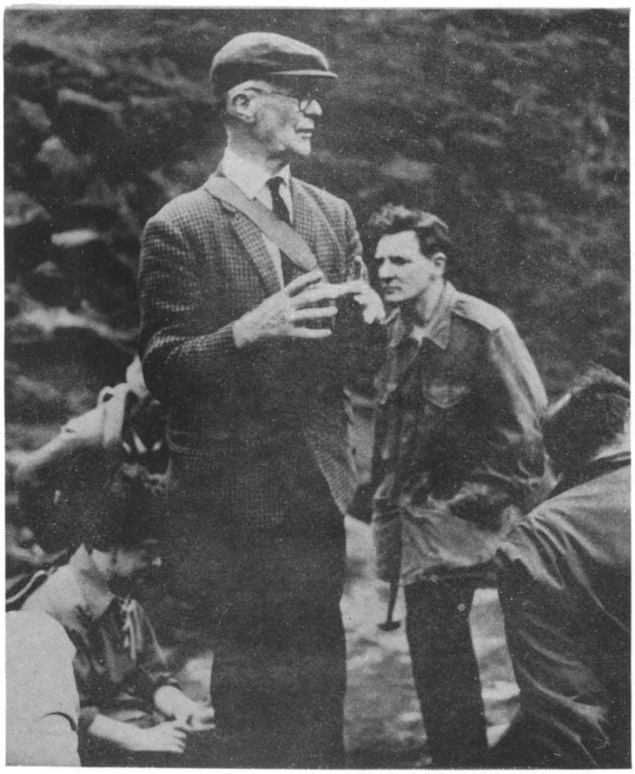
W.H.W.

## REFERENCES


JACKSON, J.W. 1927. The succession below the Kinder Scout Grit in North Derbyshire. J. Manchester Geol. Assoc., vol. 1, p. 239.

HUDSON, R.G.S. and COTTON, G. 1945. The Carboniferous rocks of the Edale anticline, Derbyshire. Quart. J. Geol. Soc. Lond., vol. 101, pp. 1-36, pl. 1.

Plate 5.



Upper:- Mr. W.H. Wilcockson addressing members in Grinds Brook.
(The Secretary of the E.M.G.S., Robert W. Morrell, behind)

Lower:- A rock on the margins of Kinder Scout, possibly undercut through wind erosion in periglacial conditions. (Mrs. A.M. Sarjeant acts as scale)

Photos: W.A.S. Sarjeant

## THE WREKIN AREA, SHROPSHIRE

Leader:- P.H. Speed | Sunday, 3rd July 1966

A party of 26 members and friends were conveyed by coach from Nottingham to the Forest Glen Pavilion (SJ 638094), where they were joined by those who had travelled by private car, some six in number.

The purpose of the meeting was to study the relationship between the Pre-Cambrian of the area and the adjoining Cambrian and Carboniferous beds

The ascent of The Wrekin was made from Forest Glen and the faulted junction of the Uriconian (Pre-Cambrian) and Cambrian Quartzite demonstrated; later the unconformable nature of this junction was observed as the path to Wrekin Cottage (SJ 637089) was climbed.

Between Wrekin Cottage and the summit of The Wrekin, a variety of Uriconian volcanic rocks was noted, including pyroclastics, dolerites and flow-banded rhyolites. The route from the summit to Banks Lane via Little Hill (SJ 619076) enabled the unconformity between the Uriconian and Cambrian Quartzite to be observed on the south side of The Wrekin area.

Walking westwards along Banks Lane, near The Spout (SJ 625071), some of the more energetic members of the party ascended Harper's Dingle (SJ 634073) to see the succession in the Pentamerus Beds of the Upper Valentian, noting particularly the calcareous conglomerate with well rounded Uriconian pebbles.

Between Little Wenlock and Maddocks Hill the outcrop of Carboniferous Limestone,with a layer of basalt,was observed, together with its striking unconformity with the Cambrian Quartzite.

In Maddocks Hill Quarry (SJ 645085),where the intrusive camptonite has been worked, the Shineton Shales (Tremadocian) have been metamorphosed by this intrusion.

Returning to Forest Glen, an inspection was made of the adjoining quarry, Uriconian agglomerate consisting of tuff and rhyolite pebbles in a tuffaceous matrix; it was noted that two dolerite dykes traversed the agglomerate.

After tea in The Pavilion the party visited the Cambrian Quartzite exposure opposite Buckatree Hall (SJ 641097); the quartzite here includes Uriconian fragment.

The return to Nottingham was made via Wellington and Uttoxeter.

P.H.S.

### REFERENCES

POCOCK, R.W. and WHITEHEAD, T.H. 1948. British Regional Geology. The Welsh Borderland. London. H.M.S.O. pp. 1-84.

WHITTARD, W.F. 1952. A Geology of South Shropshire. Proc. Geol. Assoc., London, Vol. 63, pp. 143-197.

## THE GEOLOGY OF SEDGLEY AND DUDLEY

Leader: Dr. I.D. Sutton — Sunday, 2nd October, 1966

The Sedgley and Dudley areas have become famed over the years for the wealth of fossil material collected from the Silurian rocks in this region. Records of fossil collections from Dudley go back to 1686, when Dr. Plot figured some specimens collected from these Silurian rocks.

Park Hill, Sedgley, and Wren's Nest and Castle Hills at Dudley are the three main areas where the Silurian rocks outcrop. Structurally the hills are in the form of periclines and are completely surrounded by deposits of Coal Measure age, which form tracts of low-lying land around the upstanding Silurian deposits.

Over 30 members of the East Midlands Geological Society attended this excursion, the fine weather adding to the enjoyment of those participating.

Having made our way into the Black Country, our first stop was just to the south of Wolverhampton at Park Hill, Sedgley (918957). Here the Aymestry Limestone is exposed in a small digging. The party were able to examine the nodular form of the limestone, a feature not uncommon in the Silurian limestones of the Welsh Borderlands. The limestone at this locality yields quite a large fauna and members had the opportunity to collect the following fossils:

Brachiopods - *Dayia navicula*, *Atrypa reticularis*, *Leptaena rhomboidalis*, *Lingula* sp. and *Salopina* sp.

Molluscs - *'Orthoceras'* sp., *Loxonema* sp.

Corals - *Favosites* sp., *Tryplasma* sp.

Trilobites - *Dalmanites* sp.

Lunch was taken at Himley Wood and afterwards some time was spent in the Himley Wood Quarry of the Baggeridge Brick Company (903910). In this quarry the Etruria Marls of Upper Coal Measure age are exposed. A considerable variation in lithology was seen, with light coloured sandstones, blue, grey and reddish marls and clays, and occasional local developments of intraformational conglomerates. The marls and clays furnish the material for the well known blue bricks, while red bricks are also made from the same clays by firing them at a lower temperature and without subjecting the clay to a reducing atmosphere.

The sandstone horizons of the Etruria Marls, which are known by shaft sinkers as 'espleys', often yield a good number of fossil plants. Members were able to collect the plant remains from Himley Wood Quarry, but the state of preservation was poor and rendered identification difficult.

