WILLIAM BUCKLAND, 1784 - 1856:
SCIENTIFIC INSTITUTIONS, VERTEBRATE PALAEONTOLOGY, AND QUATERNARY GEOLOGY.

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5. THE QUATERNARY DILEMMA

5.1 DILUVIALISM

Although I have not attempted to carry out a sterile statistical analysis of the published history of science studies dealing wholly or in part with Buckland and his work, still less a word-count of their contents, there can be no doubt at all that, in these, references to Buckland in relation to the Diluvial Theory outnumber several times over those relating to all of the many other facets of his work combined. To take only two of the more substantial examples, Gillispie's extremely influential Genesis and Geology. A study in the relations of scientific thought, natural theology, and social opinion in Great Britain, 1790-1850 makes Buckland the centrepiece of a chapter ostensibly devoted to "Catastrophic Geology" as a whole (Gillispie, 1951: 98-120), whilst in their excellent and very influential history of geomorphology, Chorley, Dunn and Beckinsale (1964: 99-124) gave the title "Dean Buckland and the Diluvialists" to their Chapter 9. In this Chapter, therefore, my task is quite different from that in most, if not all, of the fields covered in the other chapters, which have frequently proved to be almost virgin territory so far as modern re-evaluations are concerned.

Much of what has been (and indeed still is) written about Diluvialism and Fluvialism in the first two or three decades of the 19th century, particularly in the more general histories of science, would in my view be totally unrecognisable and indeed incomprehensible to the participants in the perceived dramas of the period. Certainly there were differences of opinion, confrontations even, between Neptunists (or Wernerians) and Plutonists (or Huttonians), Catastrophists and Uniformitarians, and between Diluvialists and Fluvialists , but it is a dangerous fallacy to suppose either that these three controversies were different manifestations of the same confrontation, or indeed that individuals involved in more than one such controversy were always on the same side. For example, three of the Scottish geologists most closely associated with the promotion of Hutton's views, John Playfair, Sir James Hall and Sir George Mackenzie, all accepted diluvialism, and appear to have seen no inconsistency in this. Similarly, the author of the Doctrine of Uniformity, at least in its purest and most forcibly argued form, Charles Lyell, appears to have accepted diluvialism without question on the basis of the British evidence, and only adopted an uncompromisingly fluvialist stance during his visit with Murchison to the Auvergne following the publication of G P Scrope's Memoir on the Geology of Central France (Scrope, 1827), and did not publicly reject the Diluvial Theory until the celebrated joint paper given to the Geological Society in December 1828, (Lyell and Murchison, 1828; Wilson, 1972: 183-217). In many aspects of the history of geology both geographical factors and the geological periods in which different workers were currently specialising have been seriously under-estimated as influences on theoretical positions. Lyell's Doctrine of Uniformity both then and now can be made to work extremely convincingly in analysing the very stable and uniform conditions that prevailed in the Tertiary of France and Italy, and in the comparatively recent volcanic activity of the Auvergne, but the field evidence is strongly against Lyellian Uniformitarianism in attempting to interpret Quaternary phenomena of a recently glaciated area of Scotland or Northern England. Indeed, when Lyell was persuaded by Buckland to look in detail at the superficial deposits immediately around the Lyell family home at Kinnordy near Kirriemuir, Angus, in the autumn of 1840, Lyell immediately adopted the glacial theory very enthusiastically (see Chapter 5.2 below), although he quickly abandoned this and reverted to his non-catastrophist submergence theory, for which there was virtually no convincing field evidence.

As Gordon Davies has demonstrated:

> The history of the fluvial doctrine during the years immediately after Hutton's death has been strangely misunderstood. Historians have viewed the doctrine as one of the points at issue in the controversy between the Neptunists and the Plutonists, and one history of geomorphology refers to a Wernerian counter-offensive against Huttonian geomorphology. In reality no such event occurred. A vigorous controversy between the Neptunists and the Plutonists certainly did take place, ... Geomorphology, however, had no place in this controversy; the disputants were concerned almost entirely with one problem - were granite and basalt of chemical or igneous origin? (Davies, 1969: 223-224).

In fact, almost all of the studies examining Buckland in relation to diluvialism have done so largely if not wholly from the point of view of either geomorphological processes or the philosophical and theological basis of his work (for example, Gillispie, 1951; Hooykaas, 1959 & 1970; Cannon, 1960, 1976 & 1978; Page, 1969; and even the new study by Rupke, 1983). In contrast with this kind of approach, my purpose in this and the following chapter is to re-examine Buckland's work as a Quaternary geologist.

I have chosen the title of "The Quaternary Dilemma" for this Section because it is clear that Buckland, like many perceptive observers before him, as well as those of his own generation, found many enigmatic features of the superficial deposits that could not be explained and understood in terms of commonly observed geological processes. This enigma was to be finally resolved by the turning of what Gordon Davies has aptly termed "The Glacial Key" (Davies, 1969).

In the absence of any coherent and tested hypothesis of the nature and origin of the terrestrial deposits of the temperate Quaternary, both within and outside the glaciated regions, the geology of this period was regarded as superficial, in both senses of the word, through at least the first half of the 19th century. It is probably fair to say that few if any geologists of note worked exclusively, or even predominantly, on the Quaternary before the last quarter of the 19th century, and "Quaternary Research" in its modern sense did not begin to develop until after the first world war. As in so many aspects of Quaternary studies, Charlesworth aptly summed up the usual 19th century view of the "drift" in his monumental The Quaternary Era:

> Although the clays, sands and gravels belong to the youngest and most accessible formation, their apparently chaotic state and seeming lack of interest made them the last to be investigated: they were for long a synonym for confusion, and except for their fossil shells and bones seemed unattractive and unimportant. The "extraneous rubbish" was a troublesome hindrance in examining the "solid" geology. Long after Agassiz had revived the glacial theory, official state surveys ignored them. Thus the British drifts were passed over almost without scrutiny until most of southern England had been examined. (Charlesworth, 1957: 614).

Buckland's serious and continuing interest in "superficial" geology was, therefore, exceptional for his period (although not unique). When he finally presented his evidence in support of the glacial theory to the Geological Society in November and December 1840, he stressed that his first contact with the various puzzling phenomena that could at last be explained in terms of the glacial theory was during his first tour of Scotland in 1811 when, amongst many other things, he had been mystified by the rounding and polishing of the rocks on the side of the gorge of the Tay, above Dunkeld, which he had at that time attributed to "diluvial action", (Buckland, 1841A: 332).

When he read his Inaugural Lecture in May 1819, Buckland confidently asserted not only that there had been a Deluge, but that this could be equated with that of Genesis. However, in the lecture itself he dealt in detail with only one specific area of evidence in support of this, quoting De Luc who, in Buckland's view:

> has completely settled the long disputed question on this subject, ... with observations on the escape of many rivers in Switzerland from their native valleys by vast chasms or gorges, the production of which is not referable to any causes now in action, and which indicate a series of different operations conducted at an ancient period of time, (Buckland, 1820: 16).

However, before the Inaugural Lecture was finally published, Buckland added a four-page Appendix refuting a current claim that there was no geological proof of the Mosaic Deluge. This Appendix post-dates the reading of the Lickey Hill paper (Buckland, 1821D) at the Geological Society meeting of 3 December 1819, but was, of course, published more than a year earlier because of the slow rate of production of the Society's Transactions. In the Appendix to the published version of the Vindiciae Geologicae, Buckland listed and elaborated on nine "proofs" of the Mosaic Deluge, which may be summarised and paraphrased as follows:

1. The general shape and position of hills and valleys, particularly what Buckland called "valleys of denudation" and related phenomena which could not be explained by normal present-day processes and which therefore "shew them to owe their existence entirely to excavation under the action of a retiring flood of waters";
2. The pattern of minor rivers leading into major valleys caused by the drainage of the flood waters to the sea;

3. The existence of outliers at considerable distances from the main outcrop, "and from which they have been at a recent period separated by deep and precipitous valleys of denudation";

4. "The immense deposits of gravel that occur occasionally on the summits of hills, and almost universally in valleys all over the world; in situations to which no torrent or rivers such as are now in action could ever have drifted them";

5. "The nature of this gravel, being in part composed of the wreck of the neighbouring hills, and partly of fragments and blocks that have been transported from very distant regions";

6. The nature and geological "youth" of the organic remains in this gravel;

7. "The total impossibility of referring any one of these appearances to the action of ancient or modern rivers";

8. The occurrence of similar phenomena in almost every part of the world that had been at that time scientifically investigated "consistent with the hypothesis of a contemporaneous and diluvian origin";

9. "The perfect harmony and consistency in the circumstances of those few changes that now go on ... with the hypothesis which states the commencement of all such operations at a period not more ancient than the Mosaic Deluge". (Buckland, 1820: 37-38).

Buckland concluded the Appendix by emphasising that each of these arguments "whether considered collectively or separately, present such a general conformity of facts, tending to establish the universality of a recent Deluge" (Buckland, 1820: 38). In fact, he appears to have quietly dropped the diluvial theory of the formation of outliers, (no. 3), and accepted that the form of at least some hills and valleys (no. 1) and most concordant river drainage systems (no. 2 above) could be explained in terms of present-day processes, but remained certain to the end of his life that some extraordinary process had to be invoked for some exceptional phenomena, particularly "diluvial" gravels (no. 4), erratic blocks (no. 5) and some discordant land form features, such as certain kinds of gorges. Buckland's views were very close indeed, if not identical to, those of George Bellas Greenough whose Critical Examination of the First Principles of Geology (1819) discussed and then rejected both the Huttonian and Wernerian systems, at least in their most fundamental forms, by reference to many hundreds of detailed field observations which he considered to be evidence of the diluvialism of the English (and particularly Geological Society) perception, and Buckland quoted approvingly from Greenough's new work in his Lickey Hill paper (Buckland, 1821D: 542-543).

The late Appendix to the Vindiciae Geologicae was a bald statement of Buckland's views on the geological evidence for the Mosaic Deluge, with no supporting evidence of geological detail. These were to be presented in great detail in the published version of Buckland's 3 December 1819 paper to the Geological Society: "Description of the Quartz Rock of the Lickey Hill in Worcestershire, and of the Strata immediately surrounding it; with considerations on the evidences of a Recent Deluge afforded by the gravel beds of Warwickshire and Oxfordshire, and the valley of the Thames from Oxford downwards to London; and an Appendix, containing analogous proofs of diluvian action. Collected from various authorities." (Buckland, 1821D). Although the full title was a very long one, it seriously under-sold the true scope and emphasis of a work that laid the foundations of Quaternary geology for the whole of the Midlands and the Thames Valley, citing no less than 79 localities (including a number of overseas locations which were compared with those of the region studied).

Buckland's starting-point was the widespread dispersal of erratic pebbles over much of the Midlands. He paid particular attention to previous work in the field, noting that both John Playfair and John Kidd had suggested that the origin of the dispersed quartzite pebbles must be the Lickey Hills. Although not cited by Buckland, Playfair's note on this was in fact in his classic Illustrations of the Huttonian Theory of the Earth (1802: 375-376), although the reference was included in his chapter on "Remains of Decomposed Rocks" not the following section on "Transportation of Stones, &c." (Playfair, 1802: 381-412), which concluded with what amounted to a challenge to those who objected to strict Huttonian uniformity:

> Lastly, If there were any where a hill, or any large mass composed of broken and shapeless stones, thrown together like rubbish, and neither worked into gravel nor disposed with any regularity, we must ascribe it to some other cause than the ordinary detritus and wasting of the land. This, however, has never yet occurred; and it seems best to wait till the phenomenon is observed, before we seek for the explanation of it. (Playfair, 1802: 411-412).

By the time of his death in 1819 Playfair's challenge had been taken up by a number of geologists, and Buckland cited some of the most important of these, including in particular John Farey's Agriculture and Minerals of Derbyshire (Farey, 1811), Sir James Hall, with his extensive account of the "Diluvian Facts in the Neighbourhood of Edinburgh" in which he described as "diluvial" glacial striations and grooves running approximately west to east in and around Edinburgh, as well as the re-shaping by the "diluvial currents" of Castle Rock, Calton Hill and Corstorphine Hill, Edinburgh, (Hall, 1814), and papers by Thomas Weaver (1819) and William Richardson (1808) on the eastern and northern parts of Ireland respectively.

Buckland began by describing how in the company of Count Breunner of Vienna, he had first traced the origin of the abundant quartzite pebbles, during extensive fieldwork carried out in the summer of 1819. He described how the material in the "diluvium" had its origins in the solid quartzite rock of the Lickey Hills or perhaps of several isolated quartz rock outcrops, including that of the Wrekin, Caer Caradoc and the Stiperstones. From these original outcrops quartzite had been eroded, rounded and re-deposited as rounded pebbles in the very extensive coarser horizons of the New Red Sandstone of the Midlands, whence they had been re-excavated and re-deposited for a second time in the diluvium. He also identified many other types of pebbles similarly derived from Primitive rocks via the New Red Sandstone to the diluvium, including pebbles of jasper, slate, porphyry and of various sandstones. (Buckland, 1821D: 507-515).

The second, and much longer, part of the paper used his elegantly argued (and entirely correct) interpretation of the history of the pebbles to reconstruct the "Evidences of a Recent Deluge". In this, Buckland's main evidence was the distribution of erratics, of which many different kinds had been identified across the region in addition to the quartzite pebbles that had originally drawn him to the area. Other erratics firmly or tentatively identified included limestone pebbles containing Wenlockian fossils, Charnwood Forest slates and porphyries, gneiss, volcanic "trap", sandstones "of several kinds", Lias, Chalk, flints derived from the Chalk, Red Chalk (derived from the Yorkshire and Lincolnshire Wolds but found just north of Moreton in the Marsh and at Ridlington in Rutland) and rock crystals (Buckland, 1821D: 517-520). Buckland deduced that the extensive rounded gravels of the area between Shipston on Stour (south-east of Stratford) and Moreton in the Marsh (now recognised as part of the type Wolstonian - see Shotton, 1976), had been derived from the north-east by the "diluvial currents" on the basis of the occurrence of red chalk for which the nearest locality was around Spilsby, Lincolnshire (Buckland, 1821D: 518).

Even more significant was Buckland's recognition of the same erratic pebble suites at high levels on the Cotswolds, and then "bursting in over the lowest point of depression of the great escarpment of the oolite", (Buckland, 1821D: 518-519). On the dip slope of the Cotswolds he then traced the same deposit bearing the quartzite pebbles and other erratics down both the Evenlode and Cherwell valleys to the Thames at Oxford, and thence all the way down the Thames Valley to London and beyond. In the paper he paid a warm tribute to Mary Morland (his future wife) "to whose exertions in the cause of geology I am under extensive obligations", (Buckland, 1821D: 525), who had been responsible for tracing the quartzite pebble and flint gravels down both the Cherwell and Evenlode valleys, and who had identified Charnwood Forest erratics at Abingdon.

Buckland included some detailed notes supplied by William Conybeare on the superficial gravel deposits of Rutland, Leicestershire and Buckinghamshire, and commented on Continental parallels that he had seen personally in Switzerland, Italy and Hungary. Other parts of the paper were devoted to descriptions of fossil mammal finds in the gravels (discussed in Chapter 4.1 above).

He drew a distinction between angular gravel, which he had found largely if not exclusively close to the source rock outcrop, compared with the rounded pebbles from more distant sources. However, at the time he appears to have restricted his attention entirely to pebble and gravel deposits, and drew no parallels at all with comparable occurrences of erratics in tills. He ended by quoting from the Introductory Essay on the Theory of the Earth of Cuvier (1812), with its confident assertion, indeed "certainty", that the human race was of low antiquity and that the present state of the surface of the Earth was the result of a recent transient deluge. Buckland concluded that field observations and the evidence of the several scientific authorities cited were:

> all conspiring to establish the important fact, that accumulations of superficial gravel more modern than the most recent of the regular strata are found in all parts of the world, under circumstances of such exact resemblance, that it is impossible not to refer them to one and the same cause, viz. a recent deluge acting universally and at the same period over the surface of the whole globe. (Buckland, 1821D: 544).

In April 1822, two months after the presentation of his Kirkdale paper to the Royal Society, Buckland turned to the "diluvium" and - especially - the geomorphology of his home territory of East Devon and the Dorset Coast (Buckland, 1822D & 1824A). In this he was far more explicit in his assertion that the valleys of the area had been formed by "aqueous excavations", referring once again to Richardson (1808) on the Antrim coast, Geenough (1819) and to Alexander Catcott's Treatise on the Deluge (1761). In fact, his description and interpretation was entirely reasonable in terms of geomorphological process as such, but not in terms of the relative force or effectiveness of natural processes, nor in terms of the time-scale. In Buckland's opinion the action of "modern causes" such as torrents cutting ravines, rivers forming deltas, or coast erosion were "very limited and partial action", (Buckland, 1824A: 96). Essentially the problem was one of time-scale: in reality there was little or no evidence of exceptional forces in relation to the erosion of the south coast valleys that had been systematically examined by Buckland (in many cases in close association with De la Beche). It was simply that the moment that the time-scale available was artificially constrained by the contemporary preconceptions about recent geological time: the invoking of a "deluge" was virtually inevitable if the degree of erosion and of transport of the removed material was to be achieved within the self-imposed (albeit subconscious) time constraints. (Buckland was very much in the mainstream of geological thought of the time in finding himself and his interpretations restricted in this way, and the sophisticated diluvialism of the early 1820s is by no means the only example of rigid frameworks inhibiting progress: for much of the 20th century preconceptions of a rigid and stable crust held back serious consideration of the continental drift hypothesis, and hence the emergence of the modern plate tectonics model of the Earth.)

In the April 1822 paper Buckland also examined the continuity of strata on both sides of major valleys, such as that of the River Exe, and across the English Channel between Dover and the Pas de Calais and between the geology of the Devon and Dorset coasts and that of Normandy, and postulated that the English Channel might be "a submarine valley, which owes its origin in a great measure to diluvian excavation, the opposite sides having as much correspondence as those of any valleys on the land." (Buckland, 1824A: 101). He concluded the paper by referring to many occurrences of "diluvian gravel" in Devon and Dorset, both in the valleys themselves, and on the high summits of Blackdown, drawing parallels with the quartzite pebble gravels found on the tops of the hills around Oxford, and - perhaps prophetically - referring to "the blocks of granite that lie on the mountains of the Jura and on the plains of the north of Germany and Russia" (Buckland, 1824A: 102).

By the time of the April 1822 paper Buckland was already hard at work on the book that was to be published the following spring as Reliquiae Diluvianae (Buckland, 1823). Although this is viewed today as a major benchmark in fossil mammal studies in the English language, or perhaps - from a different viewpoint - as an important milestone in the development of cave science, Buckland's objective was to present an integrated study of what we would now term Quaternary geology. The work was presented in two parts, the first being a gratly expanded presentation of the original Royal Society paper on Kirkdale (Buckland, 1822B) incorporating all of the additional localities and new evidence relating to fossil mammals that he had discovered and worked on during 1822 (discussed in detail in Chapters 4.1 and 4.4 above). Part II was somewhat shorter (87 pages compared with 170 pages for the cave studies of Part I), but was on a very ambitious scale indeed, discussing the "Evidences of an Inundation" from "diluvial" indications in Scotland, Wales, Ireland, the Continent, North America, Africa and Asia. His previous papers in the field were the basis of appendices on the Midlands, the "excavation of valleys by diluvial denudation" and a discussion of the "diluvial gravels" of Devon, Dorset, Wiltshire and Berkshire, based on his "On the Formation of Valleys" paper (Buckland, 1822D & 1824A). Writing at a time when scientific interest in Buckland and his period was at a decidedly low ebb, the distinguished 20th century Quaternary geologist, A S Kennard, in his Presidential Address to the Geologists' Association confidently (and with justification) asserted that the publication of Buckland's Reliquiae Diluvianae was the starting point for British Quaternary studies, (Kennard, 1945). Similarly, Fred Shotton in his

Philosophical Transactions paper on the Pleistocene of the area between Coventry, Rugby and Leamington, which is still very much the starting point of contemporary Pleistocene studies in the Midlands (Shotton, 1953), made considerable use of Buckland's work of 130 years earlier, particularly in relation to the finds of fossil mammal remains in the Quaternary gravels of the area, such as those at King's Lawford, near Rugby.