One interesting feature seen by the party was the presence of a mineral vein along a small fault line in the Etruria Marl. The most dominant mineral was a pink variety of barytes, accompanied by subordinate amounts of calcite, chalcopyrite, and a dark metallic mineral which has yet to be identified.

The third and final exposure the party visited was the famed outcrop of the Wenlock Limestone at Wren's Nest Hill, Dudley (937920). Wren's Nest Hill is formed by an elongated dome with an axis roughly NNW - SSE (see Sarjeant 1964, p. 65). The Wenlock Shales, which are poorly exposed, form the core of the dome and are surrounded by the Wenlock Limestone, which has been divided into 3 main lithological divisions by Butler (1939):

| | |
|---|---|
| Upper Limestone | 34 feet |
| Nodular Beds | 123 feet |
| Lower Limestone | 42 feet |

Both the Upper and Lower Limestones have been extensively quarried in the past, the outcrop today consisting almost entirely of the Nodular Beds. As the name implies, the Nodular Beds are lithologically argillaceous limestones with a distinct nodular form.

The Wenlock Limestone as a whole is extremely fossiliferous, the Upper and Lower Limestones being particularly so. In the years around the turn of the century, vast collections of fossils were obtained from this locality and one trilobite in particular, Calymene blumenbachi, was so abundant that it aptly received the name 'The Dudley Locust'. Besides the trilobites, crinoids were also very abundant, being in an excellent state of preservation. Representative collections of these fossils are now housed in many museums in the Midlands and in a large number of the major museums throughout the world.

Today collecting of specimens is not possible on such a large scale, but a very good fauna is still obtainable from the Nodular Beds, particularly brachiopods and corals.

The following list of fossils collected by members is by no means complete, but gives some idea of the varied nature of the fauna still obtainable.

Corals: Favosites gothlandicus, Palaeofavosites asper, Heliolites megastoma, H. interstinctus, Stelliporella parvistella, Propora tubulata, Halysites catenularius, H. sp., Cystihalysites westwoodensis, Coenites juniperinus, C. linearis, C. repens, Thecia swinderniana, Syringopora fascicularis, S. bifurcata, Kodonophyllum truncatum, Ketophyllum subturbinatum, Acervularia ananas, Arachnophyllum murchisoni, Tryplasma loveni.

Trilobites: Mainly fragments of the following genera: Calymene, Cheirurus, Dalmanites and Phacops.

Brachiopods: Atrypa reticularis, Camarotoechia nucula, Dolerorthis rustica, Eospirifer radiatus, Gypidula dudleyensis, Howellella elegans, Leptaena rhomboidalis, Resserella elegantula, Rhynchotreta cuneata, Sphaerirhynchia wilsoni, Strophonella euglypha.

Gastropods: Bembexia lloydi and Poleumita discors.

Crinoids: Various fragments of crinoidal stems.

Stromatoporoids: Stromatopora typica and Clathrodictyon sp.

Bryozoa: A great variety of stick-like bryozoans.

The Wenlock Limestone is mainly a well stratified limestone but, at various levels, the party were able to see the unstratified masses of hard limestone known locally as 'ballstones' or 'crog-balls'. These 'ballstones' are in fact small reef structures and consist of calcareous organisms, mainly a coral-stromatoporoid assemblage in position of growth and a lot of fragmentary organic debris, mainly crinoidal;

these are cemented together by a fine-grained blue cement. Many of the tabulate corals in the 'ballstones' tend to assume a branching form of growth; members were able to see this in one of the reef structures where a very large, branching colony of Stelliporella parvistella formed a large part of the reef. A more complete description of the reef structures is given by Crosfield and Johnston (1914).

By walking round the outcrop of the Nodular Beds, the party were able to see the gradual change of dip and the periclinal nature of the outcrop. Along the outcrop the thoroughness of the working of the Lower Limestone could also be seen; it had in fact been mined out from below the Nodular Beds, the latter beds themselves being held in place by strategically placed pillars.

From the highest point on Wren's Nest one can look out across country to Castle Hill and picture the type of topography which must have existed during Coal Measure times. Wren's Nest and Castle Hill would have stood up as islands above the mud flats, forests and estuaries during Lower Coal Measure times, while the Upper Coal Measures would have been banked up against the islands.

The weather remained perfect throughout the day and the members were able to make their way back to Nottingham dry, but in some cases overladen with specimens.

I.D.S.

## REFERENCES


BUTLER, A. J. 1939. The stratigraphy of the Wenlock Limestone of Dudley. Quart. J. Geol. Soc. London, vol. 95, pp. 37 - 74.

CROSFIELD, M. C. and JOHNSTON, M. S. 1914. A study of the ballstones and the associated beds in the Wenlock Limestone of Shropshire. Proc. Geol. Assoc. vol. 25, pp. 193-194.

SARJEANT, W. A. S. 1964. The Dudley canal tunnel and mines, Worcestershire. The Mercian Geologist, vol. 1, pp. 61 - 66.

# CORRESPONDENCE

## Geological Societies in the English Midlands

Dear Sir,

During an investigation of the Natural History Societies of Derbyshire (now published in the Sorby Record 2, 2, 73-76) I found your paper on the "Geological Societies and Geologists of Midland England" (Merc. Geol. vol. 1 pp. 35-48) most useful. You may find the following additional notes of interest.

Bakewell Naturalists' Club Referred to in the Naturalist (1901, p.291) when it had a Museum, whose Curator was William Boulsover. This may be a different name for the Bakewell and District Naturalists Field Club. Storrs Fox was definitely a member of the latter, but it was largely founded by Dr. E.M. Wrench of Baslow.

Derbyshire Natural History & Philosophical Society Mentioned by Simpson (1960) 'Bibliographical Index of the British Flora'. No other details.

East Derbyshire Field Club A predecessor of the North-East Derbyshire Field Club. Probably had little geological interest.

Matlock Field Club A new society has recently been formed.

Operation Mole One of the older speleological groups in Derbyshire, formed 1949. Its declared objects (1959) include a serious interest in geological aspects.

Peakland Archaeological Society A group of recent formation which has specialised in cave excavations. An annual duplicated newsletter is produced.

Although not connected with Derbyshire, further information on the Dudley Geological Society has also caught my eye. The meeting of this Society of 17th January 1842 is reported at length in the Geologist, Vol. 1, p. 58, as 'the first general meeting of the members and friends of the Society', implying inauguration in 1842 or late 1841.

Yours faithfully,

DAVID A.E. SPALDING,
(Deputy Director)
Sheffield City Museums,
Weston Park,
SHEFFIELD, 10, Yorks.

26th July, 1966

# REVIEWS

## H. H. READ & JANET WATSON: Beginning geology. London: Macmillan and Allen & Unwin 30s.

In the writing of an introductory text to our science, a number of very considerable problems have to be faced. The dimensions of the subject render difficult its compression into a small compass, so that it is difficult to attain a balanced treatment. The terminology, even at its most basic level, is unfamiliar to most readers; each term must be defined before it is employed. Illustration must be both good and full; descriptions, however accurate, never have the impact of a good photograph or drawing. Finally, the authors must have a thorough command, not just of clear expression, but also of layout and paragraphing, in order to facilitate both reading and learning.

In most of these regards, "Beginning Geology" is admirable. The presentation is attractive and the illustration excellent, consisting of well-chosen photographs, plus clear line-diagrams and maps. No term, however basic, is used unless it has been defined: examples are given wherever possible and are often imaginatively chosen. In all, this is a most attractive work and will be of considerable assistance to the beginner in geology.

A dust-jacket note suggests that the book has been designed for G.C.E. "O" and "A" level geology students and it is probable that syllabuses have been very much borne in mind in planning the work. This may well account for certain inequalities in treatment. Palaeontology is compressed into 22 pages, an unenviable task: it is hardly surprising that this section is indigestible and that the definition of major groups is often very vague. Trace-fossils earn only the sketchiest of treatments; and little mention is made of sedimentary structures. Almost nothing is said about the origins of the Earth or about meteorites, these topics perhaps being considered to lie rather in the province of the astronomer or physicist. The origins of glaciations and the phenomenon of polar wondering are not discussed; and continental drift is treated very cursorily - the authors probably decided that these topics were inappropriate to an elementary text such as this.

In general, the illustrations are adequately labelled, but in a number of cases, locality and stratal names are not given (e.g. Figure 15.1) or given so imprecisely as to be unhelpful (e.g. 6-2 "Potholes in an African river"). This reduces their interest somewhat. Still, it is refreshing, after the recent flood of American textbooks, to have one illustrated primarily by British examples!

In general, however, Professor Read and Dr. Watson merit the highest praise: there is no question that this is the most attractive and best balanced elementary text on geology currently available. It can be thoroughly recommended to anyone wishing to acquire a sound grounding in our science.

WILLIAM A.S. SARJEANT

## "The Amateur Geologist" Vol. 1, Part 1. Summer 1966. Liverpool Geological Society and the Manchester Geological Association. 2s. 6d.

The many amateurs who find in geology an absorbing hobby soon become aware that, while the science is fairly well served by a number of journals, none of these publications (at least in Britain) exists specifically to serve their needs. Some journals do try to cater for the amateur, but not exclusively, and those that do are of a regional or local character rather than national.

An attempt to fill this very real gap in geological literature has recently been taken by the Liverpool Geological Society and the Manchester Geological Association, who have jointly sponsored a new journal which has been simply titled "The Amateur Geologist." Produced by a duplicating process and without illustration, other than a handful of maps, the journal is priced at the modest sum of 2/6d.

The two editors, Ian M. Wild and Anthony Green, in their first editorial state the reason behind the journal's publication as stemming from the growing conviction on the part of the sponsoring bodies that the "interests and enthusiasm of their non-professional members should be stimulated and channelled by a journal couched in terms they can readily comprehend." "The Amateur Geologist" is thus aimed from the start at the amateur who has made geology his hobby; at the same time the new journal also, as its editors indicate, seeks to help students at colleges and universities who are not advanced enough to have graduated to professional journals, and teachers and pupils in secondary schools, where, remark the editors, "Geology is slowly gaining favour as a curriculum subject."

Few there are who would object to the sentiments quoted above: however, the editorial then introduces a somewhat jarring note by stating that it is the intention of the journal to direct attention to the "wealth of geological interest in the North-West." Such a bias can only harm a journal seeking to aid the amateur, in that this regionalism will tend to rob it of the truly national stature implied in the title. The regionalism is reflected all too clearly in the first issue, which (apart from the editorial, a feature on the activities of other societies, and a paper on the Wrens Nest National Nature Reserve) is confined to papers on the geology of the area within easy reach of Liverpool. A point coming to mind here is that, while the papers published in "The Amateur Geologist" are geared to the level of the rather raw amateur, it should also be borne in mind by the professional geologists who write some of them that it is no use writing articles at that level and then giving references to other papers which, if consulted by the amateur, are likely to confuse because their "concepts and terminology" are "beyond the comprehension of the amateur" (to quote from the Editorial).

The new journal is a worthwhile venture and worthy of support, but certainly has its limitations, the most obvious being the total lack of illustrations and its pronounced regionalism. If it can remedy the former and escape the latter, "The Amateur Geologist" could establish itself as a journal of national importance - a medium through which amateurs might not only learn but would be able to publish the results of their own research. Some of these could be of great value, but are lost because amateurs do not consider themselves as worthy of approaching established journals, mainly with professional geologists as their readership. A good start has been made; time will show whether or not the impetus can be maintained and the limitations overcome.

ROBERT W. MORRELL

D.T. DONOVAN, 1966: Stratigraphy - an introduction to principles. London: T. Murby & Co., Allen & Unwin. 30s.

It is always a pleasure to find a book which fills a long awaited need in any subject. The need filled by this book was on the general principles of stratigraphy with special reference to British rocks. In recent years a number of books have appeared on stratigraphical principles, mainly from N. America, and examples naturally have been chosen from that continent. At last a book is available which gives many examples, not only of British stratigraphy but also of the work of British stratigraphers.

In this book reference is made to the great men of British Stratigraphy who laid the foundations for the subject, including Arkell, Buckman, de la Beche, Hutton, Lapworth, Lyell, Murchison, Sedgwick, Smith, Spath, Trueman, and Vaughan. A number of these spent a lifetime's work on Mesozoic rocks; it is therefore fitting that an expert on the Jurassic should write a book about the difficulties which befell the early stratigraphers and which have been discussed ever since.

It is also appropriate that this book appears at a time when many British stratigraphers are attempting to produce an ordered code of stratigraphy which can be applied throughout this country and perhaps further afield.

Donovan's book considers the necessity to establish a sequence and shows how this is built up from a number of local sections to generalized sections covering many square-miles. The essential use of fossils for correlations is quickly established and examples are given from the Chalk, Ordovician graptolite zones, and the Carboniferous Limestone, all referring to the British Isles. Examples from elsewhere refer to trilobites in the Cambrian and to Lower Jurassic and Cretaceous ammonites. The discussion of these examples leads on to a review of zones, considered a basic unit of classification, and the special requirements for zonal fossils. In addition to the well-known attributes of short vertical range and wide geographical extent, Donovan suggests (p. 53) that such fossils should be reasonably common and easily recognisable. This last point is certainly of importance to the stratigrapher, who must become increasingly more expert in identification. The stratigrapher despairs when palaeontologists alter existing classifications for esoteric reasons. The palaeontologist, for his part, distrusts identifications made by the stratigrapher, who may not be a specialist in the group with which he is dealing.

It is shown that zones are grouped together as stages. Stages are more easily correlated over wide areas (Continents). A table showing the correlation of the Cambrian of North America (fig. 12) is given; it is unfortunate that some of the lettering on this diagram is illegible.

A chapter is included on lithological correlation. Of particular interest here is the section on cyclothems or rhythmic sequences (p. 76). Correlation is possible using these rhythms, particularly within coalfield areas. However, the author mentions three methods of correlation (using goniatites, non-marine lamellibranchs and plants) which have been used in these rocks and which render lithological correlation an academic topic. It would have been more interesting to read about correlation in the Permian and Triassic formations of this country, where fossils are rare. ( For instance, are the Bunter Pebble Beds of the East and West Midlands of the same age?) The use of the term Formation is advocated by the author as the other main basic unit of classification.