As is already noted in Chapter 4.1 above, in addition to describing and discussing occurrences of fossil mammal bones in caves, Buckland devoted a substantial chapter at the beginning of Part II to "Evidence of diluvial action from the dispersal of the bones of elephants, &c." (Buckland, 1823A: 171-184), and which amongst many other things finally laid to rest the old argument that elephant fossils were the remains of animals imported by the Roman armies. He then continued with a chapter which first asserted the aqueous origin of superficial deposits of gravel, sand and loam, because of the manner of their dispersal, and continued by distinguishing in some detail the deposits of what we would now term the Flandrian (or Holocene) from the earlier deposits that we would now refer to the Pleistocene. In his view the formation of the former, which he termed "alluvium" (a Neptunist term - see Davies, 1969: 149-150), could be explained by observable present-day river and stream processes: "and is visibly forming every day", (Buckland, 1824A: 186). The second and older category could not, in the view of Buckland, (or indeed almost any of his scientific contemporaries), be explained away by the processes that were observed to be forming the alluvium, and he therefore introduced the term "diluvium" or "diluvian formation" for them. (In a footnote he attributed the use of the name "diluvium" to the Hon. William Strangways in a Synoptic Table published during Strangways' residence in St. Petersburg - Buckland, 1824A: 187 - but I have not so far traced this original publication.)

Buckland continued by giving many examples of the nature of various occurrences of diluvium and the directions from which the "diluvian waters" had invaded each area, using in particular the evidence of erratics:

> But the deposits of gravel contain solid fragments, and often large blocks of granite and other rocks, which can be traced to their parent mountain; the position of which with respect to the fragments is important, as affording a proof of the direction of the currents that drifted them to their present place of lodgment. This diluvial gravel is almost always of a compound character, containing amongst the detritus of each immediate neighbourhood, which usually forms its greatest bulk, rolled fragments of rocks, whose native bed occurs only at great distances, and which must have been drifted thence at the time of the formation of the gravel, in which they are at present lodged. (Buckland, 1823A: 191).

In contrast with the Geological Society paper on Devon and Dorset a year earlier, by the time the Reliquiae Diluvianae went to press Buckland had turned his attention to the glacial tills of eastern England and of Scotland, using the name "loam", and citing occurrences from the Tweed to the Thames, including Tynemouth, Holderness, Lincolnshire and the coastal areas of Norfolk, Suffolk and Essex. Referring to these deposits, he described them as follows:

> Their most common character in the localities here enumerated is that of a tough bluish clay, through which are dispersed irregularly pebbles of various kinds, together with the bones of elephants and other animals before spoken of. The pebbles are of two classes, 1. composed of the wreck of the adjacent inland districts of England; 2. large blocks and pebbles of many varieties of primitive and transition rocks which do not occur in England, and which can only be accounted for by supposing them to have been drifted from the nearest continental strata of Norway,

> by a force of water analogous to and contemporaneous with that which drifted the blocks of Finland granite over the plains of Russia, and the North of Germany. A diluvial current from the North is the only adequate cause that can be proposed, and is one that seems to satisfy all the conditions of our problem. (Buckland, 1823A: 192-193).

He continued by describing "pebbles of iridescent felspar, like that of Labrador" (Buckland, 1823A: 193) which were found on the Yorkshire coast near Bridlington - a clear reference to the common erratic of Norwegian larvikite of the Bridlington Crag and Basement Till, probably of the Wolstonian glaciation (Catt & Penny, 1966: 376-384). Buckland referred to finds of similar pebbles in northern Russia near Petersburg and mentioned particularly a large block of this rock which had been found on the bed of the River Neva, while the Duke of Devonshire was visiting Petersburg, and which had been brought back to Chatsworth where Buckland had seen it in 1821. From such occurrences Buckland deduced a mode of geological transport of quite a different scale from that seen at the present day, moving southwards from the Norwegian mountains into Russia, and south-westwards into eastern England, and which was responsible not just for the transport of the erratic blocks but also for the deposition of the "diluvium", which in most localities consisted of a mixture of locally derived material with more exotic pebbles and blocks (Buckland, 1824A: 192-194).

Buckland continued by referring to similar examples of dispersal within northern England, looking particularly at the transport of erratics from the Lake District, and especially the highly distinctive Shap Granite. Buckland paid particular attention to the natural form of valleys and the levels of the various watersheds, as he had done in his careful work on the dispersal of the Lickey Hill and Charnwood Forest pebbles over the crest of the Cotswolds in his first paper on the subject. In the Reliquiae Diluvianae other, even clearer, examples were identified of cases in which large blocks of Shap granite and other characteristic Lake District material had been moved by some great force, far stronger than that of any present-day river or torrent in the area, and had then been carried over "the lofty ridge and escarpment of Cross Fell and Stainmoor Forest" (Buckland, 1823A: 195).

After summarising the Lickey Hill paper, with its evidence of a southwards movement of great force over central and south-eastern England, Buckland turned to the North-West, and cited occurrences of erratics of Criffel granite from Galloway, in southern Scotland, south of the Solway Firth at some altitude on the north face of the Lake District mountains, and of Ravenglass granite from the Lake District which had been dispersed over the plains of Lancashire, Cheshire and Staffordshire: "and they lie in masses of some tons weight on the west of the towns of Macclesfield and Stafford, and between Dudley and Bridgnorth". (Buckland, 1823A: 199).

From Scotland, he gave examples of not only tills and erratics, but also extensive striations, all with a marked orientation, and quoted approvingly from Sir James Hall (1814):

> The whole of this paper is so very accurate and satisfactory, that I strongly recommend the perusal of it to the attention of every one who has the smallest doubts as to the evidence there is to prove that the surface of th earth owes its last form not to the gradual action of existing causes, but to the excavating force of a suddenly overwhelming and transient mass of waters. (Buckland, 1823A: 205).

Evidence of "diluvial action" in Wales and Ireland was also described, with in the former case references to striations, transported blocks and diluvial gravel, and in the case of Ireland, Richardson (1808) was extensively quoted for descriptions of large erratics, as well as what are now recognised as eskers and drumlins:

> The limestone field also abounds in rolled calcareous masses, pebbles, gravel, sand, and Marl, often raised into hillocks or long extended ridges, which seem to owe their form to the action of eddies and currents. There is scarcely any part of the extensive limestone tract in the centre of Ireland, that is not more or less marked by them. Sometimes these ridges appear like regular mounds, the work of art, forming a continuous line of several miles in extent: that which passes by Maryborough, in the Queen's County, is a remarkable instance of this kind; and a similar mound, hillocks, and ridges, also occur in the counties of Meath, Westmeath , Kildare and Carlow, and other portions of the limestone field, in which the calcareous gravel and sand frequently exhibit a stratified disposition, the alternate layers being very distinct from each other. (Buckland, 1823A: 209 - quoting William Richardson).

Buckland concluded the section on the evidence of "diluvian action" in the British Isles by two paragraphs that appear at first sight to be completely displaced, as though they were a typesetting error, since they refer to two English localities - Holderness, East Yorkshire, and by the side of the Great North Road in Northumberland. However, on closer examination the implication of Buckland's juxtaposition of these with the descriptions of Irish eskers becomes apparent, since Buckland is clearly making the point that he could see a direct parallel between the Irish "ridges" and those of Holderness, particularly the large elongated gravel ridges of Brandesburton, north-east of Beverley, and to the Northumberland "Bradford Kames" (see Chapter 5.2 below) respectively (Buckland, 1823A: 209-210).

Buckland concluded the main text by surveying foreign evidence of occurrences of diluvium and of "diluvial" phenomena including the transport of erratics, the deposition of loam (i.e. till) and gravel, and in particular their occurrence at high levels to which they could not have been transported by normal river or stream action, drawing on both a wide range of other authors who had written on various parts of Europe, North America, Africa and Asia, and on his own continental field observations. In this he disagreed with the great Cuvier, who had argued that the "diluvian" remains occurred only in lower altitudes and the large valleys of the world (Cuvier, 1812(1): 202). Buckland stressed the occurrences of large erratics at very high altitudes, including blocks of Mont Blanc granite transported from near the summit of the mountain to high levels in the Jura, and also pointed out that in general there was no basic difference in the form of denudation in high mountain areas such as the Alps or Carpathians (both of which Buckland had visited) compared with the form of valleys at a lower level. He also drew attention to the occurrence of mastodon bones at an altitude of 7,800 feet in South America, and of fossil bones of horses and deer at an elevation of 16,000 feet in the Himalaya:

> The occurrence of these bones at such an enormous elevation in the regions of eternal snow, and consequently in a spot now unfrequented by such animals as the horse and deer, can, I think, be explained only by supposing them to be of antediluvian origin, and that the carcases of the animals were drifted to their present place, and lodged in sand, by the diluvial waters. (Buckland, 1823A: 223).

The main text of the Reliquiae Diluvianae ended with a re-assertion of the nine "proofs" of the diluvial theory that had been offered as an Appendix to the Vindiciae Geologicae, and which have been summarised earlier in this Chapter. Two other parts of the book are also of special interest in terms of the history of Quaternary geology. Although all but three of the 27 quarto plates were devoted to fossil mammal finds, Buckland included as Plate 27 a hand-coloured map of the Cotswolds and Upper Thames Valley originally published in the Lickey Hill paper (Buckland, 1821D). In addition to mapping the "solid" geology, Buckland used hill-shading to demonstrate the topography, and mapped the erratic-bearing gravel deposits, all on a scale that is not stated, but which point to point comparisons show to be consistent at about 1:350,000, i.e. 5½ miles to the inch. This map is of considerable historic importance in Quaternary studies as one of the earliest (and possibly the first) published large-scale map of Quaternary deposits, and is reproduced (at a slightly reduced scale) as Fig. 9.

Also, although the chapter of Reliquiae Diluvianae on Kirkdale is mainly devoted to the Cave itself and the nature and origin of the fossil remains, the introduction to the chapter (reproduced, of course, from the Philosophical Transactions paper of the previous year), is of much wider interest in terms of Quaternary geology. In this, Buckland clearly recognises the significance of the Kirkham Gorge and the former existence of what Kendall (1902) was to name Lake Pickering within his classic "System of Glacier Lakes in the Cleveland Hills":

> the following rivers from the moorlands pass down southwards to the vale of Pickering, viz. the Rye, the Rical, the Hodge Beck, the Dove, the Seven Beck, and the Costa; their united streams fall into the Derwent above New Malton, and their only outlet is by a deep gorge, extending from near this town down to Kirkham, the stoppage of which would at once convert the whole vale of Pickering into an immense inland lake; and before the excavation of which, it is probable that such a lake existed, having its north border nearly along the edge of the belt of limestone just described, and at no great distance from the mouth of the cave at Kirkdale. (Buckland, 1823A: 3-4).

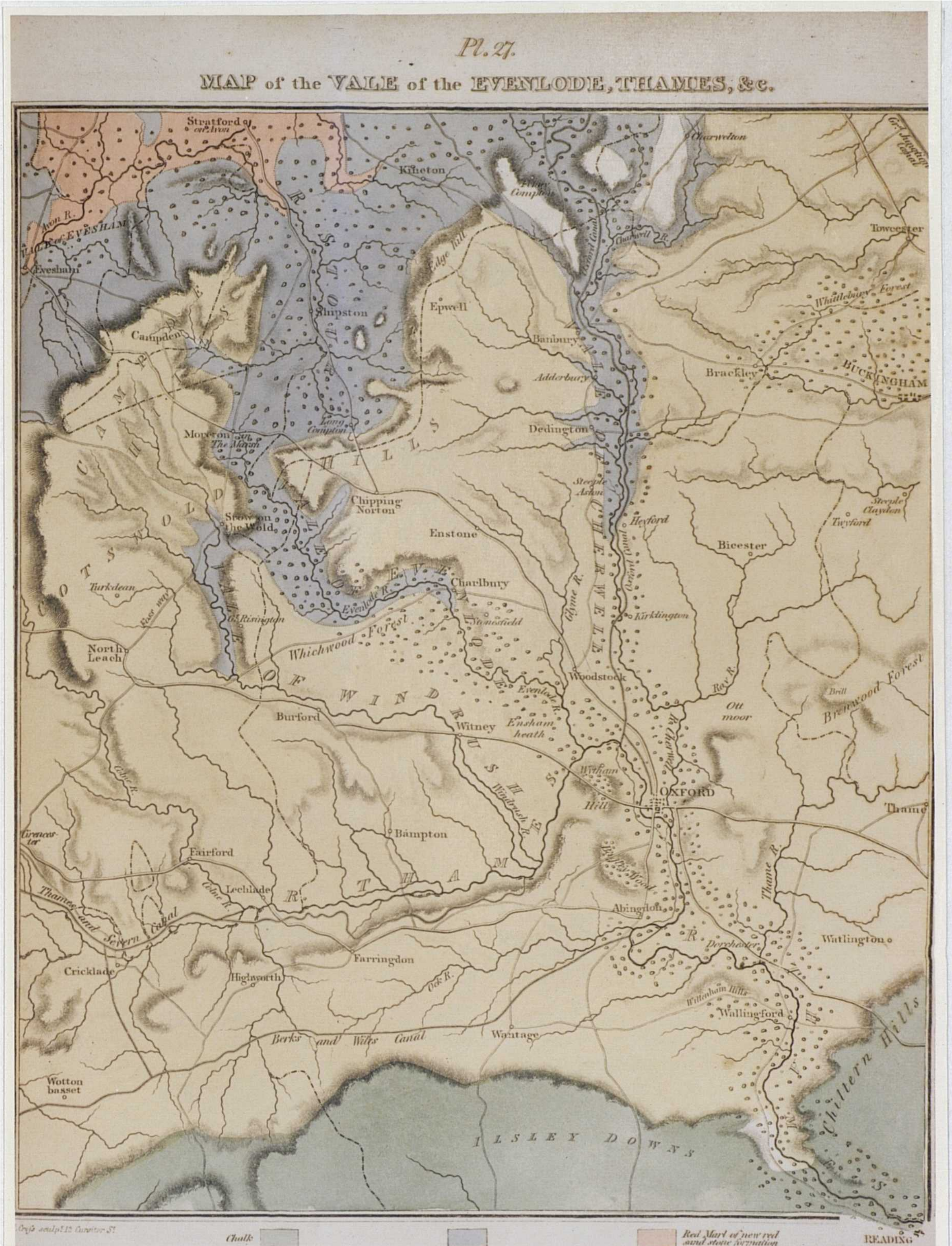

Fig. 9. Geological Map of the Evenlode Valley and Upper Thames, including "Drift" deposits, from Buckland's Reliquiae Diluvianae, 1823, Plate 27.

Despite the fact that Buckland was "wrong" in 1823 in terms of the geological mechanism by which he explained the diverse abnormal phenomena of the Quaternary of Britain and of other parts of the world, Reliquiae Diluvianae was a major landmark in the development of scientific perception of the Quaternary, and aroused very great interest at the time, as evidenced by the rapid sale of 2,000 copies in two editions (an extremely high number for such a work before the introduction of steam powered printing machinery in the 1830s halted and then reversed the spiralling cost of buying books), and by the large number of abstracts and reviews that appeared over the next two years or so in most parts of the scientific world. Indeed, despite Buckland's use of the diluvial theory to explain the many hundreds of anomalous observations, the Reliquiae remained a standard work well into the period of the glacial theory, and arguably was not superceded until, 51 years later, James Geikie published his The Great Ice Age (1874).

Although Buckland has often been portrayed in popular literature as little more than an eccentric religious bigot, unwilling to face scientific reality because of some kind of addiction to biblical literalism, nothing could be further from the truth. Although at the time of his Inaugural Lecture he had certainly equated the cause of the diluvial phenomena with the Mosaic Deluge, this view was no longer pressed four years later in the Reliquiae Diluvianae, and by the beginning of 1825 in his Geological Society paper "On the Formation of the Valley of Kingsclere and other Valleys by the Elevation of the Strata that enclosed them ..." (Buckland, 1825C & 1829A), he had identified, and understood, structurally-generated valleys in denuded anticlines. Although he did identify small occurrences of "genuine" diluvium in the area, it is clear from the paper (although not explicitly stated by Buckland), that the diluvial phenomena were far rarer south of the Thames Valley than they were from the line of the Thames northwards. Davies (1969: 251-252) has pointed out how the discovery that diluvial phenomena were more abundant in northern latitudes, and absent in middle and low latitudes seriously undermined the concept of a "universal deluge" during the 1820s and 1830s. Although Buckland sided with Conybeare first in the criticism of Lyell and Murchison (1829) in their paper "On the Excavation of Valleys", and in Conybeare's reply in the form of a paper on the Valley of the Thames (Conybeare, 1829) Buckland had by then abandoned the idea of a single Universal Deluge (whether that of Genesis or not). Instead, those who genuinely (and justifiably) found it impossible to reconcile Lyell's strict uniformitarian history of the world with the evidence that they saw in the superficial deposits, particularly of northern latitudes, moved towards the position of Elie de Beaumont (best developed in English in Beaumont, 1831), that there had been a number of catastrophic mountain-building episodes (which he termed "Revolutions"), each of which had, in Beaumont's view thrown up the floor of the ocean, displacing the waters in the form of giant tidal waves, which inundated and eroded the land. Lyell was clearly referring to Conybeare and Buckland's espousal of what Davies (1969: 252) has termed "neo-diluvialism" in the much-quoted comment of Lyell writing to Mantell about the reading of Conybeare's paper (quoted in full in Chapter 2.4 above) that:

> Conybeare's memoir is not strong by any means. He admits 3 deluges before the Noachian! & Buckland adds God knows how many catastrophes besides so we have driven them out of the Mosaic record fairly. (Wilson, 1972: 264).

Buckland still insisted that he was continuing to work on a revised edition of Reliquiae Diluvianae to which he would add a second full volume of new observations and discoveries (especially but not exclusively in the Quaternary mammal field), but seems to have made little progress on this. Instead, he moved into other areas, particularly following the identification of Ichthyosaur coprolites, although in the substantial paper on the Geology of Weymouth and adjacent areas read to the Geological Society in 1830 (Buckland & De la Beche, 1830 & 1845) diluvial terminology was retained, and even though the full text did not appear till 1835, they retained a neo-diluvialist position as advocated by Beaumont to explain the elevation of the land "by a tremendous catastrophe" after which the inundations excavated the valleys and spread the diluvial gravel, (Buckland & De la Beche, 1835: 46).

However, long before this time Buckland had followed Sedgwick and most other prominent members of the Geological Society in abandoning diluvialism. The final public recantation came in a footnote in the Bridgewater Treatise (eagerly seized on by the Quarterly Reviewer - thought to be Scrope). In the Bridgewater Treatise Buckland concluded his introductory survey of geology with the Tertiary, referring the reader to Reliquiae Diluvianae, but made it clear that the "catastrophe" responsible for the diluvial phenomena was no longer considered by him to be that of Genesis:

> The evidence which I have collected in my Reliquiae Diluvianae, 1823, shows, that one of the last great physical events that have affected the surface of our globe, was a violent inundation, which overwhelmed great part of the northern hemisphere, and that this event was followed by the sudden disappearance of a large number of the species of terrestrial quadrupeds, which had inhabited these regions in the period immediately preceded it. I also venture to apply the name Diluvium to the superficial beds

> of gravel, clay, and sand, which appear to have been produced by this great irruption of water. The description of the facts that form the evidence presented in this volume, is kept distinct from the question of the identity of the event tested by them, with any deluge recorded in history. Discoveries which have been made, since the publication of this work, show that many of the animals therein described, existed during more than one geological period preceding the catastrophe by which they were extirpated. Hence it seems more probable, that the event in question, was the last of the many geological revolutions that have been produced by violent irruptions of water, rather than the comparatively tranquil inundation described in the Inspired Narrative. (Buckland, 1836B: 94-95).

Even though his views had, like those of most if not all of his closest associates, been greatly modified compared with the confident diluvialism of the early 1820s, Buckland knew that the abundant evidence of some abnormal force that he had been observing and recording, particularly in the north, for more than a quarter of a century, could not be explained away by Lyell's new fluvialism.

5.2 THE GLACIAL THEORY*

Recognition of the geological power of glaciers and glacial ice, particularly as an agent of both erosion and geological transport, was by no means uncommon in the 18th and early 19th centuries (Davies, 1969, and Jopling, 1975). Prominent early advocates included Desmarest, Jean André de Luc and de Saussure on the Continent, whilst in Britain Hutton argued that the Alpine glaciers had been far more extensive prior to denudation (Hutton, 1795, 2: 218), and later recognised the "extremely powerful" erosional force of glacier ice despite its exceedingly slow speed of movement (Hutton, 1795, 2: 296). This view was taken up in the Illustrations of the Huttonian Theory of the Earth of John Playfair (1802), who subsequently concluded that only glacial transport could account for the present location of a rock of granite estimated to weigh 2,520 tons, that he saw near Neuchâtel, many miles from the outcrop from which it was derived, (Playfair, 1822: xxix). Many geologists followed Playfair to this enormous erratic during the following decades, including William and Mary Buckland in 1838, and J D Forbes, who recorded in his Journal for 12 September 1841:

> I walked with Agassiz and Desor to the "Pierre à Bot", which exceeded my expectations. It is a boulder 50 feet long, the largest in the Jura, composed of granite which Von Buch recognises as that of the Val de Bagnes.... That these blocks were transported by torrents seems incredible. They must have been broken into a thousand pieces! .... How came they thus to alight on the steep [sic], and there remain? What force transported them, and, when transported, lodged them high and dry 500 feet above the plain? We reply, a glacier might [sic] do this. What other inanimate agent could do it we know not. (Shairp et al, 1873: 271-272).