Readers are next treated to a discourse on radiometric dating, which attempts to give absolute dates to rocks. Despite the difficulties, calculation errors are now reduced to a low level. Even so, these can amount to many millions of years. Subdivision of geological time by fossils demands more precise results, as is pointed out by Professor Donovan (p. 96) and, to date, the use of sophisticated equipment has yet to make significant changes to the time divisions of the Phanerozoic (Cambrian - Recent). The absence of agreed major subdivisions of the Pre-Cambrian reflects the difficulties of radiometric dating in the absence of fossil control.

These three methods of subdivision, fossils, lithology and absolute time, give the basis for stratigraphical nomenclature and classification. They result in biostratigraphical, lithostratigraphical, and time terms. There is a need for co-ordination and hence the various commissions that have been set up in various countries, all to report to an International Commission. The background of this problem and the review of the present situation make fascinating reading. The Americans on the one hand require a three-fold system of classification, the Russians on the other, a single system. Perhaps the British can arbitrate, although the scheme proposed in Donovan's book (p. 157) is unlikely to find general acceptance without a struggle.

The book is completed by a study of system boundaries. Three are chosen for consideration, firstly the question of the Tremadoc, whether Ordovician or Cambrian; secondly the Silurian - Devonian boundary - no less than eight views are illustrated in fig. 34 (in this respect it is a pity that the Marloe's Bay, Pembrokeshire, section is relatively unfossiliferous); and thirdly the Triassic - Jurassic boundary.

The absence of agreement on these points (and at most of the other system boundaries) indicates how much work is still required from British stratigraphers.

The book is extremely well written and scores high for readability. It is to be hoped that we have more books by this author.

Considering the high quality of the manuscript, the publishers have not acted fairly by this author, by using out-of-date type and inferior paper and thus making the appearance of this book unattractive. (Comment has already been made concerning the reproduction of fig. 12). In view of this, the price of this book (199 pp., 36 text-figs., without half-tone plates) is high.

In spite of the above it is to be hoped that readers will persist, for it will be an extremely useful text for University students, teachers, research workers and the like.

F.M. TAYLOR

<u>Secretary's Report, June - November 1966</u>

The East Midlands Geological Society is now almost three years old and, before long, will see the first major change since its foundation. At the Annual General Meeting in February, 1967, a majority of the present Council will retire under the three-year clause in the Constitution of the Society. Looking back, it is clear that, without the hard work put in by members of the Council, who have given freely of their time and talent and have often left their expenses unclaimed, the Society would not have made nearly such a good start. It would be invidious to select any particular member of Council for especial praise, since all have done so much; as Secretary, I can only say how grateful I am for the way in which they have helped to make my job so much easier to carry out.

One person known to all members of the Society, who has already retired from office, and about whom a special word is most certainly due, is our President, Mr. P.C. Stevenson. Mr. Stevenson was our first President and members will not only recall his active support of our meetings and field excursions, some of which he led, but also his two first-rate Presidential Addresses, both of which have been published in the pages of the "Mercian Geologist". Mr. Stevenson has now retired from the Presidency, slightly earlier than the Constitution demands, and, unfortunately for the Society, taken a position with the Tasmanian Geological Survey. Australasia's gain is our loss; however, our Past-President is retaining his links with the Society and is now the first member we have in the Antipodes. We wish him success in his new post. Prior to Mr. Stevenson's departure, Council members entertained him to dinner at the Black Boy Hotel in Nottingham.

The sad news of the death of Professor H.H. Swinnerton, at the age of 91, removed from us one of the leading figures concerned with the geology of the East Midlands. The first Honorary Member of the East Midlands Geological Society, Professor Swinnerton published his last paper "The <u>Gryphaea</u> plexus in the Lower Lias of the Vale of Belvoir, Nottinghamshire" in the June, 1965 issue of "The Mercian Geologist". An obituary,written by Professor W.D. Evans, appears in this issue.

The summer excursion programme was once again well supported and, on the whole, the weather left little to complain about. The Society owes a great debt to the various leaders, who put in a great deal of preparatory work in order to give those attending a comprehensive picture of the geology of the area or exposures visited. As each leader also provides a "write up" for "The Mercian Geologist", detailed descriptions by me are unnecessary. Our popular "Cooks" Tour on Sunday, 1st May,led by Mr.P.C.Stevenson, gave a good send off to the programme; this took in the geology south-east of Nottingham. This was the first excursion which has touched the seaside; at least one exposure was visited by negotiating around and across the bodies of sunbathing holidaymakers.

On Sunday June 5th,a large party visited Edale under the leadership of Mr. W.H. Wilcockson, M.A., F.G.S. The excursion called for some fairly long climbs but as far as is known all members arrived back in Nottingham - other than a local Edale cow who made a determined attempt to join the party and was only defeated by a stile. The classic geological area of The Wrekin was visited on July 3rd,under the leadership of Mr. P.H. Speed, F.G.S. The glorious weather allowed us to examine in detail the volcanic rocks of the area and also to dodge some military manouvres, which seemed to consists of trying out radios and the firing of assorted guns.

The British Association meeting was held at Nottingham from August 31st to September 8th. This was the fourth time the Association has visited the city. The interesting series of excursions and meetings organised by Section 'C' (Geology) attracted many members of the Society to the Association, the local Secretary of which was Dr. F.M. Taylor. The Society organised a display at the Geology Exhibition held in conjunction with the Association at the University; this consisted of an exhibit showing the history and work of the Society. It was split into four sections; the first consisted of historical material, the second related to the excursion programme, the third to the production and publication of "The Mercian Geologist", and the fourth to the three projects undertaken by the Society.

Palaeontology was the dominant feature of the excursion to Dudley on October 2nd , led by Dr. Ian Sutton. Dudley is one of the best-known geological areas in Britain and the source of a mass of interesting fossils, though quarrying operations have removed for good some of the more productive exposures, while others are overgrown. Nevertheless, the bus was far heavier on the return journey.

Sunday, November 6th saw a party of 26 (plus some juveniles) paying a visit to the Geological Museum, London. This excursion was in some ways experimental, in that it was the first made specifically to a museum. On arrival, our party was met by Mr. F.W. Dunning, B.Sc., F.G.S., of the Geological Survey, who showed the members around the collection. That the experiment was a success was established beyond doubt, if the comments made by the party on the return journey are anything to go on. Consideration will be given to a similar visit next year, though to another museum next time.

The inaugural meeting of the winter session took place for the first time outside Nottingham; about sixty people assembled at Newark Museum to hear Dr. M.J. Le Bas, F.G.S., of Leicester University, give an illustrated talk on 'East African Volcanoes'. The number present is a good indication that the policy adopted shortly after the foundation of the Society to organise meetings outside Nottingham was sound. In keeping with this, the future programme will include meetings at Bakewell (in co-operation with the Peak District Mines Historical Society) and at Matlock; it is possible that a meeting will also be held in Peterborough.