There are strong grounds for arguing that the true founder of a developed theory of an Ice Age was the Swiss scientist, Ignaz Venetz (1788 - 1859),

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* NOTE: An abstract and a much abridged version of this Chapter have been previously published - see Boylan, 1978, and 1981B respectively.

(see Balmer, 1970, and Escher, 1978), although there was in fact a long delay between the initial formulation of Venetz's glacial theory between 1821 and 1829, and its eventual publication (Venetz, 1833).

In Britain, the views of Esmark were far more influential through Jameson's publication in the December 1826 issue of the Edinburgh New Philosophical Journal of his "Remarks, tending to explain the Geological History of the Earth", (Esmark, 1826). As has been noted above (Chapter 3.2), in his 1840 Anniversary Address to the Geological Society, Buckland (1840A: 261) drew particular attention to Esmark's pioneering work on the glacial theory, although the Address dates the English translation to 1827 (either by mistake or because the Journal was in fact running late at that period). Although Esmark's views on the effects of glacier ice both as an eroding and a transporting force in the geological history of northern latitudes appear to have attracted little attention at the time, in his important study of the glacial geology of areas of the Scottish Highlands including Skye, James Forbes (1846: 99) recorded that as a student at Edinburgh in 1827, he had heard Jameson suggesting "the former presence of glaciers" as the possible explanation of occurrences of erratics in Scotland. Davies (1969: 268) has found documentary corroboration of this in the Jameson Papers, which include in a manuscript lecture syllabus: "Proofs of former glaciers in countries where they are no longer met with. Norway, Scotland, etc."

In the case of Buckland an important turning point seems to have been his work on the fossil mammal remains from the Alaskan coast brought back by Beechey in 1828, (see Chapter 4.1 above). In his contribution to the published report of Beechey's Voyage to the Pacific Buckland was still seeking a diluvialist explanation in geomorphological terms, but was convinced that drastic climatic change had also to be invoked in explaining the Eschscholtz Bay phenomena:

> this northern region of the earth seems to have undergone successive changes from heat to cold, so it is probable that the last of these changes was coincident with the extirpation of the mammoth. That this last change was sudden is shown by the preservation of the carcase in ice .... and the cause producing this change of climate may also have produced an inundation, sufficient to destroy and bury in its ruins the animals which then inhabited the surface of the earth. (Buckland, 1831: 612).

Perhaps because it is buried in an obscure publication, this passage seems to have been largely overlooked by those working on the origins of the glacial theory in Britain. However, the recognition of climatic fluctuations (as opposed to earlier theories of glacial phenomena caused by geological elevation prior to denudation) was a very important development indeed. Buckland was, of course, very familiar with the Edinburgh New Philosophical Journal, and it is quite likely that he knew of Esmark's views from the Journal paper (Esmark, 1826), or even before that since the December 1826 paper was in fact a translation of an address originally published in Norway in about 1824.

Beechey's book was published in 1831, and there is evidence to show that Buckland's contribution was the last part to be finished. In an incompletely dated letter relating to the contested election to the presidency of the Royal Society which, from its context, must have been written on Friday 26 November 1830, Buckland told Murchison:

> Moreover Capt. Beecheys book is waiting for my contribution to its Geological Departments which I must finish before applying an hour to any other matter that is not of urgent necessity. (M.S. DRO 138M/F257).

In other words it seems most likely that the crucial comment on climatic fluctuations was written in late November or early December 1830. If that is so, then it seems quite possible that Buckland was by that time familiar with the views of Venetz who had presented his arguments on 22 July 1829 to the Schweizerischen Naturforschenden Gesellschaft, although only a one paragraph summary was published in the Jahresversammlung. A füller text published four years later was quite explicit:

> Nous ne doutons nullement, qu'il ne soit survenu plusieurs époques, où notre climat étoit beaucoup plus froid qu'à présent; comme nous ne doutons pas non plus qu'il n'y en ait eu de celles, où il étoit considérablement plus chaud, et que la température s'élève et s'abaisse périodiquement. (Venetz, 1833: 35).

In fact the complete text of Venetz's 1829 paper was not published until shortly after his death, (Venetz, 1861), but his views were taken up by one of the most influential Swiss geologists of the day, Jean de Charpentier, who read an important paper on the glacial origin of erratics and tills to the Lucerne meeting of the Société Helvétique in July 1834, (Charpentier, 1836). In July 1837 the 30 year old Louis Agassiz assumed the presidential chair of the Société Helvétique and to the surprise and consternation of its members gave his presidential Discours not on his studies of fossil fish and echinoderms, with which he had established his reputation, and in which field he had already published 21 significant papers, but on the glacial theory of Venetz and de Charpentier. Although written in a single night immediately before the opening of the annual meeting of the Société Helvétique in his new museum building at Neuchâtel, the "Discours de Neuchâtel" showed no sign of its hurried origin. Instead, after a few words of formal welcome, Agassiz proceeded to draw together all of the evidence of a former glaciation of the Alpine region in the recent geological past as an integrated hypothesis, drawing on the phenomena of present-day glaciers, occurrences of moraines in relation to both existing and conjectured former glaciers, the transport of erratic blocks and stones, and an examination of the climatic fluctuations needed to produce glaciations.

The Société (or perhaps Agassiz) appears to have distributed the proceedings of the Neuchatel meeting, including Agassiz's Discours, in pamphlet form in advance of the publication of the Actes, (Agassiz, 1837A), (a copy in this form survives in the Tracts series in the Library of the Geological Society of London, for example), and the Discours was published at the end of 1837 in Geneva under the title "Des Glaciers, des Moraines, et des Blocs erratiques" (Agassiz, 1837B). However, there seems little doubt that it was through Jameson's widely distributed and internationally respected Edinburgh New Philosophical Journal that Agassiz's views first became widely known outside of Switzerland or his immediate circle of correspondents, first with a short note "On the Erratic Blocks of the Jura" published in January 1838 (Agassiz, 1838A), which was followed in the next quarterly issue (April 1838) by a verbatim translation of the Discours de Neuchatel itself, (Agassiz, 1838B). Gordon Davies (1969: 268-270) has demonstrated the importance of Jameson in disseminating information about the increasingly forceful arguments in favour of the glacial theory, with five key studies appearing in English translation in the Edinburgh New Philosophical Journal between October 1836 and October 1839, and through these translations the views of de Charpentier and Agassiz must have been far more widely known than has generally been supposed by historians of science.

The publication by Jameson of two separate papers by Agassiz in the first two quarterly parts of 1838 is at first sight puzzling, since both post-dated the Société Helvétique meeting of the previous July. However, a careful study and comparison of the texts of the two papers has convinced me that the paper "On the Erratic Blocks of the Jura" published in the January 1838 Journal (Agassiz, 1838A), clearly pre-dates the Discours de Neuchatel read to the Société Helvétique on 24 July 1837. The opening reference to "Last year" (Agassiz, 1838A: 176) in relation to his several months' work in the Alps studying glaciers and testing the views of Venetz and de Charpentier must refer to 1836, not 1837, since the paper would have had to be in Jameson's hands by December 1837, if it was to be proofed and published in January 1838. (Agassiz, of course, had every reason to expect a sympathetic hearing from Jameson, because of his publication of de Charpentier, and in addition Jameson could offer very rapid publication for urgent or innovatory publications, in a journal that had a very wide circulation in terms of both scientific discipline and geographical distribution.) The Discours de Neuchatel follows on logically from the Jura erratics paper in both chronological and philosophical terms and took the glacial theory far beyond the somewhat tentative, although very important, speculations of Venetz and de Charpentier.

The young Agassiz was seen in Britain as very much a protégé of Buckland, who had arranged many introductions for Agassiz to study fossil fish collections, and had frequently accompanied Agassiz on his travels in Britain. Also, Buckland had persuaded the British Association to provide very substantial funds to enable Agassiz to continue and extend his work on British fossil fish collections, and these funds were renewable on an annual basis. It is not clear exactly how and when

Buckland learned of Agassiz's sudden diversion into the highly contentious field of the glacial theory, but the publication of the paper on Jura erratics in the January 1838 Edinburgh New Philosophical Journal must be a terminal date for this, and it seems most likely that he would have heard from Agassiz himself earlier than this. Despite Buckland's own speculation about climatic change in his contribution to Beechey's report seven years or so earlier, Buckland seems to have been very alarmed about the implications for Agassiz's reputation of his espousal of such a heterodox theory. Consequently, he determined to travel to Switzerland as soon as he was free to do so to convince Agassiz that he was wrong. Because of teaching and other commitments the opportunity did not arise until September 1838 following the Freiburg meeting of the Deutscher Naturforscher Geselleschaft, which William and Mary Buckland attended along with a number of other representatives of the British Association. Agassiz was also present at Freiburg, and the Bucklands travelled with him up the Rhine Valley and to Neuchatel where they stayed for several weeks with Agassiz. Sometime between an extensive tour of present-day glaciers during August 1838 and the Bucklands' arrival, Agassiz had written to Buckland:

> Since I saw the glaciers I am quite of a snowy humor, and will have the whole surface of the earth covered with ice, and the whole prior creation dead by cold. In fact, I am quite satisfied that ice must be taken in every complete explanation of the last changes which occurred at the surface of Europe. (Agassiz, 1885: 289).

In reply Buckland wrote:

> I am sorry that I cannot entirely adopt the new theory you advocate to explain transported blocks by moraines; for supposing it adequate to explain the phenomena of Switzerland, it would not apply to the granite blocks and transported gravel of England, which I can only explain by referring to currents of water. (Agassiz, 1885: 290).

Soon after their arrival at Neuchatel, the Bucklands set off on a tour of what Agassiz considered to be the key localities for an understanding of the glacial theory in terms of both erosional features such as striation and grooving, and depositional features such as moraines, and transported blocks. In opening his Geological Society on 4 November 1840 Buckland began by referring to this visit in the first paragraph:

> Dr. Buckland's attention was first directed by Prof. Agassiz in October 1838 to the phaenomena of polished, striated, and furrowed surfaces on the south-east slope of the Jura, near Neuchatel, as well as to the transport of the erratic blocks on the Jura, as the effects of ice; but it was not until he had devoted some days to the examination of actual glaciers in the Alps, that he acquiesced in the correctness of Prof. Agassiz's theory relative to Switzerland. On his return to Neuchatel from the glaciers of Rosenlaui and Grindelwald, he informed M. Agassiz that he had noticed in Scotland and England phaenomena similar to those he had just examined, but which he had attributed to diluvial action: thus in 1811 he had observed on the head rocks on the left side of the gorge of the Tay, near Dunkeld, rounded and polished surfaces; and in 1824, in company with Mr Lyell, grooves and striae on granite rocks near the east base of Ben Nevis. About the same time Sir George Mackenzie pointed out to the author in a valley near the base of Ben Wyvis, a high ridge of gravel laid obliquely across, in a manner inexplicable by any action of water, but which, after his examination of the effects of glaciers in Switzerland, he recognises the form and condition of a moraine. (Buckland, 1841A: 332-333).

Confirmation of Buckland's continued scepticism about the glacial theory during the early part of the tour, prior to his detailed examination of contemporary glaciers, is found in a letter that Mary Buckland wrote from Interlaken to Agassiz just before travelling to Grindelwald:

> We have made a good tour of the Oberland and have seen glaciers, etc., but Dr. Buckland is as far as ever from agreeing with you. (Agassiz, 1885: 290).

Nevertheless, by the time that they returned to Neuchatel Buckland was totally convinced that not only had the existing Alpine glaciers extended far beyond their present limits in the recent geological past, but also that in the developed Glacial Theory of Agassiz Buckland at last had an entirely convincing mechanism to explain much if not all of the British Quaternary phenomena that he had been trying to explain for well over 20 years. Equally, however, he must have realised that there would be a major problem in persuading the majority of English geologists (especially those most closely associated with the Geological Society) of the validity of the glacial theory. Whilst Jameson and his circle might well be receptive, to the dominant strict uniformitarian view of the Geological Society, the glacial theory, especially if introduced to the Society by Buckland, of all people, was almost bound to be seen as yet another attempt to revive Catastrophism.

In addition to confiding in Agassiz, there is some evidence to suggest that during this Swiss visit Buckland may also have consulted Jean André De Luc while passing through Geneva since De Luc wrote several letters to Buckland over the next 2½-3 years which clearly appear to be attempts to steer Buckland away from the Glacial Theory (for example in a letter dated Geneva, 23 November 1839 about the distribution of erratics and transported blocks - M.S. DRO 138M/F208). However, Buckland seems to have said nothing about his views to anyone in Britain, but instead began to plan carefully the way in which the glacial theory could be presented to English geology.

His first opportunity seems to have been the obituary notice on Esmark at the February 1840 Anniversary Meeting of the Geological Society, with its warm praise of Esmark and his views, already mentioned above. Because of pressures of work on the Continent Agassiz was unable to visit Britain to continue with work on British fossil fish collections during 1839, but instead worked on specimens sent to Neuchatel and on the exquisite and highly accurate watercolour drawings being prepared for him largely at the expense of the British Association, by the artist Joseph Dinkel. In addition, Agassiz was working on his major monograph Etudes sur les Glaciers, comprising an historical survey of work on glaciers and their present-day features, as well as his recent work on both present-day glaciers and the glacial theory, all accompanied by thirty-two large plates, (Agassiz, 1840). He had also determined to establish a permanent glacier observatory beside the lower Aar Glacier, under a huge, stable, boulder on the median moraine, which was quickly dubbed the "Hôtel des Neuchâtelois" by the local guides, and from which detailed investigations of ice temperatures and movements could be made on a long-term basis, (Agassiz, 1885: 298-306).

However, once the observatory was fully established, towards the end of the summer of 1840, Agassiz at last felt free to accept Buckland's invitation to travel to Britain both to present his glacial theory to first the British Association and then the Geological Society, and also to seek out with Buckland evidence for a former glaciation of northern Britain, looking in particular at the features that Buckland had ascribed to a glacial origin at the end of his autumn 1838 visit to Switzerland.

Buckland clearly planned the whole operation most carefully. Whether or not the Esmark obituary was an integral part of this plan is not clear, but what is certain is that at Buckland's invitation and urging Agassiz sent to the Geological Society (of which Buckland was, of course, still President) a paper "On the polished and striated surfaces of the rocks which form the beds of glaciers in the Alps", which was read to the Society at its last meeting of the summer 1840 session, on 10 June, (Agassiz, 1841A). It seems likely that the incomplete and untrimmed set of plates for the Etudes sur les Glaciers in the Geological Society's Library, which are bound with Sir James Hall's lithographs of striations in Edinburgh (dating from 1824), were sent to the Society by Agassiz in support of the 10 June 1840 paper, although there does not seem to be any direct evidence on this point. The reading of Agassiz's paper does not seem to have attracted much interest or controversy within the Society at the time. His views were, of course, already familiar to most if not all members of the Society through the Edinburgh New Philosphical Journal papers previously published. The general view of most of the key figures within the Society was that Lyell had satisfactorily explained the phenomena described by Venetz, de Charpentier and Agassiz in his claimed identification of a Pleistocene marine submergence in which the transport of erratics, occurrences of arctic shells in temperate latitudes, and even grooving and striation of rocks, were all attributed to the action of icebergs. Indeed, in his key paper presenting this synthesis: "On the Boulder Formation or drift and associated freshwater deposits composing the mud cliffs of eastern Norfolk" (Lyell, 1840), he was so confident of the iceberg drift theory that he proposed the use of the term "drift" to cover all Pleistocene tills, sands, gravels and other deposits, in place of the previous usage of "diluvium", and in fact this usage persists in the Geological Survey even today with the distinction between "solid" and "drift" maps, even though Lyell's drift theory was discredited and abandoned more than a century ago.

Buckland and Agassiz agreed to meet in Glasgow in September 1840 for the meeting of the British Association. (Buckland was Vice-President of Section C, Geology, that year.)

William and Mary Buckland appear to have left Oxford by the west coast route to Scotland sometime in early September 1840, travelling via Cheshire, Lancaster, Kendal and Penrith to Carlisle. Although Buckland did not explicitly claim to have identified glacial phenomena in these areas while travelling northwards towards Glasgow, it could very well be that at least some of the observations of glacial evidence in Lancashire, Westmorland and Cumberland included in Buckland's Geological Society paper the following November - December (Buckland, 1841A) were first made on the journey northwards to Glasgow. (See Appendix 3 and the locality map, Fig. 10 , for full details.)

What is quite certain is that after leaving Carlisle the Bucklands travelled through Dumfries and then northwards through the Lowther Hills, where the valley just above Crichope (or Crickhope) Linn near Thornhill, Dumfriesshire, was explored in some detail. Here a small-scale ridge about 900m long and never more than 5m high was found, and by analogy with similar features that he had seen in Switzerland, Buckland interpreted this as a small lateral moraine relating to a large glacier that had filled the Thornhill valley. The area is not a very mountainous part of Scotland - indeed, the high mountains of the Scottish Highlands are almost 200 km to the north, and the recognition of evidence of glaciation in such a locality within the Southern Uplands would have been very significant regardless of the timing of the discovery. The exact date of the Bucklands' visit to the Crichope Linn locality is not known, but it certainly must have been at least two or three days before the official opening of the British Association meeting in Glasgow on 18 September, since the Bucklands were certainly present in time for the start of the

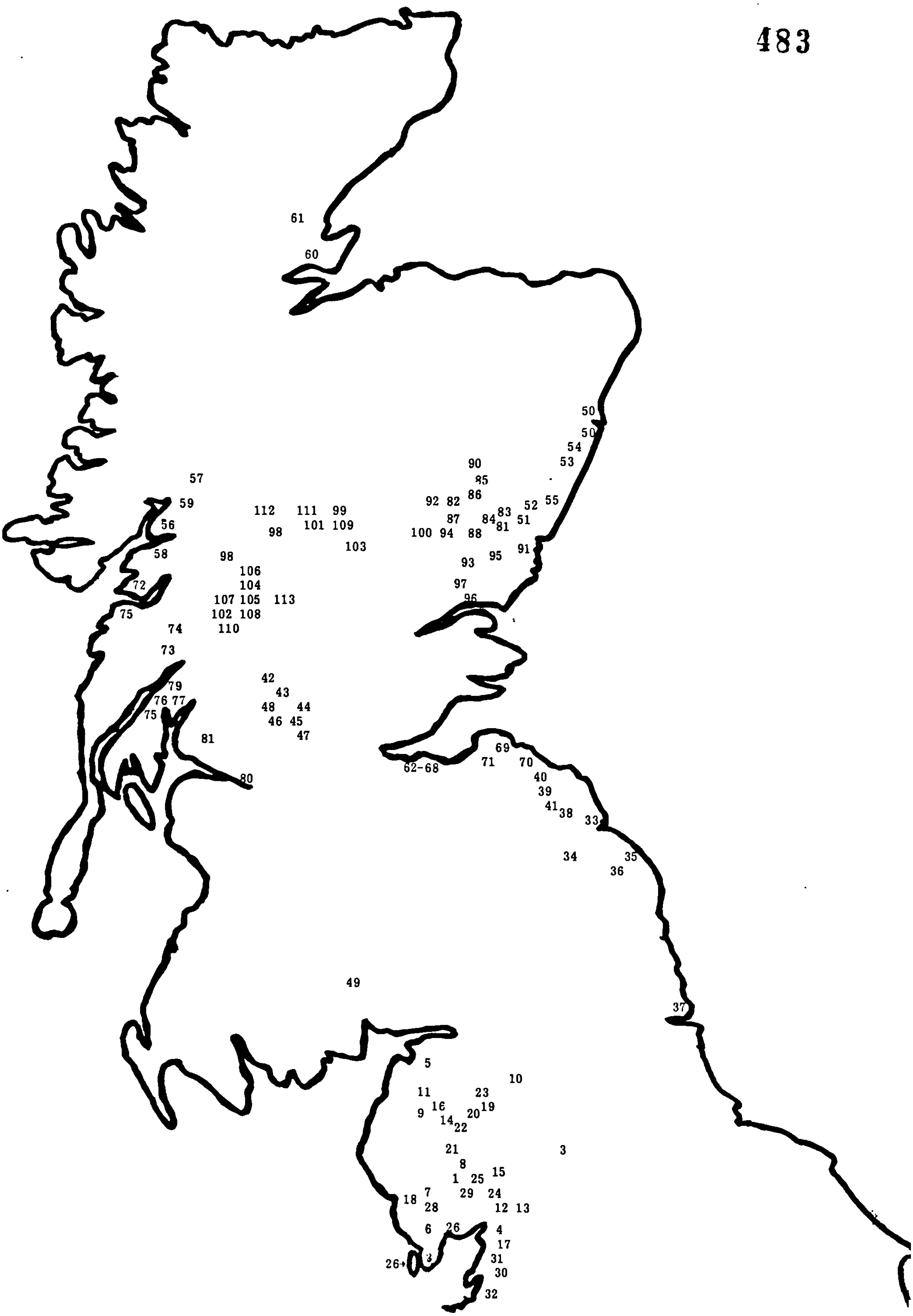

FIG.10. DISTRIBUTION MAP OF GLACIAL LOCALITIES, SEPT. - OCT. 1840 (SEE APPENDIX 3)

meeting. In contrast with this, Agassiz was definitely not present for the opening of the meeting, but in fact appears to have arrived on about the 20th of September (and immediately recognised evidence of glaciation at the building site of Bell's Park in the City Centre - see below). Consequently, the Crichope Linn moraine, identified by Buckland, probably ranks as the first glacial locality to be fully recognised and understood in Britain, pre-dating by several days (probably a week or more) the discoveries of Agassiz in central Glasgow.

The Crichope Linn feature (Appendix 3, Locality no. 49) is easily found and is still remarkably little changed from Buckland's description of 1840: the moraine is intersected by a small road, and the unstratified gravelly till core of the moraine can still be seen in natural sections.

With the arrival of Agassiz in Glasgow, Buckland must have told him of the many observations that he had made, including the Crichope Linn moraine, and together they saw extensive evidence of glacial tills and striated erratics in central Glasgow, particularly on the site of the large-scale Bell's Park development, a few hundred metres to the north-west of the Cathedral area (and which has recently been re-developed for a second time, in part for extensions to the Strathclyde University campus - see Appendix 3, Locality no. 80). As Charles Maclaren reported in The Scotsman on 7 October 1840, Agassiz said that he "had scarcely arrived in Glasgow, when I found remote traces of the action of glaciers", and Agassiz himself wrote in his very long and comprehensive paper "The Glacial Theory and its recent Progress" in the Edinburgh New Philosophical Journal for October 1842:

> far from being found lying at the surface of the ground, the large blocks are for the most part heaped up in a confused manner along with the smaller ones of all degrees of size, from the dimension of the smallest pebbles to the colossal volume of the largest erratic blocks, in a deposit of clay unequally distributed over all the lower portions of the country. This deposit of clay, which is of very unequal thickness, and exhibits no trace of stratification, is what is termed till in Scotland. There is no locality in which I have been able to study the till more completely than at Glasgow, where the numerous works carried on in 1840 for the embellishment of the town had exposed it at many points; but every where it presents the same characters; the rounded, polished, and scratched blocks of very various dimensions, are every where indiscriminately mixed together in a marly or clayey paste. It is evident that it was with this mass, and in this mass, that the rounded and polished blocks have been transported during the whole journey which they have performed together, while the angular blocks have certainly not been rubbed in this manner. (Agassiz, 1842: 228).

On 22 September Agassiz read a substantial paper "On Glaciers and Boulders in Switzerland" to Section C (Geology and Physical Geography). The paper was delivered in French, although a shorter abstract was available in English, and was published in the Report and Transactions the following year, (Agassiz, 1841C). Although not included in the official English text, Agassiz expressed the view that glaciers had spread over Scotland, and told the meeting that he intended to tour the Highlands looking for evidence of glaciers, particularly around Ben Nevis, (Davies, 1968: 134; Anon, 1840).

Immediately after the end of the British Association meeting, Agassiz, accompanied by the Bücklands, set out northwards via Loch Lomond into the Western Highlands. Buckland appears to have had a two-fold role in this famous journey, which has been reconstructed in detail by Gordon Davies (1968). First, there seems no doubt at all that Buckland acted as a very active guide during Agassiz's tour, and steered him to many localities, long familiar to Buckland, some of which had been puzzling him for 29 years, since his first tour of the Highlands in 1811. (In drawing attention to this aspect of Buckland's role in Agassiz's Highland tour of late September-early October 1840, I am not, of course, in any way wishing to denigrate or diminish the undoubted priority of Agassiz, unreservedly granted by Buckland himself, in "ruling" on the glacial or non-glacial origin of the features pointed out by Buckland.) Second, at a purely practical level Buckland's seemingly inexhaustible series of contacts throughout almost every part of Great Britain was put to good use in finding suitable accommodation and transport for the trio. For example, even though both the Duke of Argyll and his son Lord George Douglas Campbell were away, there was no difficulty about Agassiz and the Bucklands staying at Inveraray Castle, and it was as the party came into sight of Inveraray that Agassiz first identified without reservation a terminal moraine, (Appendix 3, Locality no. 79 - Strachur).

From Inveraray northwards Agassiz found abundant evidence of glaciation, including morainic features in Glen Aray (including one at Inveraray itself on which the Castle is built), in the valley of Loch Awe, through the Pass of Brander, and in Glen Etive. After crossing Loch Etive by the Bonawe ferry, they followed the coastal road around Lochs Creran and Linnhe to Loch Leven at Ballachulish, noting abundant evidence of striation, grooving, glacial polish, and down-valley transport of erratics in each of the valleys.

One of the Scottish localities that Buckland had told Agassiz about in advance of the Highland tour was the area around Ben Nevis, where as early as 1824 Buckland, accompanied by Lyell, had examined grooves and striations on granite outcrops (Buckland, 1841A: 332), and Agassiz had told the British Association meeting that it was in the Nevis area that he expected to find the best evidence of glaciers in Great Britain. Consequently, the group must have approached Fort William with some anticipation, and probably excitement, and immediately found their expectations fulfilled, with the discovery of abundant evidence of glacial erosion, transport and deposition on all sides of Ben Nevis, (see Appendix 3, Locality nos. 56 and 59 in particular). In her biography, Elizabeth Gordon (1894: 141) quoted from a letter written by Buckland from Fort William to Professor John Fleming at Aberdeen University referring to the discovery of glacial evidence around Ben Nevis. Quite recently the original of this letter was discovered by George White when he purchased a copy of a biographical memoir of Fleming, and was published in both facsimile and transcript by him, (White, 1970). The original letter shows that the much-quoted statement of Buckland: "We have found abundant Traces of Glaciers round Ben Nevis" was written from Connel House on 4 October 1840.

While in the Fort William area, Agassiz and Buckland paid particular attention to Glen Spean and Glen Roy, since the "parallel roads" of Lochaber were one of the best-known physiographic features of the whole of the Highlands, and had been a cause of much speculation from the mid-18th century onwards. Only a year earlier Charles Darwin had claimed to have resolved, at last, the origin of these well-known features in a substantial Royal Society paper "Observations on the Parallel Roads of Glen Roy, and of other parts of Lochaber in Scotland, with an attempt to prove that they are of marine origin" (Darwin, 1839). In this paper (which he later regarded as the biggest scientific mistake of his life), Darwin interpreted the "parallel roads" as a series of high-level marine shorelines, that had occurred during the fall in sea level from the deep marine submergence of recent times, currently postulated by the

Uniformitarians. Darwin's views were quickly taken up as valuable additional proof of the marine submergence with icebergs hypothesis argued so eloquently by Lyell (1840). Consequently, Glen Roy was seen as a test case of Agassiz's answer to the marine submergence theory. After spending some time in the Spean valley and Glen Roy itself, Agassiz accepted that the "parallel roads" were indeed short-lived shorelines, but rejected the argument that they were of marine origin. Instead he demonstrated that if the lower part of the Spean valley was filled with glacial ice the natural drainage down Glen Roy would lead to the formation of a large proglacial lake within which shorelines would have formed at different levels during the various stages of de-glaciation. Consequently, there was no need to postulate a marine submergence to explain the phenomena of Glen Roy. (In any case, there are below the levels of the "parallel roads" many characteristic features of glacial origin - see Appendix 3, Locality no. 57: by a curious coincidence sections in the laminated sediment of the proglacial lake of Glen Roy are amongst the few deposits in Britain in which there is good evidence of dropstones melted out of floating ice in the manner demanded by the glacial submergence hypothesis.)

After a brief stay with Lady Gordon Cumming in Moray, studying this time fossil fish (Andrews, 1982: 28), Agassiz and the Bucklands continued south-eastwards to Aberdeen (seeing further evidence of glaciation on the way), where they parted company, probably on about 8 October, since they were with Lady Gordon Cumming until 6 or 7 October, and by 10 October Agassiz had travelled all the way from Aberdeen to Stranraer, since he crossed to Ireland on about 10 October (Davies, 1968: 140). In the meantime, on 7 October, Charles Maclaren, a noted Scottish geologist and editor of The Scotsman, had published in the issue of

7 October a letter from Agassiz to Jameson in which he referred to discoveries of moraines and polished rock surfaces:

> ... so that the existence of glaciers in Scotland at early periods can no longer be doubted.. The parallel roads of Glen Roy are intimately connected with this former occurrence of glaciers, and must have been caused by a glacier from Ben Nevis. The phenomenon must have been precisely analogous to the glacier-lakes of the Tyrol, and to the event that took place in the valley of Bagne. (Quoted by Gordon, 1894: 138).

Buckland seems to have followed his own precepts, explained to his Oxford students and recorded by Jackson in his notebook of 1832, of getting "the three best men" in support of any new idea, and turned immediately to Charles Lyell. Quite apart from the general reputation of his most successful former student, Buckland must have recognised that Lyell was seen by the geological community, particularly that of the Geological Society, as being one of the principal architects of the currently fashionable marine submergence hypothesis, and that Lyell was using this forcibly to answer the increasingly confident claims of Agassiz in support of the glacial theory. Since Lyell was known to be staying at his family home at Kinnordy House, just north of Kirriemuir, Forfarshire, the Bucklands appear to have travelled direct from Aberdeen to Kinnordy to see Lyell. On the way, they again travelled over abundant evidence of glaciation along the edges of the Grampians - see Appendix 3, Locality no. 50-55, and 83. (Incidentally, these were the first localities to be reported on by Buckland independently of Agassiz since the visit to the Crichope Linn moraine before the British Association meeting.) As the Bucklands finally entered the Lyell estates on the approach to Kinnordy, Buckland recognised that the House and its adjacent Loch were themselves on glacial deposits, and even better evidence was found in the surrounding country-side, including the valleys of Glen Clova and Glen Prosen, and along the whole length of more than 40 miles of the northern slopes of the Tay valley down to the sea. Even the succession of "marl-lochs", which had been the subject of Lyell's first research paper, read to the Geological Society in 1824, (Lyell, 1829), were shown to be ultimately the result of glacial deposition. Lyell's response was generous and enthusiastic, as Buckland was able to explain in a letter to Agassiz dated 15 October 1840:

> Lyell has adopted your theory in toto!!! [sic] On my showing him a beautiful cluster of moraines within two miles of his father's house, he instantly accepted it, as solving a host of difficulties that have all his life embarrassed him. (Agassiz, 1885: 309).

Following a few days in the field with Buckland, Lyell agreed to summarise the glacial phenomena of Forfarshire on a map of the county, and further accepted a proposal from Buckland that he should describe the glacial features of the area in a paper to the Geological Society, which was to be presented at the same time as contributions from Agassiz and Buckland, all to be presented to the Society at the beginning of its winter session in November 1840. In confirmation of this agreement, Buckland wrote on 12 October to the Secretary of the Geological Society, Lonsdale, saying:

> Lyell will have a very long and elaborate paper on the moraínes of Forfarshire after Agassiz and me. He is a complete convert. (M.S. GSL LR6/32).

In fact, when the papers were given Buckland included a number of references to the Forfarshire localities examined with Lyell in his own paper, in addition to the examples given by Lyell in his contribution. One particularly interesting and important locality is that of Cortachy (Appendix 3, Locality no. 82). In this case, Buckland suggested that an extensive series of sand and gravel kames and a massive ridge of gravel lying between the Carity valley and the Prosen river had been "produced by glaciers, and modified in part subsequently by water", (Buckland, 1841A: 333). In this, Buckland seems to have been closer to a full recognition of their fluvioglacial origin than was Lyell (1841: 339) who appears to have regarded them as lateral moraines of glaciers. The Bucklands must have left Kinnordy no later than 11 October, since the 12 October letter to Lonsdale referred to above was sent from Blair Athol. In the same way that Gordon Davies (1968) reconstructed the route followed by Agassiz after the British Association meeting at Glasgow, using the small number of surviving letters and other manuscript references, together with the evidence of localities visited and described, I have been able to reconstruct with a fair degree of confidence the movements of the Bucklands following their visit to Lyell at Kinnordy. They travelled first along northern Tayside over the enormous areas of thick fluvioglacial gravels and sands to Blairgowrie and then looked at the succession of small lochs on the floor of the upper part of the valley of the Lunan Burn, where Buckland recognised the transverse barriers forming the lakes as "moraines" (in the continental sense of the time, i.e. moulded glacial deposits, not necessarily terminal or lateral moraines in the narrow sense). Continuing westwards along the Tay valley, Buckland noted extensive glacial deposits around Dunkeld, and then turned northwards, clearly seeking out the striations that he had first noticed in 1811. Although these particular ones were no longer visible, he found abundant evidence of glacial erosion when he turned westwards again along Glen Tummel, including "mammillated", polished and striated rocks at the Linn of Tummel, and by the side of Loch Tummel itself (Appendix 3, Locality nos. 101 and 109). Continuing up Glen Tummel to the foot of Schiehallion (Locality no. 112), Buckland evidently turned southwards to Taymouth Castle (Locality no. 113), where the Bucklands joined a house party being offered by its owner, the Marquess of

Breadalbane (who had been President of the Glasgow meeting of the British Association) in honour of some of the most distinguished scientists who had attended the Glasgow meeting. After a short stay at Taymouth, the Bucklands continued southwards, again seeing and noting much evidence of recent glaciation right down to the floor of the Tay valley at Crieff (Locality no. 108) and Comrie (Locality no. 102). At Comrie Buckland carried out a bold experiment, reminiscent of the brilliant inductive study that he had made of the fossil bone deposit of Kirkdale Cave 19 years earlier. As he explained in his Geological Society paper in November 1840, before going to the area around Comrie, he had:

> tested the value of the glacial theory by marking in anticipation on a map the localities where there ought to be evidences [sic] of glaciers having existed, if the theory was founded on correct principles. The results coincided with the anticipations. (Buckland, 1841A: 335).

Most regrettably, the field map itself does not appear to have survived, but all 13 localities in this area alone at which Buckland had identified glacial *activities of all kinds, entirely in accordance with his expectations,* can be identified on the ground today, thanks to the excellent standard of his observation and published description. These include rounded and striated rock surfaces and roches moutonnées near Lawers Farm, Comrie (Locality no. 102), Funtullich (no. 107), and near the Falls of Turret (no. 108), and "moraines" (including kames, kame terraces and hummocky moraine) in Glen Turret (no. 108), Glen Lednock (no. 107).

With his confidence in his understanding of glacial phenomena further reinforced in this way, Buckland continued southwards again through the Trossachs, and thence to Sterling, making further extensive observations on the way, before continuing to Edinburgh, in time for a planned reunion with Agassiz there on 20 October (after Agassiz's brief but rewarding visit to Ireland - Davies, 1968: 141-142). Other leading figures expected to meet together in Edinburgh at that time included Robert Jameson, Edward Forbes, Charles Maclaren and T S Traill, all of whom were, of course, from Edinburgh, together with Murchison and his wife. In fact, Agassiz appears to have extended his stay in Ireland by several days, probably because of his discovery of extensive evidence of glaciation in Ireland, (Agassiz, 1841B; Davies, 1968: 141-142), and did not arrive in Edinburgh until 24 October.

It seems clear that whilst the original publications of Venetz, de Charpentier and Agassiz, and even the Geological Society paper of the previous June, had raised very little interest or even comment in Britain, the confident claim of Agassiz at the British Association meeting in Glasgow, followed by a considerable number of both written and verbal communications from Agassiz and Buckland in the course of their tour of the Highlands, had aroused very great interest by the time the Bucklands arrived in Edinburgh. (Buckland's stay with the Marquess of Breadalbane at Taymouth Castle must have been of some importance in spreading the news of the discoveries made in the Highlands and of Agassiz's interpretation of these features, since, as mentioned above, a number of the most prominent Scottish and English scientists of several disciplines were in residence at Taymouth over a period of several weeks immediately after the Glasgow meeting, and the Murchisons were almost certainly there at the time of Buckland's visit, and had then preceded them to Edinburgh.) For the first three or four days, from about 20 September to about 23 September, Buckland seems to have held court on the glacial theory in Edinburgh without the support of Agassiz, and by all accounts once again let his sense of humour off the leash. "Scratchings" of all kinds had long been one of Buckland's favourite entertainments, as in his graphic description of the Megatherium. ("Old Scratch" was a common 19th century nickname for the Devil, and Buckland seems to have been only too happy to have his friends and students refer to himself light-heartedly as Old Scratch as well.) Certainly, Buckland appears to have made quite a pantomime of glacial "scratching" during his stay in Edinburgh, but when he identified (probably correctly) glacial striations, or in his words "scratchings", on the surface of bare volcanic rock on an unpaved area during the widening of the Royal Mile from Edinburgh Castle down to Holyrood, even his closest friends seem to have had difficulty in trying to decide whether Buckland was being serious or whether in fact the whole story was an elaborate practical joke.

Because of the continued absence of Agassiz, Buckland appears to have worked with Charles Maclaren in examining Edinburgh itself for evidence of glaciation, finding striations on Castle Rock (Appendix 3, Locality no. 66), and both appear to have visited what is now known as "Agassiz's Rock" on Blackford Hill (Locality no. 64) before the arrival of Agassiz himself, since the Bucklands seem to have left Edinburgh by 24 October, three days before Agassiz's well-documented visit to the locality on 27 October. Leaving Edinburgh, the Bucklands travelled by the Great North Road (now the A1) south-eastwards to Berwick on Tweed, noting evidence of glacial deposition along much of the line of the road (e.g. Locality nos. 69-71 and 33). Successful searches for evidence of glacial transport and deposition were also made over the eastern part of Northumberland, looking in particular at features such as the till of the coast (Locality no. 37), the Bradford Kames near North Charlton (Locality no. 35) that Buckland had first examined in 1821, and that was one of the first British localities that he re-assigned to glacial deposition in the course of his Swiss studies of 1838 (Buckland, 1841A: 346). In the same area he deviated from the Great North Road in order to search for evidence of glaciation on the eastern slopes of the Cheviots, and identified as glacial the spectacular area of drumlins and kames in the Wooler area (Locality no. 36). Of special interest is his description and interpretation of a small moraine in the valley of the College Burn on the north-east slopes of the main Cheviot summit near Kirknewton (Locality no. 34). Here Buckland recognised and described substantial contortions within the structure of the moraine, which he interpreted as the result of the deposits being:

> severed from their original position, moved forward, and contorted by the pressure of a glacier, which descended the deep trough of the College Burn from the northern summit of the Cheviots. (Buckland, 1841A: 346).

On 4 November Agassiz, Lyell and Buckland gathered together at the Geological Society in London, with Buckland in the Chair, to present their findings and interpretations to the Society. Agassiz spoke first, giving the whole of his paper "On Glaciers, and the evidence of their having once existed in Scotland, Ireland and England" (Agassiz, 1841B). In this he began by summarising his investigations in Switzerland and the adjacent areas of France and Germany, and made it clear that as a result of this work he had become:

> desirous of investigating a country in which glaciers no longer exist, but in which traces of them might be found. This opportunity he had recently enjoyed, by examining a considerable part of Scotland, the north of England, and the north, centre, west and south-west of Ireland; and he has arrived at the conclusion, that great masses of ice, and subsequently glaciers,

> existed in these portions of the United Kingdom at a period immediately preceding the present condition of the globe, founding his belief upon the characters of the superficial gravels and erratic blocks, and on the polished and striated appearance of the rocks in situ. (Agassiz, 1841B: 328).