The dinner held by the Society last year was so popular that another is to be held in January, 1967; following the dinner, Dr. T.D. Ford is to show slides of his recent visit to the United States. Future meetings will be addressed by Professor W.D. Evans, Dr. W.A.S. Sarjeant, Professor J. Sutton, F.R.S., and Dr. F.M. Taylor. The winter programme will be rounded off with another 'Collectors Evening', an event of proven popularity. Incidentally, perhaps members reading this might note the date of the evening, May 4th at 7.30 p.m., and give some thought to bringing along material for display.

R.W. Morrell

# OBITUARY

## PROFESSOR H.H. SWINNERTON

Henry Hurd Swinnerton, C.B.E., D.Sc., F.Z.S., F.G.S., was born on the seventeenth day of September 1875 in Bungay, Suffolk. He was the son of the Wesleyan Minister, the Reverend G.F. Swinnerton, and spent his early life moving from one parish to another. As a boy he first attended the Woodhouse Grove School, near Leeds and then, when his father was transferred to South Wales, he was placed in Kingswood School, Bath. On obtaining matriculation of the University of London at the age of nineteen, he became assistant master at Trowbridge High School. During his spare time in this capacity, he continued his studies by means of what was called the 'University Correspondence Course'. Zoology was his great love and his ambition was to obtain an honours degree in that subject. To satisfy the requirements of the University of London, he decided to study Botany and Chemistry along with Zoology. Since he lacked laboratory facilities, the tutor of the correspondence course suggested he should replace Chemistry with Geology and so, by chance, he made his first real contact with a subject which was to rival and ultimately replace his love for Zoology.

By travelling to Bristol on Saturday afternoons, he made himself familiar with the minerals, rocks and fossils in the show-cases of the museum. His regular visits to the museum ultimately attracted the attention of the Curator. This was how he met Edward Wilson, a kindly, dedicated man, who realised that here was an exceptional young man and gave him the use of a small quiet room in which Swinnerton could carry out his work on Saturday afternoons. The only way in which Swinnerton could repay Edward Wilson was by collecting fossils from the Bradford Clay. This he did on his weekends, cycling out to localities and afterwards preparing the fossils for the Museum.

Throughout his correspondence course his tutor was anonymous, but one day he received a private letter from him explaining that the 30 hours allotted by the correspondence college for this purpose was already consumed. However, the letter went on to say that the tutor was prepared to help Swinnerton to pursue his studies to completion. The letter was signed by Dr. A. Morley Davies. Thus began yet another lifelong friendship between palaeontological enthusiasts. Morley Davies invited young Swinnerton to spend his Christmas holidays in London and introduced him to Professor G.B. Howes. This professor was so impressed by Swinnerton's drawings of dissections that he recommended him for a studentship at the Royal College of Science. The value of the Studentship was 18/- per week during term time. So, in 1897, Swinnerton went to London, determined to fulfil his ambition. Two years later he graduated at the Royal College of Science with a first class honours degree in Zoology.

The influence of Wilson and Morley Davies must have been profound, as Swinnerton spent his spare time furthering his knowledge of Geology. He often spoke of the generosity of these two men and how in London he would visit Morley Davies at his home in the evenings to be taught the use of the petrological microscope. Likewise Professor Howes had Swinnerton's interests at heart and made him his personal assistant in a momentous piece of research work on the development of the skeleton of *Sphenodon* (the Tuatara Lizard, the only surviving representative of the reptilian Order Rhynchocephalia). Howes had received a superb collection of embryonic material from New Zealand, and this included a dozen live eggs of Sphenodon. With Swinnerton's assistance these eggs were successfully hatched out in trays of damp sand placed under the heating pipes of the Professor's room. In this way Swinnerton became associated with the first sight of a baby *Sphenodon* ever produced in Europe. Moreover, this fired his life-long thirst for research.

In those early days working for Professor Howes he became accustomed to dealing with problems as they presented themselves and never to allow the lack of facilities to hold up the progress of his research. His remarkable hands held the skill of the surgeon, which enabled him to extract the most delicate traces of fossilised material of all kinds. The records show that his skill as a dissectionist was in a class of its own. His work on the skull of the stickleback was a remarkable piece of work. In this he exercised his superb knowledge of comparative anatomy over the surgical revelation of the cranial details of the stickleback. His thesis on this work was rewarded with the degree of D. Sc. in 1902. This achievement was even more more remarkable when one appreciates the financial and domestic difficulty which dominated his life in this formative period. In the middle of his work on the stickleback, he was faced with the problem of finance. He had no financial resources to assist him in this work and he was forced to seek employment. Consequently, he was glad to accept the post of Science Master at his old school in Bath. At Kingswood School he completed his dissections and his thesis. Nevertheless he treasured the memories of this part of his long and eventful life and he often referred to them as the best of his days. He kept all his student notebooks and in looking at these today one is left in no doubt, by the beautiful drawings of Zoological dissections and of minerals, of rocks and particularly of fossils, that this had all been truly a labour of love.

Many other men would have emerged from such a background having little patience with a potential scholar who lacked enthusiasm for knowledge. On the contrary, Swinnerton emerged only too anxious to use every means in his power to enthuse even the most backward of his students. Thus he was destined to become one of the finest teachers that this country has ever seen. His seductive influence in the lecture theatre and in the laboratory was to have a profound influence on the studies of men and women who had no initial intention of entering the realm of natural sciences.

In 1902 he was appointed to a lectureship in the Natural Science Department of the University College of Nottingham. This was the turning point in his fruitful career as a natural scientist. When he arrived, the College had no formal library facilities, but he found ways and means of obtaining the literature he required for his lectures and his personal work. He never allowed his environment to dominate his scientific ambitions, and he used every device imaginable, not the least his personal charm, to obtain access to books and materials for his work. In this he was helped by John Wesley Carr, the Curator of the Public Natural History Museum of Nottingham. Carr had received his training in the Sedgwick Museum and had developed in the Museum at Nottingham a very excellent collection of vertebrate and invertebrate fossils. Eventually Carr was appointed Professor and Head of the Natural Sciences Department in the University College, and Swinnerton for the first time had a professor to whom he could appeal for assistance in developing his ideas. Eventually potential graduates entered the department and in 1902 students were being entered for the London External B. Sc. degrees in Botany, Zoology and Geology.

For many years the heavy load of teaching, and building up departmental collections, absorbed Swinnerton's time. But he never wasted time. Time to him was an exceedingly precious thing and he organised his life from day to day and always had something concrete to show for his efforts. The development of the Natural Sciences in Nottingham, as elsewhere, during the early part of this century was aided by the growth, in schools, of the subject which was broadly called Nature Study. The various educational authorities were anxious to promote nature studies in schools and as a consequence Swinnerton was asked to supply courses of study for practising teachers. He recounts how many of these scholars took advantage of these courses as it meant free travel from the surrounding countryside into Nottingham on Saturday mornings. Many were prepared to accept the attendance at his classes with the prospect of indulging in the City's entertainments in the afternoon. Despite this, his enormous ability as a lecturer awakened in these reluctant scholars a new and wider interest in nature; and soon the afternoons were characterized by field excursions to ponds and rivers and quarries rather than to shops and the venues of sport in Nottingham.