He continued by outlining the main features by which glacial action could be recognised, using 17 specific localities in the British Isles, most of which were compared with parallel features in Switzerland. He admitted that he did "not suppose that his views respecting glaciers will at once meet with the general concurrence of geologists;" (Agassiz, 1841B: 328) but after surveying the evidence argued:

> that great sheets of ice, resembling those now existing in Greenland, once covered all the countries in which stratified gravel is found; that this gravel was in general produced by the trituration of the sheets of ice upon the subjacent surface; that moraines, as before stated, are the effects of the retreat of glaciers; that the angular blocks found on the surface of the rounded materials were left in the present position at the melting of the ice; and that the disappearance of great bodies of ice produced enormous debacles and considerable currents, by which masses of ice were set afloat, and conveyed in diverging directions, the blocks with which they were charged. He believed that the Norwegian blocks found on the coast of England had been correctly assigned by Mr. Lyell to a similar origin. (Agassiz, 1841B: 331).

In this last point Agassiz was clearly attempting to produce a synthesis that would satisfy all parties, by referring what were clearly high-energy water-lain deposits to meltwater torrents of near "Catastrophist" proportions, whilst admitting the possibility of iceberg transport of large blocks, as postulated by Lyell. Equally, however, Agassiz was quite confident that it was not necessary to invoke a deep marine submergence to explain the phenomena recently observed.

Buckland's contribution: "On the Evidences of Glaciers in Scotland and the North of England" (Buckland, 1841A), was much the most substantial and detailed of the three Geological Society contributions, citing over 90 localities and areas (some of them very extensive indeed, and which have therefore been subdivided in Appendix 3), at which evidence of glaciation could be observed. Because of the length of the paper, Buckland's contribution was read in two parts, spread over three successive fortnightly meetings of the Society. The first part, dealing with Scotland, was started on 4 November, after the completion of Agassiz's address, and was concluded on 18 November, with the second part of that evening being devoted to the first half of Lyell's contribution "On the Geological Evidence of the former existence of Glaciers in Forfarshire" (Lyell, 1841). Finally, on 2 December Lyell completed his paper, and Buckland then gave the second part of his contribution, dealing with large areas of northern England.

Buckland began his paper by stressing his initial reluctance to accept the glacial theory, and also the length of time that he had been aware of glacial phenomena, although without understanding the cause of them, (see quotation above). He then outlined the route that he had followed on his autumn travels, and continued with a description of the Crichope Linn locality already mentioned (Appendix 3, Locality no. 17). After this, localities in Aberdeenshire, Forfarshire and Tayside were all very briefly referred to, before proceeding to refer in more detail to "Evidences of Glaciers on Schiehallion" and adjacent areas. The experiment of attempting to predict in advance the location and nature of glacial evidence in the Comrie area was described, and the first part (Scotland) concluded with notes on glacial evidence in the Trossachs and in the Edinburgh area, including the Agassiz Rock and the small cave to the side of it. (Buckland, 1841A: 333-337).

Unfortunately, the published abstracts (written in the third person) included by the Geological Society in the Proceedings (Buckland, 1841B) have been not only somewhat abridged compared with the original text, but have also been quite subtly, but clearly, edited. The draft of the original text (never published - see below) is far more confident, even assertive, on key points. In fact Buckland rarely wrote out in full detail a paper before it was delivered, but a working note for the first part dealing with Scotland reads:

> Being one of ye very few Engl. Geologists & I believe ye only one who has yet studied the Phenomena of glaciers with a view to their bearing on this question & have passed through the same stages of ... [?] as I trust & [sic] viz. that of a gradual conversion from a violent opponent to a Convert to ye conclusions of Prof. Agassiz, I feel myself in a position that enables me to appreciate ye merits of ye question in a manner wh. wd. have been impossible had I not ... [? supplied] many days in Swiz. in Oct. 1838 in examining the Evidences wh. my conviction that as far as relates to Switz. the Theory of Agassiz must be admitted. ... Ice Bergs will not explain local Drifts from lower to higher levels, e.g. Shap granit. [sic]. (M.S. OUM BuP Glacial File).

The second part, read on 2 December, dealt in a similar manner with the evidence of glaciation in northern England, and again a comparison with the 22-page manuscript for this second section shows that the published abstract in the Proceedings was subtly edited and watered down. For example, in the manuscript Till was defined as "of the argillaceous detritus of Glaciers interspersed with pebbles" (M.S. OUM BuP Glacial File) whereas the published version defined Till as "unstratified glacier-mud containing pebbles". Similarly, the steep-sided cones of gravel and sand on the top of the Bradford Kames esker near North Charlton in Northumberland (Locality no. 35) was described in the published abstract in the Proceedings as "supposed to be an inexplicable work of art", whereas in fact Buckland's actual words were:

> For nearly twenty years this unintelligible vallum has retained its place in my memory, amongst the Geological enigmas which, as time advanced further, experience might solve; and this solution I found in Switzerland, in 1838, when, returning to Neuchatel from the study of the Glacier of Grindelwald & that of Rosenlaui, I included the Gravel Reef of North Charlton in the list of Morains [sic] which my recent Alpine experience enabled me to recognise in England & Scotland. (M.S. OUM BuP Glacial File).

A further example of the reluctance of whoever was responsible for editing the paper to form the Abstract for inclusion in the Proceedings to allow even the Society's President full rein is found in the account of the very significant find by the College Burn at Kirknewton (Locality no. 34). Here the laminae in the moraine were described as "for the greater part, variously contorted", (Buckland, 1841B: 346) whereas the original manuscript states unambiguously:

> the summit ... to the depth of a few feet only, was stratified, & the remainder part [sic] composed of unstratified gravel, wherein were suspended several fragmentary portions of a stratified bed of sand about three feet thick: these had apparently been severed one from another by the presence of ice, & dispersed in insulated angular fragments, through the unstratified gravel, as fragments of Slate Rocks are imbedded in the Granite & Granitic veins of Cornwall. In some of these fragments the strata are vertical, in others, inclined, whilst, in the greater number, the laminae are variously & violently contorted, in a manner only explicable on the theory of a bed of laminated sand having been severed into fragments, which had subsequently been moved, &, contorted by the slow pressure of a Glacier descending the deep trough of the College Burn. (M.S. OUM BuP Glacial File).

There appears to have been considerable scepticism, to put it politely, about Buckland's claim in respect of the prediction of the glacial phenomena that he would find in the Comrie area, so in the final part of the 2 December paper Buckland offered even more predictions, this time in respect of areas of the Lake District that he had not in fact been able to search for glacial evidence, and in effect challenging the sceptics to go and look for themselves to see whether or not Buckland's predictions were correct:

> Dr. Buckland was prevented from personally examining, during his late tour, the south-west and west frontiers of the Cumberland mountains, but he conceives that many of the conical hillocks laid down on Fryer's large map of Cumberland, in the valley of the Duddon, at the south base of Harter Fell, are moraines; that some of the hillocks in the same map on the right of the Esk, at the east and west extremities of Muncaster Fell are also moraines formed by a glacier which descended to the west side of Sca Fell; and that many of the hillocks near the village of Wastdale were formed by moraines descending westward. Dr. Buckland is likewise convinced that moraines exist near Church in the Valley; also between Crummoch Water & Lorton, in the valley of the Cocker, & near Isle, in the valley by which the Derwent descends from Bassenthwaite lake towards Cockermouth, though there are no indications of them on Fryer's map. (Buckland, 1841B: 347).

There is no evidence that any of the sceptics in the Geological Society took up Buckland's challenge, but had they done so they would have found that Buckland's predictions were entirely correct on every point. Indeed, perhaps the most remarkable thing of all was the high standard, and sheer volume, of observations in terms of their present-day identification and interpretation of the accounts of Agassiz, Lyell and Buckland, with the latter as the link person who saw personally every one of the localities cited by Agassiz, most if not all of those of Lyell, and in addition added several dozen localities that he visited independently. Moreover, in 1840, with only limited public transport and extremely poor roads, particularly in the Highlands, it is simply astonishing that so much could be achieved in a period of certainly no more than six weeks in the field.

As explained in the Introduction (Chapter 1.1 above), one substantial part of my research has been to attempt to identify on the ground every one of the localities referred to by Agassiz, Buckland and Lyell in the three Geological Society addresses of November - December 1840, and to re-assess each in turn in terms of a late 20th century view of the Pleistocene geology evidence that it presents. The detailed results of this part of the work, covering 113 named and identified localities, is included as Appendix 3 in Volume 2 of this study, but an analysis of this extensive programme of fieldwork in terms of types of glacial "indicator" (from a present-day viewpoint) has been prepared as Fig. 11 within this Chapter. What is immediately apparent from this analysis is the wide range of glacial feature that was known to Agassiz, Buckland and Lyell, covering 14 different categories of glacial erosion, transport, deposition and temporary or permanent drainage modifications. Indeed, there are very few aspects of the effect of glaciation on northern Britain that could not be effectively demonstrated and taught from one or other of the "classic" localities identified by the three pioneers in September - October 1840.

However, as is well known, there was remarkably little support for the glacial theory in England at least, and especially in the Geological Society, despite the fact that Buckland's unwritten rule of the support of three of the "best men" had certainly been achieved, with Lyell, the Society's most important theoretician, Buckland, its President, and Agassiz, one of its most distinguished and highly respected foreign members. Buckland had no doubt whatsoever about the enormous importance of the turning of the "glacial key" in terms of solving the long-standing "Pleistocene dilemma", and appears to have made his own position about the epoch-making nature of the presentation of the glacial theory to the Society in a part of his paper that was, yet again, omitted from the printed abstract in the Proceedings:

> For some time to come the Glacial Theory must occupy a prominent place in Geological Investigation. The Subject appears to me the most important that has been put forth since the propounding of

Type of Glacial Indicator	Total Number of Sites	% of Total	Locality Numbers (Appendix 3)
1. Striations	21	8.3%	1, 8, 21, 23, 47, 56, 58, 64, 65, 66, 67, 72, 74, 76, 81, 92, 101, 107, 109, 110, 112
2. Grooving	9	3.5%	56, 58, 65, 68, 75, 77, 81, 92, 110
3. Roches Moutonées	8	3.1%	25, 56, 58, 74, 76, 81, 101, 107,
4. Glacial polish and rounding	26	10.2%	1, 8, 21, 23, 25, 29, 47, 58, 62, 64, 66, 72, 74, 75, 76, 77, 81, 92, 98, 101, 102, 103, 107, 108, 109, 112
5. Glacial erratics	22	8.7%	5, 19, 27, 49, 52, 56, 58, 63, 74, 75, 76, 80, 81, 83, 86, 88, 89, 90, 93, 95, 97, 104
6. Terminal or lateral moraines	28	11.0%	9, 11, 16, 22, 28, 34, 39, 42, 46, 49, 50, 57, 58, 59. 61, 73, 76, 78, 79, 83, 85, 87, 89, 90, 92, 98, 107, 108
7. Glacial re-advance	1	0.4%	34
8. Till	24	9.4%	2, 3, 5, 6, 14, 15, 17, 23, 24, 26, 37, 38, 39, 60, 63, 69, 71, 80, 84, 86, 88, 99, 110, 111
9. Kames/Kame Terraces	33	13.0%	7, 9, 16, 18, 33, 36, 39, 40, 41, 44, 45, 51, 52, 57, 59, 73, 74, 82, 83, 84, 86, 87, 90, 92, 96, 98, 102, 103, 105, 106, 107, 110, 111
10. "Hummocky Moraine"	20	7.9%	3, 7, 9, 16, 19, 23, 28, 70, 73, 85, 86, 98, 100, 105, 106, 108, 110, 111, 112, 113
11. Fluvioglacial/Outwash	33	13.0%	9, 12, 18, 30, 31, 32, 33, 36, 43, 44, 45, 48, 50, 51, 52, 53, 54, 55, 58, 69, 82, 83, 91, 92, 94, 96, 99, 100, 103, 104, 108, 111, 113
12. Drumlins	10	3.9%	2, 4, 10, 12, 13, 17, 24, 30, 31, 80
13. Eskers and related features	8	3.1%	9, 19, 35, 36, 43, 51, 70, 71
14. Ice damming and drainage diversion (temporary or permanent)	11	4.3%	48, 57, 59, 84, 85, 87, 94, 96, 98, 100, 103

FIG.11. ANALYSIS BY INDICATORS OF GLACIATION OF THE 113 LOCALITIES CITED BY AGASSIZ, BUCKLAND AND LYELL: SEE APPENDIX 3

> the Huttonian Theory & the surface of the whole Globe must be examined afresh with the view of ascertaining how far the effects of glaciers [inserted: + Icebergs], & of floods produced by melting ice & snow can be found and identified with the actual effects of ice & snow in our present Polar and Alpine Regions. (M.S. OUM BuP Glacial File W/2).

Whatever the public position of the great majority of the leading members of the Geological Society, the importance of the three evenings in November and December 1840 does, in fact, seem to have been well-recognised at the time, to such an extent that the Sub-Curator of the Society, Samuel P Woodward, (fortunately for history) broke one of the Society's strictest rules, and made detailed notes of the various contributions to the heated discussions that followed the presentation of the papers on 4 and 18 November 1840. Woodward's notes relating to 18 November were eventually published by his son, Horace B Woodward (1883), and these were reprinted together with notes relating to the 4 November meeting as well in Horace Woodward's centenary History of the Society (Woodward, 1907). From these it is clear that robust comment, interspersed with rumbustious behaviour, began on 4 November as soon as Buckland had finished reading the first part of his paper. (As a guest and foreign member, Agassiz appears to have been treated rather more courteously!) Murchison opened the attack by calling: "upon the mathematicians and physical geographers present to speak of the objections to Dr. Buckland's glacial hypothesis" (Woodward, 1907: 138). Murchison continued by heaping ridicule upon all aspects of the glacial theory, and asserting his support for a traditional diluvial viewpoint: he even objected to the use of glacial terminology. (It is interesting to note that it was Murchison, during the time that he was Director of the Geological Survey, who introduced the term "drift" as the Survey's official description of most Pleistocene deposits.) Greenough's primary objection appears to have been philosophical and he : "spoke of the arguments derivable from analogy, &c., and objected to the mode in which the Geological Society was in the habit of accounting for phenomena" (Woodward, 1907: 140)! Then, as the exchange became more heated:

> Dr. MITCHELL inquired if Dr. Buckland confined the glaciers to the Highlands or whether he made them descend to the Lowlands.
>
> Dr. BUCKLAND expressed himself ready to answer any question on the subject under discussion, or any involved in his paper, but considered the present question irrelevant.
>
> Dr. MITCHELL considered his question relevant to the subject.
>
> Dr. BUCKLAND rose to reply, but Mr. WHEWELL rose. (Cheers, and 'Mr. Whewell!') (Woodward, 1907, 140).

Whewell's objections were once again philosophical, and he accused Lyell in particular of arguing in a way that "is not the most fair and legitimate" (Woodward, 1907: 141). As the debate became more and more heated, Buckland's position in the Presidential chair became more and more difficult to sustain, and towards the end of the meeting he temporarily handed over the chair to Greenough so that he could enter the verbal melée on equal terms:

> He referred to Professor Agassiz's book, and condemned the tone in which Mr. Murchison had spoken of the "beautiful" terms employed by the Professor to designate the glacial phenomena. That highly expressive phrase "roches moutonnés," which he had done so well to revive, and that other "beautiful designation," the glacier remanié! remanié! remanié! continued the Doctor most impressively, amidst the cheers of the delighted assembly, who were by this time elevated by the hopes of soon getting some tea (it was a quarter to twelve p.m.), and excited by the critical acumen and antiquarian allusions and philological lore poured forth by the learned Doctor, who, after a lengthened and fearful exposition of the doctrines and discipline of the glacial theory, concluded - not as we expected, by lowering his voice to a well-bred whisper, "Now to," etc., - but with a look and tone of triumph he pronounced upon his opponents who dared to question the orthodoxy of the scratches, and grooves, and polished surfaces of the glacial mountains (when they should come to be d——d) the pains of eternal itch, without the privilege of scratching! (Woodward, 1883: 229).

Over the next two years or so a growing number of members of the Geological Society began to admit the possibility that existing glaciers might have been more extensive than they are at the present day, but rejected the idea of a large-scale glaciation. Agassiz himself (1842), along with Buckland, recognised the philosophical difference between postulating a comparatively modest extension of existing glaciers (or perhaps even the formation of small-scale valley glaciers in high mountain areas that are at the present time unglaciated) and the confident assertion of Agassiz and Buckland that there had been a glaciation on a quite massive scale of the greater part of northern Europe, within which Scotland, northern England and most of Ireland had been under an ice cap of Greenland proportions. Indeed, Agassiz made it clear that it was his Highland tour with Buckland that finally led him to make the conceptual leap to an explanation based on a massive glaciation rather than local phenomena, in the face of the overwhelming evidence found in the British Isles.

North of the border the Glacial Theory was far more readily accepted, and on 21 January 1841 W C Trevelyan wrote from Edinburgh to Buckland:

> Have you seen Maclarens series of articles on the Glaciers in the Scotsman - an excellent exposition of Agassiz's Essays - he intends printing some copies separately - so that if he has not sent you the papers he will probably send you the series when completed. Most [my emphasis] of the naturalists here I think are giving in their faith to the Glaciers. When the evidence of their existence is so complete, the difficulty of accounting for the change of climate is a bad reason for disbelieving them. The cause of the change may have been an astronomical one - an obscuration of the sun for some years would be sufficient. (M.S. OUM BuP Glacial File).

Buckland appears to have accepted that the absence of an acceptable mechanism to explain the change of temperature necessary to create a glaciation was a problem, and collected material on this, including information from discussions with Herschel - manuscript note dated 14 November 1842 entitled "Sudden change of temperature now accounted for?" (M.S. OUM BuP Glacial File). There were, however, at least two far more serious problems. First, quite early in 1841 Lyell appears to have abandoned completely the glacial theory in the face of the onslaught of opposition from the Geological Society members and reverted to his marine submergence with icebergs hypothesis. (Lyell was in fact one of the last of the prominent geologists to adopt the glacial theory in its modern sense, sometime between 1861 and 1863.) Second, there was the problem of explaining fluvioglacial phenomena, particularly outwash gravels, which had demonstrably been deposited in extremely fast-flowing water. Most if not all geologists of the day (certainly including Agassiz and Buckland) seem to have taken it as axiomatic that neither terminal moraine outwash streams nor subglacial watercourses had sufficient strength to account for fluvioglacial phenomena, and hence what might be termed a "glacio-diluvialism" emerged as an explanation, and which was not displaced until well into the 1860s. In Britain, Buckland was perhaps the first to argue for this compromise in his 19 February 1841 Anniversary Address to the Geological Society, although he gave no ground overall, and began a substantial section of the Address entitled "Geological Dynamics - Glacial Theory" :

> During the last year M. Agassiz has introduced a new and powerful machinery into the Dynamics of Geology, by asserting the claims of ice to be admitted to the list of locomotive forces that have operated largely not only in forming morains (i.e. mounds and ridges of gravel and clay intermixed with large fragments of rocks) on the flanks and at the lower extremity of existing glaciers, but also in transporting erratic blocks with the detritus of morains to distant regions, and re-arranging them by the force of floods that originated in the melting of ice and snow. (Buckland, 1841B: 509).

The attempted compromise came at the end of this section (which took up almost eight pages of the Address):

> One great cause of the difference of opinion between the diluvialists and the glacialists, is the exclusiveness with which each party would insist upon the agency of the cause which they respectively adopt: the diluvialist apparently errs in refusing to admit the agency of glaciers in mountain valleys that are below the existing limits of ice and snow; whilst Agassiz may have erred in urging too far his theory of expansion as the great locomotive power of glaciers over regions whose surface is too little inclined to admit their progression by the force of gravity; a middle way between these two extreme opinions will probably be found in the hypothesis, that large portions of the northern hemisphere which now enjoy a temperate climate have at no very distant time been so much colder than they are at present, that the mountains of Scotland, Cumberland, and North Wales, with great part of Scandinavia and North America, were within the limits of perpetual snow accompanied by glaciers; and that the melting of this ice and snow was accompanied by great debacles and inundations which drifted the glaciers with their load of detritus into warmer regions, where this load was deposited and re-arranged by currents at vast distances from the rocks in which it had its origin. (Buckland, 1841B: 516).

Buckland attempted to use this proposed compromise position (which was in effect also largely adopted by Agassiz as well) in what proved to be the last major piece of fieldwork that Buckland, now aged fifty-five, was to undertake. This was a very detailed and extensive study of the glacial phenomena of northern and central Wales, carried out in the company of Thomas Sopwith (one of the few enthusiasts for the glacial theory in the Geological Society) in October 1841. For more than a century the hotel at Beddgelert, in the heart of Snowdonia, displayed a signed entry made in the visitor's book by Buckland on 16 October 1841:

> Notice to Geologists. - At Pont-aber-glass-llyn, 100 yards below the bridge, on the right bank of the river, and 20 feet above the road, see a good example of the furrows, fluting and striae on rounded and polished surfaces of the rock, which Agassiz refers to the action of glaciers. See many similar effects on the left, or south-west, side of the pass of Llanberris. (Davies, 1969: 263).

Buckland's report on his successful hunt for glaciers in Wales was read to the Geological Society on 15 December 1841 under the title: "On the Glacia-Diluvial Phaenomena in Snowdonia and the adjacent parts of North Wales" (Buckland, 1842A). Perhaps the most serious stumbling-block to a comprehensive interpretation of Snowdonia in terms of the glacial theory was the occurrence of marine shells in the till at altitudes of well over 1,000 feet above sea level on Moel-tryfan, as a result of which Buckland reverted to "consider the re-modification of glacial detritus by violent inundations" (Buckland, 1842A: 583). As Gordon Davies (1969: 311-312) has demonstrated, the Moel-tryfan shells remained a serious problem until well into the 1870s, when at last shelly deposits within tills began to be recognised as erratic rafts of sea-floor deposits picked up by the advancing ice, and carried up to considerable altitudes as in the case of the Moel-tryfan shelly till. Buckland's Snowdonia paper did produce one very substantial bonus, in that it prompted Charles Darwin to study the evidence for glaciation in North Wales, looking in particular at the localities identified by Buckland, and Darwin (1842) quickly wrote of his conversion to the glacial theory.

The majority of the members of the Council of the Geological Society remained as hostile as ever, however, and Buckland's successor as President, Murchison, used his first Anniversary Address in February 1842 to wage war on the glacial theory and its supporters. By this time the full texts of Agassiz's paper on glaciers of 4-18 November 1840, and Buckland's two parts (on the former existence of glaciers in Scotland, and on the evidence of glaciers in the North of England) had already been "referred" for more than 14 months without a decision (M.S. GSL CM1/5). (Lyell had formally requested permission to withdraw his paper on 5 May

1841, and the Council had approved this.) In the case of Buckland's paper, referees' reports had been received by the Council on 17 November 1841, but contrary to normal practice no ballot was held amongst the Council to decide whether or not it should be published. At the following Council meeting, on 1 December 1841, Agassiz's paper was "referred" for a second time without any explanation being recorded in the Minute Book (M.S. GSL CM1/5). Soon after this the full text of Buckland's paper on the glacial geology of Snowdonia, (see Buckland, 1842A for the Society's Abstract), only added to the evident embarrassment, and there seems little doubt that by the middle of 1842 an impasse had been reached. The Council clearly was not prepared to publish any of these contributions about the glacial theory, and yet was reluctant to take the final step in this by rejecting the already widely discussed contributions of Agassiz, one of the Society's most distinguished and respected foreign members, and of Buckland, read from the Presidential chair.

In the case of his own papers, Buckland appears to have resolved the matter with a terse note dated 28 June 1842 to Lonsdale, Secretary to the Society:

> I beg to apply to withdraw my papers read some time since on Glaciers in Scotland and on Glaciers in N. Wales. (M.S. GSL LR7/193).

The Council under Murchison quickly granted the necessary "permission", no doubt with a sigh of relief, although it does appear from the Society's official records that the question of Agassiz's paper was never formally resolved, in that it was never officially accepted or rejected by the Society. The full texts of Agassiz's two important papers to the Society were never published anywhere, and only the short abstracts in the Proceedings

(Agassiz, 1841A and 1841B) ever appeared, although much of the material was presumably re-used in the long review paper published by Jameson in the Edinburgh New Philosophical Journal, (Agassiz, 1842). Similarly, Buckland's papers of 1840 on Scotland and Northern England, and of 1841 on North Wales were never published in full and only the selectively edited abstracts in the Proceedings (see above) ever appeared (i.e. Buckland, 1841A and 1842A). In addition Buckland, by tradition, could not be censored in any way in his Anniversary Address, (Buckland, 1841B), and very brief abstracts of two lectures to the Ashmolean Society (given in 1840 and 1841 respectively) also eventually appeared, (Buckland, 1844C & 1844D): all of these were far more explicit and forceful in their advocacy of the glacial theory than were the abstracts in the Proceedings.

On a more positive side, the inner caucus of the Geological Society so vehemently opposed to the glacial theory of Agassiz became slowly but steadily more and more isolated from the mainstream of geological and geomorphological thought, until the glacial theory became widely accepted even in the Society by the early 1860s. As Trevelyan had made clear in his encouraging letter to Buckland of January 1841 and quoted above, the response to the glacial theory was totally different in Scotland, thanks at least in part to Maclaren's use of his newspaper and particularly through Jameson's acceptance of a continuous series of important papers on the glacial theory for the Edinburgh New Philosophical Journal through the 1840s. These included many reports on present-day glaciers, the very important review article on the progress of the glacial theory by Agassiz (1842), already referred to, and perhaps most important of all a series of "Letters" by James D Forbes which cumulatively did much to establish the science of glaciology in general and the study of glacier physics in particular.

As for Buckland, the projected second edition of Reliquiae Diluvianae originally promised in 1825 remained no more than an idea (perhaps a collection of a few working papers) when he became Dean of Westminster in 1845 and to all intents and purposes stopped carrying out original scientific research. In the meantime the excellent field observations of Agassiz, Lyell, and above all Buckland, in Britain remained largely ignored and untested for the greater part of a generation, while the Pleistocene submergence theory reigned supreme, at least in England.

However, even without his projected final synthesis, Buckland's contribution to the development and progress of the glacial theory in collaboration with his friend and protégé Agassiz, was a most significant one. Above all, in Agassiz's glacial theory Buckland had at long last found a geological mechanism that could explain most, if not all, of the otherwise inexplicable features of the British Pleistocene that Buckland had been puzzling over for more than 30 years, and that was to provide a sound basis for the future study of the superficial deposits of Britain and northern Europe.

6. CONCLUSIONS

Before starting the present study, my previous work on Buckland (Boylan, 1967 & 1970) had already led me to conclude that he was a far more complex and interesting character than could be discerned from the conventional views of Buckland as either a decidedly bizarre eccentric, or an obscurantist religious bigot standing in the way of scientific progress. (In either of these verbal caricatures Buckland was - significantly - almost invariably referred to as "Dean" Buckland, to emphasise his status within the Church, even though virtually all of his important scientific work was completed before his nomination to the Westminster Deanery.)

My own previous work in the fields of Quaternary geology and Pleistocene mammals had led me to appreciate, at least at a superficial level, Buckland's significance at least in the history of these two areas of geology, and led directly to this study of aspects of Buckland and his work.

The "Biographical Framework" (Section 2), although far short of the much-needed full biography of Buckland, has demonstrated two fundamental points. The first is the way in which Buckland progressed from a relatively modest middle class provincial background, through the vicissitudes of the patronage system of Georgian England, to become a national celebrity, accepted at all levels of moderately liberal society, up to the Court itself, by means of his extraordinary hard work, innate intelligence and ability, and considerable charm (of which his well-documented eccentricities were an integral, and probably deliberately contrived at times, part). The second important point to emerge from the biographical part of this study is the extremely wide range and strength of Buckland's scientific and "institutional" activity in so many fields. Taking two very different examples from the beginning and the end of his working life respectively, Buckland would have earned himself a respectable niche in history solely on the strength of either his early geological mapping and structural work on the Cross Fell Inlier, the structure of the Alps, and the joint work with Conybeare on the Bristol region, (Chapters 2.2 and 2.3), or his final work in the far-reaching liturgical, architectural and educational reforms at Westminster (Chapter 2.6). So far as future work is concerned, there is a clear need for further basic cataloguing, indexing and analysis of the rich variety of manuscript sources in various collections, while the need for a full-length biographical review of Buckland has been referred to several times in the course of this thesis. I very much hope that my "Biographical Framework" will form a useful starting point, and indeed stimulus, for such a project.

Although he worked on his own for many months on end, often far into the night, Buckland was by instinct a gregarious man and greatly enjoyed intellectually stimulating company. This natural inclination, coupled with his long experience of collegiate living from his first days at Blundell's School in 1797 through to his marriage at the end of 1825, made Buckland a very effective member of many different academic and scientific organisations and clubs. Despite its scant regard for the sciences, Buckland was a loyal and active member of the University of Oxford for over 49 years, and for at least half of that period was its most distinguished and respected scientist, at least in the eyes of the external scientific world. The review of Buckland's role in Oxford in this study (Chapter 3.1), coupled with relevant parts of the "Biological Framework" (especially Chapters 2.2 - 2.4), show how the young Fellow of the intellectually stimulating and stretching Corpus Christi College first expanded the office of Reader in Mineralogy and the associated museum facilities of the University, and quickly proceeded to a successful petition for the establishment of a new regius chair of Reader in Geology which he held jointly with the older office. Within three years of the establishment of the chair in Geology, Buckland had, largely through his own efforts, raised geology to a level of popularity in terms of attendances at his lecture courses that has never been achieved either before or since, at least in terms of the percentage of the students of the University following courses in geology (although student numbers fell sharply during the 1830s and 1840s in the face of pressures from the largely unreformed examination system of the University). The discovery of the lecture notes taken by Newman and Jackson while students on Buckland's courses in 1821 and 1832 respectively, coupled with Murchison's notes on two Buckland lectures and one of his celebrated student geological expeditions to Shotover Hill, now all transcribed and reproduced for the first time as Appendix 1 of this thesis, have been particularly revealing in terms of both Buckland's teaching methods and his position on current geological and political issues. Overall, my work on Buckland and Oxford has confirmed, and significantly amplified, the earlier assessments of, for example, Sollas (1905) and Taylor (1952) on Buckland's importance in Oxford science of the first half of the nineteenth century. In addition, it has demonstrated for the first time the significance and influence of Buckland's approach and methods on the teaching of geology at all levels, with his emphasis on learning through practical experience of geological specimens in the classroom, the museum and the field, his extensive use of maps and specially prepared diagrams and geological models, and his emphasis on both guided field excursions and personal geological mapping and other research projects, as integral parts of the teaching and learning process. The fact that Buckland's geological teaching techniques have not been regarded as in any way exceptional, or even particularly noteworthy, by most historians of science or of educational methods, is perhaps the best measure of the extent to which Buckland's major innovations in this area have permeated the teaching not only of geology, but of related areas such as geography or the life sciences. Again, there is clearly scope for much further work in this area, using in particular the large collection of large-scale maps and diagrams clearly intended for classroom teaching, and still preserved in the Oxford University Museum, together with the very extensive Lecture Notes files, once these and their contents have been fully catalogued and listed to proper archival standards.

So far as the Geological Society is concerned, *it was within the walls* of its successive suites of Rooms (up to the impressive accommodation in Somerset House), and in the company of the Society's large and varied membership, that Buckland found the greatest intellectual stimulation. Despite the very considerable rigours and discomfort of travel between Oxford and London in the pre-railway era, and the pressures of both teaching and - from 1826 - family responsibilities, Buckland was an assiduous attender at the fortnightly meetings of the Society for almost 40 years from his election in 1813. The great majority of his scientific papers were offered first (and frequently exclusively) to the Society. Buckland was also an active member of the

Council of the Society in one capacity or another almost continuously from his initial election, direct to the office of Vice President in 1818, until the 1847-1848 year, when (because he was no longer a member of the Council) it was at last possible for the Society to present the most prestigious award in geology, its Wollaston Medal, to Buckland.

However, Buckland's most significant contributions to the Society were his two presidencies of 1824-1826 and 1839-1841 respectively, particularly the first of these during which he guided the Council and Society through a critical period as the Society successfully petitioned the Crown for a Royal Charter of Incorporation. One other far-reaching innovation of Buckland's first presidency was his introduction of open debates on both the papers presented, or any other topical geological subject, at the end of each Society meeting. Following the lead of the Geological Society, most other learned societies in a wide range of fields eventually adopted this practice so that such a practice is regarded as a matter of course nowadays, and the origin of this minor, although significant, reform has been all but forgotten. Buckland's second presidency, from 1839 to 1841, was marked by deep divisions between prominent members of the Society over two important geological issues: between Murchison and Sedgwick against De la Beche on the geology of Devon, and of virtually the whole of the senior members of the Society other than Charles Darwin against Agassiz, Buckland and Lyell over the glacial theory. In each case, despite his own position at the very centre of the controversy in the second case, Buckland skilfully held the Society together so that despite the heat generated the disputes did not become personalised to any great extent, and all were able to leave Somerset House after a perhaps very heated meeting and proceed to an excellent dinner under the auspices of the Geological Society Club (of which Buckland was, not unexpectedly, a founder member). The two Anniversary Addresses of Buckland's second presidency do, however, indicate that he was probably getting out of step with the most influential members of the Society, such as Murchison and Lyell, because of his continued emphasis on the utilitarian and social aspects of geology, both of which were given considerable prominence in both February 1840 and February 1841 Anniversary Addresses (Buckland, 1840A & 1841B), hence his growing interest in the potential role of the British Association as a force for social, indeed political, change. So far as future research in this area is concerned, the origin and earliest years of the Geological Society have been very extensively studied in recent times, but there is in my view a clear need for further work on the Society and its development from the 1820s onwards. Another potentially fruitful area for research is a comparison of the views of geology, the Geological Society, and its role, as seen in the successive Anniversary Addresses of the President - an innovation of W H Fitton at the end of his first presidential year in February 1828 which continued into this century.

In contrast with the Geological Society, the British Association for the Advancement of Science has been the subject of extensive research for well over a decade, culminating in the various studies published to coincide with the 150th anniversary celebrations of 1981. Even though for family reasons Buckland was unable to attend the inaugural meeting in York in September 1831, he enthusiastically accepted the Presidency of the Association for the June 1832 meeting of the Association held in Oxford. Chapter 3.2 of this study has examined Buckland's role in the Association and in addition a computer analysis of all of the office holders within the

Association during its first 25 years (1831-1855 inclusive) has been made.

Buckland found in the Association that inter-disciplinary voice that could and did plead the cause of science and technology that he believed to be so necessary. The 1832 Oxford meeting, held under his Presidency and organised by Daubeny, Powell and Buckland, to a very considerable extent set the pattern for the programme and activities of the Association that survived for several generations virtually intact, and which is still discernible in a British Association meeting even today. Indeed, in the late 19th century and early 20th century Buckland was quite often referred to as the first President of the Association, with the Yorkshire Philosophical Society's President, Lord Milton, who chaired the inaugural 1831 meeting in York, being discounted as not a "real" British Association President. (I do not agree with this unfair assessment of Milton's useful part in the inauguration of the British Association.) Two other significant points have emerged from this research. First, the computer analysis of office holders within the Association during its first quarter century shows that geologists and others closely associated with geology were the dominant force in the Association during that period, with a majority of the top 20 office holders (in terms of the total number of offices held over the 25 year period) being in one way or another part of Buckland's circle. Second, within the Association Buckland rarely missed an opportunity to develop and expand the Association's role as both a direct promoter of scientific research (as in its sponsorship of the work of Agassiz on British collections of fossil fish, or his own work with Milne on British seismology), or in promoting the cause of science and technology both in the political arena, with

Buckland's old friend and patron Robert Peel being an especially valuable supporter in this field, and in the celebrated public events such as the traditional public lectures arranged by the Association during each Meeting (although few if any of these can have matched the extraordinary performance of Buckland in his 1833 Meeting public lecture on the Megatherium).

Within the field of vertebrate paleontology Buckland can be viewed in a number of very different ways. Certainly, he was the most enthusiastic and influential follower of the great Cuvier in England in terms of his approaches to taxonomy, functional morphology and the analysis of fossil vertebrate faunas. Unlike Cuvier, however, Buckland did not have the luxury of a large and excellently equipped laboratory and up to a dozen scientific assistants, so Buckland carried out enthusiastically his own fieldwork and detailed analysis of his finds with very little assistance apart from discussion with his friends. Nor was he a mere shadow of Cuvier in terms of the results of his research in this area. Both the historical research summarised in Chapter 4.1, and the detailed "case study" re-evaluation of Buckland's classic site of Kirkdale Cave (Appendix 2) demonstrate not only the high quality of Buckland's original identification and analysis of the Kirkdale fauna and its origin, as put forward by Buckland in his Royal Society paper (Buckland, 1822B), but also that his developed synthesis in Reliquiae Diluvianae (Buckland, 1823A) was, and still remains, a very significant landmark in the development of vertebrate palaeontology. Moreover, his international reputation in this field was further enhanced by an important series of studies of other Pleistocene mammal faunas, including those of other cave sites in both Britain and on the Continent, and from distant parts of the world, as in the case of his work on the Arctic fauna from Eschscholtz Bay (Buckland, 1831) or in his much-discussed work on the South American Megatherium (Buckland, 1833).

In the field of human palaeontology, Buckland began by expecting that human fossils would eventually be found, but equally appears to have understood the need for extreme caution in making inadequately substantiated claims in this most sensitive of all the areas of palaeontology. In the absence of unchallengeable evidence of the exact stratigraphical position of the shallow grave containing the "Red Lady" of Paviland, Buckland drew back from his original hope that the skeleton might prove to be "antediluvian", and published it as a much later intrusive burial in the fossiliferous cave deposit. Similarly, he was not convinced that the paleolithic flint implements found in Kent's Cavern from the mid-1820s were contemporaneous with the well-established "antediluvian" mammal fauna that occurred so abundantly in many parts of the cave, but suggested that these too were intrusive. Although McEnery was certainly very convinced that the flints were contemporaneous with the mammal fauna, there is in fact no evidence to suggest that Buckland personally witnessed the opening up of an undisturbed area of the cave in which both extinct fossil mammals and humanly worked flints were found together. The review of Buckland's work in this field (Chapter 4.2) also discusses and rejects the claim of Vivian (in McEnery, 1859) that Buckland was responsible for the suppressing of similar findings to those of McEnery when they were submitted to the Geological Society by Godwin Austen in 1840.

In the other two areas of vertebrate palaeontology examined in detail, Mesozoic reptiles, mammals and coprolites (Chapter 4.3), and palaeontological and environmental reconstructions (Chapter 4.4), the significance of Buckland's work has been largely overlooked or ignored in modern times. Although not an important discoverer of ichthyosaurs in the sense of the taxonomic description and naming of new species, Buckland's understanding of the functional morphology of the whole animal, and especially his analysis of the function of the eye in opthalmosaur ichthyosaurs in his Bridgewater Treatise (Buckland, 1836B) was particularly significant and influential. His priority in relation to the identification and description of true terrestrial dinosaurs has been demonstrated by Delair and Sarjeant (1975), and although Desmond (1979) has tried to re-establish Richard Owen's "claim" in this respect by trying to minimise the contributions of Buckland and Mantell, I have no doubt that Buckland (and indeed Mantell just a few months later) were perfectly well aware of the significance of the dinosaur fossils. Buckland's identification of pterodactyl bones in the Upper Jurassic of England was of considerable importance, whilst his long-contested identification of an opossum-like small mammal in the Stonesfield Slate was at least as important as the identification of the first dinosaur, not least because it upset completely the generally accepted tidy division of vertebrate faunas in which the Mesozoic was an "age of reptiles" whilst the Tertiary was the "age of mammals". Buckland's identification of fossil coprolites attributable to a wide variety of Mesozoic animals, including ichthyosaurs and fishes, led directly to "coprolite fever" in two quite different areas, with geologists in many parts of the world seeking out, and quickly finding, fossil coprolites, soon to be followed by agriculturalists and quarrying entrepreneurs seeking phosphate-rich coprolite beds for the manufacture of agricultural fertilizer (something that Buckland himself strongly advocated). So far as future research in this area is concerned, I would suggest that the highest priority would be a comprehensive re-examination and re-evaluation of Buckland's original working material in the field of Mesozoic vertebrates, along the lines of my own tracing and re-examining of the surviving Kirkdale Cave specimens.

Buckland does not fit in easily to current historical or philosophical models of 19th century palaeontology. Although he was so critical of the anonymous author of the Vestiges of Creation that he included a specific reference to this in the Broadsheet advertising his 1848 Oxford lecture course, he worked closely with Owen for many years, and at the 1841 British Association meeting he went out of his way to emphasise his praise and support for Owen's fossil reptiles report to the Association, which is generally regarded (e.g. Bowler, 1976) as one of the key studies in the "Progressionist" debate. On the other hand, in his own palaeontological work Buckland had little time for such abstract theorising. To him, probably the only philosophical value of the study of fossils was in relation to the Proof of the existence of a Deity from the evidence of Design, as in the Bridgewater Treatise (Buckland, 1836B). With this one exception, therefore, the study of fossils had, in Buckland's view, just two fundamental objectives. The first was the obvious utilitarian value of the identification of distinct fossil forms in stratigraphy and mapping work. The second, however, was to a very large extent a further innovation of Buckland himself: the use of fossil evidence in the reconstruction of the biology of the living animal from the perhaps very fragmentary surviving fossil remains, and the reconstruction of past environments.