With characteristic foresight Swinnerton included the lectures on soil, rock weathering and geomorphology in the Nature Study course for teachers. The class grew so large that it eventually led to

Henry Hurd Swinnerton, C.B.E., D.Sc., F.G.S.,
F.Z.S., A.R.C.S.

the foundation of Geography on a departmental basis. It is not unimportant to record that D.H. Lawrence was among the many students who attended Swinnerton's lectures on these Saturday mornings. In addition, F.M. Burton, a headmaster, and A.T. Metcalf, a solicitor, became well-known names associated with the interests which Swinnerton stimulated in the somewhat neglected studies of the Permo-Triassic rocks of Nottinghamshire. In 1911, having built up a tremendous local reputation as a lecturer, Swinnerton was asked to become the Head of a new Department and the choice of its title was left to him. When considering this, he decided to call it the Department of Geology and Geography. In doing so, he had to subtract these subjects from the Nature Study course to allow the remainder to form the basis of a new Biology Department. This was a hard decision, as it meant losing direct contact with the teaching of Zoology. Nevertheless, he continued to assist this department by carrying out dissection work and preparing teaching material for students who wished to study biology. He used to recall that his only compensation for making this hard decision in the partition of the old Natural Sciences department was the fact that he was for the first time able to take charge of his departmental finances. In other words, he was now allowed to spend up to £10 without seeking special permission from the college Council. This is a very interesting reflection upon the amount of money which was allocated to heads of departments in those distant days. Moreover, his resources were confined to very restricted spaces in the building. In fact he had to secure any space he could find and eventually he found that his research work had to be carried out in a windowless basement of the building. It is therefore interesting to note, in passing, that with such primitive conditions he nevertheless succeeding in carrying out an amazing amount of delicate work. He had virtually no material to begin with when he started to teach geology and therefore he had to collect minerals, rocks and fossils. This gave him the excuse to be out in the coutryside and he regarded this as pleasure and not work. He had no assistance apart from one laboratory assistant. It is therefore not surprising that his scientific approach to this problem resulted in teaching techniques which have influenced many other departments of geology throughout the country. He believed in the practice which circumstances forced upon him, that undergraduates should work as much as possible on their own. To assist them he produced schedules of work which exercised their imagination and at the same time trained them to systematise their studies in the laboratories.

In due course there was a steady stream of students taking geology as a subject for the intermediate examination of the University of London. They were excellent students. Many went on to degree courses and eventually to finalise at honours levels in Geology. In one of his letters he records how

> "places in the first class Honours results now became a regular event. Indeed, one year, the whole of the University Honours list in Geology was made up of our students. Four of whom were in the First Class. It is natural that some of them decided to take up Geology for a career and willingly repaid by instalments the money that had been expended upon them by the Board of Education. Among these may be mentioned F. G. Percival (1912), who became geologist to the Tata Iron and Steel Company of India; A.E. Trueman (1912); F.T. Ingham (1919), who became Director of the Geological Survey of Cyprus; S.H. Straw (1923), who became Lecturer in Palaeontology in the University of Manchester; and S. G. Clift (1923), who was for many years lecturer in the Department of Geology at Nottingham. The case of A.E. Trueman was outstanding. He entered the College as a normal student taking a degree course; his main interest was zoology and he wished to take an Honours degree in that subject. For some years, however, there had been no demand and therefore no degree course in that subject. Meanwhile my commitments in Geology and Physical Geography had increased to such an extent that I felt unable to cope with a merely temporary revival of Honours Zoology. In conversation with Dr. Holden, he quickly grasped the situation and kindly offered to discuss the matter with Trueman, who soon realised that in the study of fossils he would find an outlet for his zoological interest. He therefore decided to take Honours Geology with special Palaeontology and subsidiary Zoology. In 1914 he gained a First Class Honours degree in the University of London. Trueman was medically unfit for National Service and I accordingly pressed Principal Heaton to give him help to stay on and do research. He therefore put his name forward for one of the new D.S.I.R. grants which were being initiated at that time. This effort was successful and the grant was given for two years.

For some time I had been making a careful study of the development of the ammonite septum. As numerous measurements were needed to put my conclusions to the test, I enlisted the help of Dr. Shaw of the Physics Department, a great expert on measuring instruments, to devise and construct for me a suitable one for my purpose. I then set Trueman to make the measurements, a piece of work which he carried out with the greatest precision. The resulting paper was read before the Geological Society in 1918 (Q. J. G. S. vol. 73). This work gave him an insight into the value of measurements in the study of fossils and was put to excellent instructive uses in later years. When Trueman got his degree it was his intention to go as a missionary to China. (An unfavourable medical examination prevented the late Sir Arthur Trueman from embarking on this career). It was at this time that Professor Franklin Sibly, later to become Sir Franklin Sibly, who had been the external examiner for Trueman, wrote to ask me the whereabouts of this young man. He said he had been so impressed with Trueman's answers to the examination that he would like to have him in his own department at Cardiff. Thus was Trueman launched upon his brilliant career. From Cardiff he went to Swansea as Professor of Geology, then to Bristol for four years and finally to Glasgow. He eventually left Glasgow to become Chairman of the University Grants Committee."

This quotation is worthy of inclusion in this biography of Swinnerton, as it reflects the great pride he took in the development and in the achievements of his students. He took this pride without any feeling of credit and this was the hallmark of his great influence over every student who came into contact with his precise, imaginative and instructive methods of teaching. He worked his students very hard and believed that they should derive pleasure from their studies. In this they were aided by Swinnerton's imaginative and graphic approach to every aspect of Geology.

His deep sense of religious belief and his earnest wish to do all he could for young people also occupied a great deal of his spare time. He was very interested in Sunday School work and was a Superintendent in the local Methodist Church. An interesting outcome of this interest was the fact that he once visited a a Conference held in London and there met Leonard V. Dalton. In conversation he discovered that Dalton was interested in oil geology and out of this emerged the suggestion that two of his students should go to Venezuela to work for a few months for the oil company with which Dalton was then associated. The two students who decided to accept this invitation were F. G. Percival and Arthur Radford. Percival has already been mentioned, but Arthur Radford went on to study social sciences and eventually became the first Professor of Social Science in the University of Nottingham.

One had to work with Swinnerton in order to understand how he was able, throughout his life, to keep up a steady stream of important publications on a great variety of topics. Mention has already been made of his superb contribution to our knowledge of Sphenodon and also to the anatomy and life history of the stickleback. These were purely zoological publications and they led to his interest in the development of the pectoral fin of fishes. This produced an important publication in Natural History in 1905. By 1910, his ideas were beginning to formulate regarding the relationship of geology to scenery and a very important paper was written describing the relationship of the Bunter Sandstone to the geomorphology of the County. With his great keen eye for detail, he discovered organic remains in the Trias of Nottingham; and this he published in 1910. Moreover, he became impressed by the record of footprints in the Triassic rocks and wrote a most illuminating and attractively assembled paper on what he characteristically called "The Palmistry of the Rocks."

Year after year saw a steady stream of papers, ranging from the palaeogeographic significance of dreikanters at various horizons in the Trias to palaeontographical problems concerning trilobites. By 1928 he was heavily engaged in planning the new department, which was to be instituted in the new University College building which was being erected in Highfields Park. This building, now known as the Trent Building, housed most of the departments of the University College. Space was limited, but with characteristic foresight Swinnerton secured one of the most attractive parts of the building in which to install the Department of Geology and Geography. Concerning this, he used to attribute this to the inability of other heads of departments to read architectural plans.

The early thirties saw the growth of his interest in Lincolnshire and the opening phases of his work on the faunas of the Jurassic and Cretaceous. No-one has improved upon his account of the cephalopod fauna of the pre-Red Chalk deposits or added a great deal to his work on the Lower Cretaceous of that county. An earlier study of belemnites, collected and submitted to him from East Greenland, formed the prelude to his monumental monograph of this neglected group of fossils which was published by the Palaeontographical Society. Hundreds of specimens were examined, photographed and described in detail over the twenty years or so which he spent on this task along with a multitude of other lines of research. For example, he published papers on the development of underground waters from the Spilsby Sandstone and thus was involved in the sinking of important boreholes into this formation. In this way he made significant contributions to our stratigraphical knowledge of this poorly exposed formation. The problem of the Lincoln Gap intrigued him and this stimulated a series of important papers on the geomorphology of Lincolnshire and the East Midlands.

Endowed with a remarkable memory, he collected and collated knowledge which resulted in a stream of publications and lectures on archaeological and antiquarian subjects. Even so, his disciplined mind maintained the patient meticulous progress of his palaeo-zoological studies. During the Second World War, he collected thousands of specimens of Gryphaea from trenches dug for defence purposes in the Lias. Single handed, he cleaned and described this vast collection in order to establish beyond doubt his earlier views on the variations which develop in a single community of invertebrates. This and other examples he used to establish the principles he developed in his Presidential Address to the Geological Society of London in 1939.

He was the author of sixty-four important scientific papers and numerous articles. Seven books also bear his name. In 1954, at the age of 79, he was asked to write a philosophical book on geology and asked me to assist him as editor. This I readily agreed to do, little believing that within six months I would be presented with a manuscript of over 60,000 words - a fantastic achievement of authorship by any set of standards. A year later the book appeared in print and became a 'best-seller', which was translated into several languages and serialised. This remarkable piece of work indicated that he was a man whose mind and enthusiasm for knowledge would endure to the end. Indeed, at the age of 87 he was part author with his old friend and colleague, Professor Kenneth Edwards, of the superb book on the Peak District. In his ninetieth year he published his final thoughts on the Gryphaea plexus.

It is impossible to unearth all the outside services that Professor Swinnerton rendered to the community at large. He was chairman of the Joint Recruitment Board and of many boards of school governors. Of particular interest to himself was his association with the Nottingham High School for Girls. He was the first chairman of its Board of Governors and today his work on behalf of the emancipation of educational facilities for young ladies is revered and treasured by all. He thought little of personal honours and it was a source of unexpected pleasure for him to find that at national level he was recognised as an outstanding citizen when he was made a Commander of the Order of the British Empire. The University of Nottingham also recognised this by making him the first member of staff of the University to receive the honorary degree of Doctor of Science.

The life of Henry Hurd Swinnerton was a happy one. He derived happiness from the every-day discharge of his duties to his college, his students and his colleagues. High moral standards he demanded from everyone, but never was he intolerant or lacking in understanding when misfortune affected others. His old students revered him, and rightly so, but he never made claims upon them in any shape or form. The Methodist Church was his spiritual home and his practical mind and inexhaustible generosity was applied to its welfare and the care of its congregation. To be out in the fields with his hammer and knapsack was his idea of real pleasure as all things natural held a hidden meaning to him. His was a long life, from which he asked nothing and to which he gave everything.

## The Geological Publications of Professor H.H. Swinnerton

### A - Papers

1900 with G.B. Howes Tuatara Proc. Zool. Soc., London, Vol.70 pp. 516-517

1901 with G.B. Howes On the development of the skeleton of the Tuatara, Sphenodon punctatus Trans. Zool. Soc., London, Vol. 16, pt. 1, No. 1 Feb., pp. 1-86, text-figs. 1-7, Plates 1-6.

1902 A contribution to the Morphology of the Teleostean Head Skeleton. Quart.J. Microscopical Sci., Vol. 45, pp. 503-593, Plates 28-31, text-figs. 1-5.

1903 The Osteology of Cromeria nilotica and Galaxias attenuatus. Zoologischer Jahrb., Vol. 18, pp. 58-70, text-figs. A-M.

1905 A contribution to the morphology and development of the Pectoral Skeleton of Teleosteans. Quart. J. Microscopical Sci., Vol. 49, pt. II, pp. 363-382, Plate 23, text-figs. 1-3.

1905 The Stickleback, its personal and family history. Trans. Nottingham Nats. Soc., 1905-6, pp. 34-40, Plate 4

1905 The changes and variations in the position of the pectoral fin during development Ann. Mag. Nat. Hist. Ser. 7, Vol. 15, pp. 319-321, text-fig. 1-4.

1910 The Bunter Sandstone of Nottinghamshire and its influence upon the geography of the county. Trans. Nottingham Nat. Soc., 1909-1910, pp. 17-28, text-figs. 1-11.

1910 Organic remains in the Trias of Nottingham. Geol. Mag., Vol. 57, p. 229

1911 The Evolution of the functions and structures of the fins in fishes. Sci. Progress, Vol. 6, pp. 447-456, text-fig 1.

1911 The palmistry of the rocks. Trans. Nottingham Nat. Soc., 1911-12, pp. 65-67, Plates 3-5

1914 with J.W. Carr Report of an excursion to the Nottingham District Proc. Geol. Assoc. London, Vol. 25, pp. 84-89, Plates 11-14

1914 Periods of Dreikanter formation in South Notts. Geol. Mag., Vol. 61, pp. 208-211, Plate 16, text-fig. 1

1915 Suggestions for a revised classification of Trilobites. Geol. Mag., Vol. 62, pp. 487-96, 538-45, text-figs. 1-3

1918 with A.E. Trueman The Morphology and development of the ammonite septum. Quart. J. Geol. Soc., London, Vol. 73, pp. 26-58, Pls. 2-4, text-figs. 1-17

1918 The Keuper Basement Beds near Nottingham. Proc. Geol. Assoc., Vol. 29, pp. 16-28, text-figs. 2-5.

1919 The facial suture of trilobites. Geol. Mag., Vol. 56, pp. 103-110, text-fig. 1

1921 The use of graphs in Palaeontology. Geol. Mag., Vol. 58, pp. 357-64, 397-408, text-figs. 1-10

1925 A new catopterid fish from the Keuper of Nottingham. Quart. J. Geol. Soc., London, Vol. 81, pp. 87-99, Plates 7 and 8