For Buckland, perfection in either a living or fossil taxon had nothing to do with the animal or plant's place within some theoretical, perhaps progressionist, hierarchy - with Man at the apex of the triangle - but was measured in terms of the form's degree of adaptation to its environment and special ecological niche. Many of those attending the famous British Association lecture on the Megatherium were scandalised not so much by Buckland's coarse humour, profane language or theatrical demonstrations, but by Buckland's claim that such an ungainly and aberrant mammal form could be described as "perfect" on account of the excellence of its adaptation to a particular and unusual ecological niche. (For many, the very word "perfect" in relation to a fossil form meant "nearness to Man", certainly not the possession of an enormous posterior on which the animal could balance while it used its shovel-sized fore feet to dig up roots during the Argentinian Pleistocene.)

Nicholaas Rupke (1983: 158-159) has characterised Buckland's position in the phrase "the ecological theory of geological progress" - an expression that in my view is very appropriate indeed, and worthy of more general use (and indeed further and wider research and investigation). Perhaps the high point in Buckland's use of this approach was in his simply brilliant inductive analysis of the geological and palaeontological evidence that he found in Kirkdale Cave, which is characterised not only by almost flawless observation and reasoning, but also by the most vivid visual imagery in his graphic interpretation of the inferred behaviour of the pack of hyaenas that had occupied the Cave and had hunted down everything from half-grown elephants down to water rats around the shores of an interglacial Lake Pickering. Fossil footprints, coprolites, and the stomach contents of both ichthyosaurs and fossil cephalopods all enabled Buckland to build up a clearer picture of palaeoenvironments. Buckland's use of experimental methods in both taphonomy and paleoecology was also innovatory, as in for example the use of the menagerie hyaena, Billy, in testing his hypothesis on the origin of the shattered bones found in Kirkdale Cave, in the use of chemical analysis of many kinds of coprolites and of the stomach contents of both ichthyosaurs and fossil cephalopods, as well as the use of a selection of animals from the Buckland household on different consistencies of pie crust in the attempts to create tracks for comparison with supposed fossil footprints.

Finally, but by no means least, in relation to this Section of the thesis, throughout Buckland's palaeontological work there is clear evidence that Buckland's own understanding of the reconstructed past environments or fossil animals was an intensely visual one, and his vision of past environments and former inhabitants of the earth is seen not only in his teaching diagrams at Oxford, but particularly in the massive range of illustrations included as Volume 2 of the Bridgewater Treatise (Buckland, 1836B). A key part of his overall conception of the book was the hand-coloured exceedingly large Plate 1 illustrating the whole of British geology and supported by drawings of the typical plants and animals that had been identified from the earliest fossiliferous geological time to the present day. Cecil Schneer (1984) has very recently pointed out the special significance of this plate, saying:

> In this schematic section on which one and a half centuries can improve only in its details, we see the order and the architecture in the distribution of the fabric of the earth's crust. The concept of geological time consists precisely in this bringing together, in three dimensions of space and a fourth of time, the great kingdoms of nature: animal, vegetable and mineral. ... By 1837 [sic] the fundamental concept of an orderly progression

> of matter and life through space and time was already established and demonstrated irrefutably by the geological studies on which this section was based.

Buckland's vision in the area of palaeontological and paleoecological reconstruction not only delighted both specialist and non-specialist audiences and readers alike, but - even more important - established methods of interpreting and visualising evidence in these areas that are the everyday tools of the trade of present-day taphonomists and paleoecologists.

In relation to what I have termed "The Quaternary Dilemma" (Section 5), Buckland's position appears to have been widely misunderstood and misrepresented. One of the most puzzling aspects of all is the way in which 20th century "Whiggish" interpretations of the Diluvial Theory have been quick to condemn (or dismiss) Buckland for his erroneous advocacy of the Diluvial Theory in the 1820s, whilst there has been no parallel "Whiggish" applause for Buckland's passionate advocacy of the (correct) glacial theory in the 1840s (nor indeed any "Whiggish" condemnation of vehement opponents of the glacial theory such as Murchison, Sedgwick, or - after his apostasy in 1841 - Lyell).

From 1818 onwards Buckland became increasingly involved in the study of the Quaternary and found in many places in Britain evidence that simply could not be explained and understood in terms of commonly observed geological processes. It is fair to claim that Buckland's work over the next five years in particular laid the foundations for Quaternary studies in Britain (as Kennard, 1945, has pointed out), with his extensive detailed mapping of the superficial deposits of the Midlands (Buckland, 1821D), the generalised diluvial theory of the Vindiciae Geologicae (Buckland, 1820) and - above all - the very broad and detailed survey in the second part of Reliquiae Diluvianae (1823A). In each of these studies Buckland gave detailed and cogent reasons for calling into aid some abnormal geological process - interpreted as a Deluge - because of the abundance of facts that simply could not be explained in terms of normal fluvial processes. Although the mechanism called on to explain these anomalies was wrong, the evidence of some highly abnormal process of tremendous force and transporting power was, and still is, there to be seen in the many areas and localities referred to in some detail by Buckland in the various studies. With the conversion of Lyell and Murchison to strict uniformitarianism in the late 1820s, followed by the first volume of Lyell's Principles of Geology in 1830, Buckland's position came under fierce attack. However, the assaults were directed almost exclusively at the diluvial mechanism used to explain the anomalies, and there was little or no concern to examine from a uniformitarian stance the very real and substantial evidence that Buckland had gathered in support of some sort of extraordinary and exceptional force over the previous dozen years or more. Over recent years Hooykaas (1959 & 1970) has argued cogently that Catastrophism has a valid place in geological theory. Certainly, in my view strict uniformitarianism in the Lyellian sense may work very well in the Tertiary (in which Lyell specialised), but simply will not work in trying to explain the geological phenomena of an area that has suffered large-scale glaciation in recent geological time, such as the greater part of the British Isles. Quite independently, Rupke has come to the same conclusion, and has expressed himself even more forcibly on this point, quoting approvingly from criticism of Lyell's position by Whewell, and adding:

> This criticism was fully justified. Lyell's position of extreme uniformity was both poor science and bad logic. It is astonishing that later geologists and historians have so consistently and for so long sided with Lyell and dismissed his clerical opponents. (Rupke, 1983: 190).

For Buckland, the final resolution of the "Quaternary Dilemma" came in 1838, just twenty years after he had started serious studies of the British Pleistocene, with his conversion to Agassiz's glacial theory. As Agassiz himself fully realised, conceptually there was a very wide gulf between the claims of Venetz, de Charpentier and Agassiz himself that the existing Alpine glaciers had formerly extended a few tens of kilometres further down their valleys and out on to the adjacent areas of the plains of Switzerland, and arguing that massive icecaps of Greenland proportions had previously existed in areas such as the British Isles where today there is no evidence whatsoever of permanent snow and ice. Consequently, Buckland's conversion during his tour of the Bernese Oberland in October 1838 represented a very bold step indeed, even though there had been earlier, almost forgotten, speculations to this effect such as those of Hutton, Playfair and Esmark.

Nevertheless, it was the detailed field investigations carried out by Agassiz, Buckland and Lyell in the autumn of 1840 which were decisive in establishing the glacial theory as a plausible explanation of Quaternary phenomena outside of the Alps. The second substantial "case study" carried out as part of this research involved the locating and re-evaluation of all of the "classic" localities referred to by Agassiz, Buckland and Lyell in their Geological Society papers of November - December 1840, and this work (Appendix 3) has been very revealing indeed in terms of both the high quality of the observations and interpretation of 1840, and in the very wide range of glacial indicators that were recognised and cited. Indeed, the range of glacial phenomena covered by the 113 localities is such that there would be little difficulty even today in teaching an advanced course in British glacial geology using the evidence of the 1840 localities almost exclusively.

Although Buckland had, following his own dictum, brought together three of the "best men", i.e. Agassiz, Lyell and himself, he must have been very disappointed at the exceedingly negative, indeed positively hostile, response of his friends and colleagues in the Geological Society to the glacial theory, and despite his attempts to produce a compromise position between the glacial and submergence theories, most notably in his North Wales paper (Buckland, 1842A), the opposition, led by Murchison, would have none of it. Lyell's almost immediate abandonment of the glacial theory within only six or eight weeks of presenting his cogently argued and indeed forceful paper on his native Forfarshire, was particularly serious in terms of gaining acceptance for the views still advocated very firmly by Agassiz and Buckland. Despite the vehemence of the opposition, the glacial theory did not die, even in England, let alone amongst the Scottish School, which had always retained a significant pool of (entirely healthy) scepticism about the more extreme uniformitarianism that held sway in London. Although it was to be almost a third of a century before the glacial theory became more or less universally accepted amongst British geologists, by 1840 Buckland, in many ways the founder of Quaternary studies in Britain, had at last found in what Gordon Davies has aptly termed "the glacial key": a valid actualistic mechanism that could explain the abundant anomalies in British superficial geology that he had found so difficult to interpret and explain throughout the previous quarter of a century.

Buckland's catastrophism, although decidedly unfashionable from the late 1820s onwards, was, in the terms of his own major research field of the Quaternary, an entirely justifiable philosophical position in the face of the field evidence: currently observable geological processes could not account for the dispersal of the Lickey Hill quartzite or the Shap and Criffel granites, nor the formation of discordant depositional features such as the Ben Wyvis or North Charlton gravel ridges. With the recognition of the glacial mechanism, the somewhat unphilosophical catastrophism was superceded by a soundly based actualism drawing on an understanding of normal geological processes, although these had operated in what is from the present-day perspective seen as an abnormal environment, i.e. a continental-scale glaciation. By a strange coincidence, in Buckland's bicentenary year of 1984 there is probably a greater interest in non-uniformitarian geological processes than at any time in the past century (e.g. Clube, 1982, and Hsü, 1982). Moreover, in the 200th anniversary year of Buckland's birth, 1984, the Geological Society of London has awarded its Wollaston Medal to the distinguished sedimentologist and structural geologist, Kenneth Hsü, whose recent presidential address to the International Association of Sedimentologists had the provocative title "Actualistic Catastrophism" (Hsü, 1983). (The 1984 award of what is still regarded as the highest accolade in world geology is almost certainly the first to be made to a scientist willing to challenge so openly the Doctrine of Uniformity since the Wollaston Medal was presented to Buckland in 1848.)

In the seventeen years since I first wrote about Buckland, my understanding of this important figure in nineteenth century geology has, I trust, matured and developed considerably. However, I still feel that the quotation with which I ended that first paper (Boylan, 1967: 251) is still the most appropriate epitaph. This was the summing up of Buckland in the Royal Society obituary by his old friend and colleague, John Phillips (1857: 267):

> a patient student, a powerful teacher, a friendly associate;
> a valiant soldier for Geology in days when she was weak,
> an honoured leader in her hour of triumph.

APPENDIX 1.1

"THE SUBSTANCE OF A COURSE OF LECTURES ON MINERALOGY DELIVERED BY THE PROFESSOR AT OXFORD IN LENT TERM 1821."

[John Henry Newman, 1801 - 1890: Unpublished Manuscript in the Newman Archives at the Birmingham Oratory]

Mineralogy treats of every thing found on the earth or in the bowels of the earth excepting the animals & vegetables. Before we commence our subject we shall make a few remarks on the state of this department of Science in the principal countries of Europe. In Geology no one has made any great proficiency, but the English have made much greater advances than any nation of the Continent. In Mineralogy and Chemistry although we can boast great names we are decidedly inferior - nor is this any reproach to the genius or industry of the inhabitant of Britain, so far from it that proficiency in those sciences is a much greater want in him than in his neighbours - for in England it is not encouraged, it is not patronised. In Germany there are Universities for Chemistry &c - I was only last year travelling in Austria & it is astonishing to see the way in which the study of those sciences is promoted. At _____ [sic] at the expense of Government a museum is fitted up with chemical &c apparatus, with specimens, with materials; Professors deliver lectures; it is open to persons of any nation in the world, you go, hear the lectures, consult the specimens, make what chemical &c. experiments you choose, and do not pay anything whatever, it is perfectly free, & Government pays all. In France there is a body regularly chosen out of the first men of science in the kingdom; so many devote themselves to Geology, so many to Mineralogy, so many to Chemistry, so many to Electricity & so on - it is made a national concern. In England on the contrary every thing is done by individuals, there is no encouragement for study, no public institutions, no opportunities for improvement - more wonderful then is that zeal, that ardour, that talent, that perseverance that can triumph over such difficulties & produce such proud names as grace the lists of English chemists. There is another cause of our inferiority in these pursuits which though extremely natural might not be at first supposed - it relates chiefly however to that branch of Chemistry named Metallurgy or the working of Metals - it is the richness of our isle in minerals. In proportion to its size England contains more minerals than any other part of Europe; coal it has in greater abundance than the rest of the continent put together - as much copper - as much lead - more tin. This very prodigality of nature has been an injury to us. The foreigner scantily supplied with these precious gifts, husbands them with care and .... [? rule], and seeks after the best means of getting from an ore more metal at a cheaper rate. Art is called in to assist where nature has beer impropitious. Hence on the continent the science of minerals is strictly osecuted, not only with the liveliness of curiosity, the ardour of knowledg the ambition of distinction, but with the stimulus of want & interest.

The careles manner in which mines are worked in England will some time (perhaps 100 years) hence be felt by our posterity; instead of taking out what is wanted, the miners waste the precious ore, and England, prodigal in abundance, will be resourceless in want. On the continent the mines are under the prtection & inspection of government, and the owners act under its eye. "The husbandman may sow, neglect, or mismanage his crop" - it is thus they reason - "& the loss is purely his own - posterity is in no manner affected by it - not so in the case of the possessor of mines - these descend an everlasting inheritance to posterity, and mismanagement is fatal - that wh. is thrown away cannot be recalled - once pillage the vein, and it is for ever empty, metals do not grow like the sowing of the husbandman." Acting from such considerations a body of men is constituted, consisting of the younger sons & brothers of noblemen, in fact all such people as with us block up the entrances or the inside of the church - these superintend the miners and that office wh. in England is filled by private individuals of humble station narrow minds & uncultivated understandings is there held by gentlemen in a public capacity, the most learned & scientific of the day. If a mine be discovered, the proprietor is commanded to work it; if he have no capital, government advance him monies; but work it he must & under their directions.

Mineralogy is closely allied to many sciences; to Chemistry, Mathematics, Hydraulics, Metallurgy, Subterraneous Geometry. Of these it will be only necessary to explain the last, it relates to the measurement of distances &c underground - the perfection they have arrived at in this branch of science will be shown by the following circumstance which has lately taken place in Somersetshire. In a mine 500 feet below the surface of the earth a well was dug - it was then required to dig a well from the surface of the earth to the mine so, that it should just fit on to the other and be in a line with it/a continuation of it - they took their measurements, made their calculations & began digging at the surface till they arrived at the mine, & it was found that the ring/circumference of the upper well which they had just been digging fitted exactly to the ring of the one below to wh. they had meant to fit it.

The science of Mineralogy has much fewer subjects to treat upon than have Botany or Zoology, and yet it is much less known, - the whole number of Minerals is at most 500 - these a little practice will fix in the memory & a small cabinet will contain - whereas there are 40,000 kinds of plants, and 160,000 of insects alone. The reason of its being less known is the difficulty of classification. Minerals have no organization - & by this we distinguish classes in Botany & Zoology - thus animals that have claws have also certain teeth, a certain stomach adapted to digest animal food &c - animals that have certain feet, also ruminate &c &c - but there is no such consistent harmony of parts in minerals, we cannot infer from a mineral's having this quality that it has that as we can in organised bodies - thus each individual mineral is in a class by itself. The great number of subjects of Botany & Zoology above mentioned dwindles down by classification - you have not to remember 40,000 or 160,000 but this number of classes; these you must have by heart & to these you may by its organization - refer plants you never saw before; whereas you must have all 500 minerals in your head since every one is in a separate class. The only two ways of classification that have been discovered are, 1st from external form, 2nd from chemical analysis. The former is evidently defective, observe these different crystals; they are all in cubes, therefore they must be referred to the same class; but these are crystals of iron & lead, those of zinc, those of fluor spar, those of carbonate of lime, those of common salt. Nor will the second mode, though much preferable, answer to our wishes: for chemical analysis ranks the diamond & pure charcoal as identically the same thing. We must therefore make use of both methods & get on as well as we can.

The mention of organization leads me to notice an important distinction between organized bodies & minerals. Organization is attended by circulation of fluids - and the effect of circulation is to add something & to take away. Thus an organized frame is no two days the same, it is constantly changing, and in the case of our own bodies there is not a particle of matter in them which was there 14 years ago. On the contrary what is once deposited as parts of the substance of a mineral is always so, there is no change, no succession, no subtraction. Minerals do indeed increase, but not that increase which arises from circulation & is denominated growth; they do not grow. In some cases they appear to do so, but it is in consequence of incrustation; when they increase, they are built up like a wall layer on layer. This may satisfactorily be shown by observing that incrustations are divided into parallel plates, like layers of bricks. Bones on the other hand (I take the example of bones as resembling in appearance minerals) have always something added & taken away by the circulating juices - this is clear, or else the skull for instance would be continually getting thicker & thicker. These incrustations then, which are formed by means of several earths, we shall consider in our next lecture.

Before I proceed with the subject of incrustations it may be proper to notice an objection wh may be raised to my assertion of the incapacity of minerals for growth, and show the consequence of their growing, supposing they did so. The farmer will assure you that stones grow in his field - that every three years a fresh crop of these spontaneous productions appears - it is no such thing, they do not grow and the following is the true cause of the appearance wh. may best be explained by an illustration. Suppose you have two or three layers of marbles, one upon another; sprinkle over them some mould & place them on some mould; then with a watering-pot water them - the wet moistens the earth under the bottom range of marbles & forms with it a kind of incrustation which of course makes room for itself by pushing up the lowest layer & consequently all the other layers - hence the topmost layer appears above the surface of the mould which was sprinkled at top - gather off the marbles that have protruded themselves, & water the rest again - again incrustations are formed wh in like manner shoot up a second layer of marbles & so on. This is exactly the effect the rain produces - and let it be noted that according to this explanation the soil is supposed to be loose like marbles and the earth wh constitutes the base of an earth wh is accustomed to incrust - and this is the case - stones never appear to grow on clay or a hard rock, but always in a porous soil as gravel, and never but on a basis that will incrust viz limestone. If however minerals did grow, observe the consequences - they are imperishable and are not subject to the decay of vegetables - hence if they once increased their size, they would nevel lose that increase, consequently all rocks would always be growing larger & larger & the globe itself would be always increasing; - now this other sciences inform us to be not true. As it is, incrustations are partial, can only take place in certain earths & from certain favourable circumstances.

By much the principal agent & material in incrustation is calcareous earth (limestones &c) - this is continually manifesting itself in two ways - in stalactitic incrustations & in that kind wh is denominated petrifactions - the former principally takes place in caves - a drop of water is formed on the roof, it collects slowly, & is some time before its weight causes it to fall - in this while the calcareous earth with wh the water is impregnated attaches itself to the roof and is left there by the drop & gradually hardens; in the meantime a second drop has been formed & left a portion of the same substance wh. forms a case around the first - thus it gradually increases in bulk by successive coats of earth, till at last it has the appearance of a large icecle - this is a stalactite - a stalagmite is of precisely the same nature, but formed on the floor instead of the roof by the calcareous earth which accompanied the water when it dropped - this is deposited in the same way & is built up towards the stalactite - sometimes they meet & form pillars of grotesque appearance & rustic structure. (Pliny notices a cave of this sort & says a very learned man assured him the stones grew - you observe the explanation JHN). It is obvious that this natural process will in time fill up the cave and this is the reason why many caves wh were known once to exist cannot now be discovered. An instance of this has lately been afforded by the excavations in the rocks at Plymouth for the purpose of supplying stone for the Breakwater - the workmen found the bones of elephants, rhinoceroses, bears & stags imbedded in the limestone (observe calcareous earth) - the people there maintain the animals to be of the date & coeval with the rock - nay, if you happen to go there & presume to offer a different opinion, I assure you you will very much offend them - in reality, it has been a stalactitic cave, the resort of these animals, and by gradual incrustations filled up. The most beautiful stalactitic cave I ever saw was one in Styria - stalactites are generally of a dirty yellow colour but these are of a snowy whiteness - the shape & appearance I cannot attempt to describe, but you will arrive at something like an idea of it if you fancy miriads of the most delicate gossamers fringed with the most minute drops possible of rime frost. I will not quit the subject of stalactites without observing by the way that the alabaster of which the ancients formed urns &c called from its beauty "Oriental Alabaster", and wh used to be considered sulphat of lime, gypsum, has been discovered to be a carbonate of lime; calcareous; with a small quantity of strontian it forms Arragonite, a beautiful stalactitic substance; when Belzoni lately penetrated into the celebrated tomb of _____ [sic], he found it consisted of beautiful alabater - the lid had been smashed by some former visitant; they consequently analized a portion & found it to be Arragonite.