1927 Earth movements and extinction. Geol. Mag. Vol. 64, pp. 529-32

1928 A new species of Semionotus from the Keuper of Nottingham. Geol. Mag., Vol. 65, pp. 40-69, text-fig. 1

1929 The physiographic sub-divisions of the East Midlands. Geography, Vol. 14, pp. 3-14, text-figs. 1-4

1931 A specimen of Phaneropleuron from Gloucestershire. Mem. & Proc., Manchester Lit. & Phil. Soc., Vol. 75, pp. 43-46, text-fig. 1

1931 Post-glacial deposits of the Lincolnshire coast. Quart. J. Geol. Soc., London, Vol. 87, pp. 360-375, Plates 29 & 30, text-fig. 1

1932 Early man in the East Midlands. Abbott Mem. Lecture, Univ. Nottingham 1932, pp. 1-12

1932 The prehistoric pottery sites of the Lincolnshire Coast. The Antiquaries Jour. Vol. 13, pp. 239-253, text-fig. 1-9

1932 Unit characters in fossils. Biol. reviews, Vol. 7, pp. 321-335, text-figs. 1-4

1935 The rocks below the Red Chalk of Lincolnshire and their cephalopod fauna. Quart. J. Geol. Soc., London, Vol. 91, pp. 1-46, Plates 1-4

1936 The physical history of East Lincolnshire. Presidential Address. Trans. Lincolnshire Nat. Union, pp. 1-10, 4 text-figs.

1937 with S.G. Clift and P.E. Kent The geology of the district, in A scientific survey of Nottingham and District. Brit. Assoc. meeting, Nottingham 1937, pp. 45-56, 1 plate

1937 The problem of the Lincoln Gap. Presidential Address. Trans. Lincolnshire Nat. Union, pp. 1-9, text-figs. 1-6

1938 Underground Water Pressure in the Spilsby Sandstone. Summary of Progress, Geol. Surv. G.B., 1936, pp. 54-61, Plate 1

1938 Development and evolution. Presidential Address Section C, Report Brit. Assoc. Cambridge Meeting, pp. 57-83, text-figs. 1-4

1938 The biological approach to the study of the cultural landscape. Address at the annual conference of the Geographical Association. Geography Vol. 23, pp. 84-89, text-figs. 1-8

1939 Palaeontology and the mechanics of evolution. Presidential Address, Quart. J. Geol. Soc., London, Vol. 95, pp. xxxiii-lxx, 10 text-figs.

1939 Geology and water supply in the East Midlands. British Waterworks Association 28th Annual General Meeting, Nottingham July pp. 1-7, 1 plate

1940 The study of variation in fossils. Quart. J. Geol. Soc., London, Vol. 96, pp. lxxvii - cxviii, text-figs. 1-13 (Presidential Address)

1941 Further observations on the Lower Cretaceous rocks of Lincolnshire. Proc. Geol. Assoc., Vol. 52, pp. 198-207, text-figs. 18-19

1943 Belemnites from East Greenland. Ann. Mag. Nat. Hist. Ser. 11, Vol. X, pp. 406-410, 4 text-figs.

1945 A note on Lemming remains in Nottinghamshire. Geol. Mag., Vol. 87, p. 185

1946 The Middle Grits of Derbyshire. Geol. Mag., Vol. 88, pp. 118-120

1948 Permo-Trias of the East Midlands and Pleistocene and later deposits in Marshall C.E. Guide to the geology of the East Midlands. Nottingham University

1949 Man as a maker of landscape. Abbott Memorial Lecture 1948-49. University of Nottingham, 14 pp.

1950 Submerged Forest at Sutton-on-Sea. The Lincolnshire Historian, No. 6, Autumn 1950, pp. 230-231, 1 text-fig.

1952 The story of early man in Nottinghamshire. Trans. Thoroton Society, pp. 63-74, 2 plates

1954 Proposed use of Plenary Powers for the purpose of validating the specific name "minimus" Miller J.S. 1826. Bull. Zool. Nomenclature Vol. 9, Pt. 9. Oct., pp. 284-5

1956 with W.R. Chalmers and M. Posnansky The Mediaeval Tile works of Lenton Priory. Trans. Thoroton Soc., Vol. 60, pp. 83-97

1957 with Helen Boulton Lenton Priory Excavations. Trans. Thoroton Soc., Vol. 61, pp. 1-7, text-fig. 1

1936-1955 The Lower Cretaceous Belemnites. Mon. Palaeontogr. Soc. London. 86 pp., 18 Plates

1959 Concerning Mr. A. Hallam's article on Gryphaea. Geol. Mag., pp. 307-310

| | |
|---|---|
| 1964 | The early development of Gryphaea. Geol. Mag., Vol. 101, No. 2, pp. 409-420, Text-figs. 1-3 |
| 1965 | The Gryphaea plexus in the Lower Lias of the Vale of Belvoir, Nottinghamshire. Mercian Geologist, Vol. 1, No. 2, pp. 89-102, Text-figs. 1-5 |
| | Numerous book reviews, obituaries and talks |

B - Books

| | |
|---|---|
| 1910 | The Geography of Nottinghamshire. Cambridge County Geographies C.U.P. 153 pp., 54 illus., 10 text-figs., 9 maps |
| 1923-1947 | Outlines of Palaeontology. Arnold. 1st, 2nd and 3rd Editions, 393 pp., 367 text-figs. |
| 1937 (Editor) | Scientific Survey of Nottingham and District. Brit. Assoc. Nottingham Meeting Univ. of Nottingham, 111 pp., 4 plates |
| 1947 | Solving Earth's Mysteries. London, Harrop. 220 pp., 180 text-figs. |
| 1949 with P.E. Kent | The geology of Lincolnshire. Lincoln: Lincs. Nat. Union, 136 pp., 3 Plates, 22 text-figs. |
| 1955 | The Earth Beneath Us. London: Muller; also Penguin. ed. & German editions. 320 pp., 16 plates, 28 text-figs. |
| 1960 | Fossils. London: Collins New Naturalist Series. 274 pp., 24 Plates, 21 text-figs. |
| 1962 with K.C. Edwards and R.H. Hall | The Peak District. London: Collins New Naturalist Series (Chapters 2-3 particularly pp. 11-49, Plates 1-4, Colour Plates 1 and 2, text-figs. 2-6) 240 pp., 15 text-figs., 24 plates, 4 colour plates. |

ALSO

| | |
|---|---|
| 1935 | The Story of Methodism in Sherwood, Nottingham |

W. D. Evans, M.Sc., Ph.D., M.I.Min.E.,
M.I.M.M., F.L.S., F.R.G.S., F.G.S.
Professor of Geology,
The University,
Nottingham

Papers treating with any aspect of Midlands geology or on topics of general geological interest will be welcomed for consideration for publication by the Editorial Board. (Authors need not be members of the East Midlands Geological Society). Format should follow that adopted for papers included in this number.

Manuscripts should be addressed to:-


Dr. W. A. S. Sarjeant,<br>
Editor "The Mercian Geologist",<br>
Department of Geology,<br>
The University,<br>
Nottingham

# CONTENTS