The second kind of incrustation is petrifaction - the most common instance of this is the stony substance wh forms inside kettles &c if the water (used to be boiled in them) happens to contain calcareous earth. I send these specimens round. Some years back when the conduit at Carfax was removed this pipe was dug up; you see it is incrusted on all four sides with a stony substance, and (what I would particularly recomment to your attention) no obedience has been paid in the formation to the laws of gravitation , for all four sides are equally & impartially clothed - this we cannot account for. There are many streams so charged with carbonate of lime that they petrify any thing submitted to their action. There is a celebrated one at Sanfilippo in Italy - they put into it moulds of basso or alto relievos &c wh they wish formed, the stream gradually fills them up with the carbonat, they then take out the moulds, & find in them the most beautiful sculptures they could desire and glossed with this fine natural polish. At ____ [sic] in France, the calcareous earth is so abundant in the water that any thing you put in is in the course of six weeks completely petrified. You see for sale petrified flowers, furit, branches, insects, fish, cats, dogs in short all kinds of things. This basket of grapes was petrified there; it is however you see broken & spoilt by the carelessness of the Custom-house officers - not the English for they are always very attentive but in France. We often find bones, iron &c entangled together in this way by calcareous matter from the same cause. The hot springs in Iceland & at Carlsbad have the same effect. Indeed it is needless to multiply instances. This then is the great material of incrustations; they are very seldom owing to any other earth, but for silex and sometimes alumino are the only two besides wh have the property.

We will therefore say a few words on silicious incrustations. They are very scarce. Agates are formed by drops of water impregnated with silex dripping from basalt or jasper rocks: chalcedony also has the same origin. These specimens of the latter are remarkable for their shapes since they exactly you may observe resemble that of a drop or collection of drops. I forgot to observe that the phenomenon once so surprising, of living toads being discovered in stones, belongs to the subject of calcareous incrustation. The rock they are in is always limestone. Naturally a sluggish animal the toad when young retires to some recess of the rock wh is provided with a small aperture instinctively knowing that insects (its food) are fond of entering such cavities; here it thrives on its prey till good living and advancing age renders it too corpulent to escape through the entrance - when it finds this to be the case, its philosophy is exemplary; instead of fretting itself with uneasiness, it abandons itself to torpidity & slumber; &

if an incrustation forms over the entrance, it is incased in the stone - thus it will live 5 or 6 years. It sometimes is similarly situated in trees & from similar causes.

Into this digression we have been led by mentioning the common origin of the growth of minerals; greater arrangement will attend our further inquiries. In our next lecture we shall consider the elements of minerals; the next will be taken up with some introductory observations respecting the metals wh are the basis of minerals. After these two lectures we shall proceed according to the arrangements of Dr Kidd's Mineralogy, dividing minerals into the four classes of Earthy substances, saline, combustible, & metallic. We begin with limestone after wh we shall insert some observations concerning chrystallography. Before however I conclude this lecture I will just point out the line of demarcation between mineralogy & geology. The former considers simple minerals, the latter aggregated rocks, (or rocks mechanically compounded of simple minerals. JHN.). Thus to Geology belongs granite, to Mineralogy the three minerals of which granite is composed, namely felspar, quartz, & mica.

In telling over the list of the simple elements of minerals we shall begin with water. Water is a mineral in a liquid state; just as much a mineral as qucksilver is - and it combines with various substances - these compositions are then styled hydrates, thus mortar is an hydrate of lime. When it is an [sic] material agent in the formation of chrystals, it is called the water of chrystallization. We shall give four instances of this: 1st selenite - this is chrystallized gypsum, and owes its transparency to the water; many substances however are transparent without containing water - observe this plate of mica, we can see through & yet it is a compound of silex & alumine - in this case we must use heat as a test. If a transparent substance contain water, the heat drives it out and leaves it opake - not much effect is produced if water does not enter into its composition. I shall now submit both these minerals to the blowpipe - first the selenite - it is changed immediately to an opake white - now the mica; ah! the experiment seems to have failed for this appears white too; but such appearance is owing to the splitting of the lamina by the heat - if you were to take each of these little scales separately you would find them as transparent as before. - 2 Hydrargilite - called also Wavelite from Dr. Wavel the discoverer - this is an hydrate of argil or alumina, whence the name. 3 Turquois - there is but one mine in the world wh contains this mineral & that is in Persia & belongs exclusively to the Monarch - it is a compound of argil coloured by iron - here are some calves-teeth wh the colouring of iron has changed into a kind of turquois. 4. Stones from volcanoes; at first sight it does not appear very probable that water should be in such a place; however so it is, - in lava there is much: pumice is a species of lava in wh the water has fretted itself into numerous little bladders, & given the stone an appearance of sponginess. I must however observe with respect to the combination of water with minerals, that it is chemical combination of wh I speak. For some times a stone contains a little cavity inside wh is filled up with water; this is quite a different case. I send round specimens of this singular circumstance - a piece of selenite from Shotover - some agates from Italy - and a piece of fluor spar from Cumberland wh a man now in this Town for a day or two has lent me; he prizes it as high as 8 or 10 guineas for it is a very rare thing in fluor. [sic] Oxygen; - it is a solid body - half of every thing we see is oxygen in a solid state; it is the most universal agent there is; half all the chalk in the world (and chalk constitutes 1/8 of the crust of the earth) is oxygen, half silex, the most abundant earth in nature; half alumine; much of magnesia; much of soda. Yet of so coy & subtile a nature is it, that it is as yet impossible to produce it uncombined with some other substance; it will fly to some mineral or other; we cannot perceive its own peculiar form, its taste, its smell; the simplest state we can get it in is when combined with calorie; then it is called oxygen gas; in this state it is dissolved in calorie just as sugar in water; & thus becomes invisible. It was called οξυγεν by Lavoissier from the idea of its being the acidifying principle: this however is now found to be erroneous; since hydrogen acidifies fluorine & chlorine. Hydrogen - supposed to be a metal; dissolved in calorie, when in the shape of gas its presence in mines is sufficient to lead to the presumption of it being a mineral; it there is constantly issuing from the clefs [sic] and fissures of the rocks, and is particularly dangerous from its inflammable nature. It was against the frequent accidents from this circumstance that this safety lamp was invented by Sir H Davy - its construction is very simple - it is you see incased by a very fine gauze-work of metal, the inflammable air enters the apertures, the light of the lamp inflames it and all within the gauze-work explodes, but there it stops; bounds are set to these terrible agents of Nature by the powers of Art; cold metal has not the property of communicating heat rapidly, the apertures in the gauze are very small & the flame in passing through these is chilled & extinguished - to show the perfect confidence that may be placed in this contrivance I need only mention the example of Mr Conybeare last year; he went down with this lamp into the part of a mine where hydrogen was known to be most abundant; and repeatedly did plunge up his lamp into the thickest part of the gas above (for from its great lightness it is most abundant near the roof;) and as constantly did the gas within the lanthorn explode and the flame then cease; had the flame been comminicated through, the whole mine would have been robed in flames & blown up. This gas often issues through fissures of mountains, and produces what are termed pseudo-volcanoes - these are frequent in the Apennines; some are so small that our guide put them out by throwing a little water on them. They constantly occur on the coast of the Black Sea & _____ [sic] has satisfactorily proved the Chimera of the ancients to have been a mountain of this kind. There are some at Niagara; but it were endless to proceed in the enumeration. Hydrogen also is frequently present in siliceous and calcareous substances; as is proved by the disagreeable odour that attends a stroke of the hammer. Nitrogen, an ingredient in atmospheric air. Chlorine, so called by Sir H. Davy from its yellow colour - with hydrogen it forms muriatic acid gas - in common salt it is in a solid state. Fluorine - with hydrogen it forms fluoric acid, so called because extracted from fluorspar, and this again so called because it is used as a flux by the workmen in melting lead. (A flux is some substance used to make metals melt easier - thus fluorspar is a flux for lead, limestone for iron - &c - I am unacquainted with the chemical reasons. JHN.) Carbon - the diamond is pure carbon - charcoal is the same, with a little water - you would not expect to find water here - but there is water even in tinder - it is the presence of carbon or charcoal that makes common gas burn so bright, for that is hydrogen gas with charcoal dissolved in in. Vegetables contain it in abundance - if these decay underground they undergo a striking change for they come out in the shape of coal. Sulphur - Phosphorus - 4 Alkalies - Potass - Soda - Ammonia, Lithia - a description of these is the province of chemistry. 1. Earths. - speaking in general terms the earths & alkalies are metallic oxydes. The *ancients*, in assuming fire, water, earth & air as the four elements, constituted the earths the bases of the metals; unluckily this was a very bad hit indeed, for it happens to be just the reverse; the metals are the bases of the earths. The earths are generally white. I shall only mention the principal. Lime is never found pure in nature - Magnesia very rarely - Baryt is the heaviest being nearly 5 times heavier than water - Strontian - Alumine is the great constituent of most of the precious stones. Silex as I have before observed is the most abundant in the crust of the globe of any earth - it is also contained in vegetables - try these reeds against your nail & you will find it filed - this is owing to the presence of silex - it is also in grass - this mass of silex is part of an hay stack (from Lord ____ [sic]) that was burnt down - the base of this earth is supposed to be not a metal but a substance analagous to phosphorus, sulphur, &c. - so metals.

We proceed to some introductory remarks on the metals. They are in number 30, of wh gold, silver, copper, iron, tin, lead, & mercury were the only ones known to the ancients. 12 are native; by native I mean found uncombined in nature. Thus gold & silver for instance may be obtained from the ore by mere mechanical separation; not so in the case of iron, & many others. It were easy to collect what metals are native & what not by observing which are in use among barbarians who cannot have any notion of chemical analysis. Thus we find in every age copper has been the favourite metal for arms & utensils among uncivilized nations, as being native; whilst iron is not made use for a long time, because it is not native. Yet in the late expendition to the Northern regions the weapons of the Esquimaux were discovered to be iron; but made of what kind of iron? - native. This leads me to mention the only case in which iron is found native. The fact is well established that masses of metal frequently fall to the earth seemingly from the sky. Various hypotheses have been framed to meet this phenomenon - the nature of these substances seems to prove they do [? "not" missing here] proceed from any volcano &c on our globe for they consist of nickel, and iron in a pure uncombined state - which has never been found anywhere on the earth. It is not my province to build up any hypothesis. I will just mention the two opinions wh now are prevalent of wh the latter is much the more probably. The first is that these stones are formed in the air, the second that they are part of the wreck of some smashed planet the fragments of wh are wandering through space. To proceed - it is observable that metals which are the most useful things in nature are found in very great abundance, & each metal in proportion to its utility. Iron is the most useful of all, and consequently there is no country in the earth, no soil, no stratum where it is not found.

Nay there is something still more wonderful in the case of iron & indisputably showing the hand of a wise Creator. Iron as not being found native must require of stony heat (& consequently expends much fuel) to be extracted from the ore, & besides requires a flux to reduce it to a state of liquidity - now it is a very remarkable thing that in no part of the world is an iron mine found without beds of coal lying upon it, & limestone (which is the best flux and always used as the flux) beneath it. If this were not the case, fuel and limestone must at immense trouble have been brought to the mine, & the workings of this indispensible metal had been attended with excessive difficulties. Metals are found in five states in combination, alloyed, as sulphurets, as sulphates & muriates, as oxyds, and as salts. To explain these terms is the province of chemistry; I shall only observe that now the term salt is not used in the extensive sense wh was formerly given to it - it means only that species (of the genus wh used to be called salts) wh is soluble in water. Metals have many peculiar characters - 1st Lustre - the metallic lustre is easier to understand than to explain - this however is its property that the shining surfact though scratched is still shining - if I scratch this polished piece of mica, the scratch is dull - not so with the metals. 2nd The opacity of metals is a second characteristic - beat out silver to 1/100,000 of an inch, *gold to 1/280,000 and the rays of light will* not be transmitted - the latter metal however will transmit the green ray & of this you may satisfy yourselves by a piece of gold leaf. 3 Malleability, wh is much increased by heat. 4 The ductility of metals is owing to the strong attraction of the particles for each other - it is preferable they think to be united in any manner rather than to suffer separation; they therefore instead of parting on the blow of the hammer slide on one side till they are beaten out in length to an incredible extent. 5 It may surprise some of us to hear that metals are not hard. Iron itself which is the hardest is rendered harder by the addition of carbon to strengthen the interstices of the particles, that is when in the shape of steel - for steel will scratch any metal whatever. May it not be adduced a proof of the softness of metals that they will not scratch glass. Metals are rendered harder by alloying & this was known in the earliest times - these knives saws &c wh I send round are made of copper & tin. They were dug up in Cornwall & are evidently the workmanship of the Phenicians. 6. Metals have a strong ? avidity for caloric. Hence in cold climates they eagerly absorb the little heat there is from other bodies. In the late Expedition to the North if the situation of a man's cot happened to be near one of the iron nails or fastenings of the ship, in the morning might be seen a long icicle extending from the metal towards the hammock, occasioned by the freezing of his breath during sleep. I could give another instance from the same expedition. Captain's [sic] Sabine attempted to look at the Sun in the reflector of his telescope - the metal reflector had drunk in the heat & drawing it into the other focus where his eye was, had the same effect that a red hot iron would have had upon it. Many of us here are Wickhamites and can recollect that in the dinner hall of Winchester the metal mugs of beer are warmed by placing their handles between the perpendicular bars (of the grating) of the stone that stands in the middle. The mug is taken out by the body and the handle wh has been close to the fire is presented to those at dinner - does it burn their hands? No - the heat is equally communicated through every part of the metal. 7. Fusibility - this is rendered greater by alloying. 8. The Capacity for oxydating is different in different metals. I will only instance three - if we suppose the metals to be gifted with different passions, we should say that gold hates oxygen - it entertails a perfect horror & detestation of it - it is with the greatest difficulty it can be made to receive it, & then on the first opportunity it throws it off. Manganese on the contrary loves oxygen - it seizes on it wherever it can find it, keeps it & with the greatest difficulty can be made to part with it. Lead however is in a happy state of indifference - if oxygen chooses to come, let it - it receives it, does not care much about it, makes no effort to keep it, & does not break its heart when it goes away.

The division of minerals into the four classes of earths, salts, combustibles and metals is very ancient - in the 11th century Avicenna an Arabian distinguished them into salts, combustibles, metals, and stones - mineralogy however made no progress - the next who at all studied it was Linneus [sic], but he left it as he found it - he adopted the classes of Avicenna as a subdivision, while his grand division was into the three species of stones, metals, and fossiles [sic]. It was not till of late years that the science was cultivated with any thing like success, and it is indebted for its present elevated rank in the scale of philosophical knowledge to the labours & sagacity of three illustrious foreigners, Klaproth, Werner, Haüy. Klaproth was the first to analyse minerals & reported their composition; Werner distinguished their external form; Haüy has discovered the beautiful system of chrystallography & has raised the science upon the same firm mathematical base wh supports the conclusions of the Newtonian philosophy. (I will here take the opportunity of observing what would more properly have been mentioned before - that chemical analysis though an excellent classification in the case of metals by no means suits the earths - many, many minerals are composed of several earths in nearly equal proportions - what for instance am I to do, in what class am I to rank a mineral compounded of 25 per cent silex, 25 magnesia, 25 lime & 25 oxyd of iron?)

<u>The Earths</u> - Lime. 1 Carbonat of Lime, or Limestone.

There are three kinds of limestone wh when we enter upon Geology, we shall learn to call primitive, transition, & secondary. The first kind is capable of a very high polish, the next not so fine as one, & the next a very inferior one indeed. The first kind contains no organic remains, the second some, the third abounds in them, nay there are secondary limestones wh have been altogether formed by the wreck of animal matter (shells for instance). Marbles are primitive limestone & of these those from Paros & Carrara have been principally made use of by the statuary. Parian marble sustains a very high polish & has a most beautiful waxy appearance; it is however of a very coarse grain, and is now and then interlined with mica & iron ore. This latter is a most serious defect; the circumstance of its course grain is unfortunate enough, since it renders it very bad for small figures; but this is fatal - after a time the iron oxydes & the mica decays, hence the statue is ruined. It is to this fatal defect that we owe the mutilation of some of the finest figures in the Elgin Marbles, it (is not the hand of the Goth, Iconoclast, or the Frank or Scott that has wasted their proportions, the seeds of decay were in the marble, & time was the only agent necessary to make the mischief visible.) Whether the Greeks found out this or not, it is certain that about 400 years before Christ the quarries of Paros were abandoned and the white, sparkling, fine-grained marble of Carrara was universally adopted, & has continued in use to the present day. The difference of grain in the Parian and Carrarian marbles enable us to tell with pretty great accuracy the date of any statue, for we know the time when the one supercedes the other. Hence we determine the Venue de Medicis to be of ancient, & the Apollo Belvidere of comparatively modern date. The Pentelic, celebrated as coming from Attica, is of the same kind as that of Paros; so is that Antiparos. There are several marbles used by the ancients; the quarries of wh cannot now be discovered; I send round specimens of the Verd Antique & Rouge Antique; the former probably came from some part of Greece, the latter from the northern coast of Africa. This Brocatello marble comes from Spain, its name intimates its extreme richness. Here is some of Cintra marbl, &c. &c. [Footnote by Newman referring to this point: "Since very frequently in the course of these lectures minerals have just been mentioned for the sake of showing specimens, I have sometimes thought it better to leave out the mention of such altogether, rather than fill my page with a barren list of hard names."] Many attempts have been made to find marbles amongst us; they have & must be fruitless. Marble, a primitive rock, must be looked for in the primitive country; and England is not a primitive country. Here are some Scotch & Irish; the latter resemble Parian, but the grain is yet coarser & the lines of mica more frequent. Carbonate of lime may be known from sulpaht by two tests; the latter yields to the nail, the former effervesces on the application of any acid. There is a species of limestone, wh has been denominated, from the presence of magnesia, magnesian limestone - this will not at first effervesce, & therefore may deceive you. If however a small piece be immersed in an acid, it will effervesce though slowly. Calcareous earth may be known from silicious by yielding to the knife, since the latter it will not. We have said so much of carbonat of lime in our introduction that there seems no need of dwelling upon it at present.

2. Sulphate of lime. Of this there is little to say - sulphat of lime when chrystallized is named selenite; if not chrystallized, gypsum & if it contain no water, anhydrous gypsum. The specimens in this drawer are numerous & you had better consult them after lecture; this is from Montmartre, this from the Ural Mountains, this from Snowdon - you will observe they each have some peculiarity of appearance, & this so decidedly, that, were I to find this clouded kind in the deserts of Siberia, I should be certain it came from Wales. 3. Fluate of lime is of different colours, this is familiar to every one as the beautiful fluorspar of Derbyshire. Green fluor is phosphorescent by the application of heat; & a German who superintends the works at the Ural mountains has taken advantage of this prôperty to ornament his stove; it is set round with a great number of green fluor spars, & whenever the heat makes the stove at all warm, the spars present the appearance of a brilliant white illumination. $. Phosphates of lime -

our bones are composed of phosphate of lime; in a mineral state it is found in primitive mountains only; in this huge ganite block you may see the chrystals imbedded, this came from Spain. 5. Borat of lime of wh. this is a specimen.

Baryt. This appears in two forms only; the sulphat, & the carbonat; the former is abundant, the latter scarce; the latter is very poisonous. This earth may be always known by its great weight.

Strontian. This likewise shows itself in the sulphat & carbonat only, the former is blueish, hence called celestin, the latter may be distinguished by its green colour.

Silex is the most abundant of the earths; there is hardly any place where it is not present. In a simple state it forms the grand constituent of those immense plains of sand wh overspread the continents of Asia & Africa. In a compounded state it constitutes 2/3 of the granite of the mountain (as may easily shown by analysing the component parts.) - nay it so far incroaches upon the territories of its sister earths that 80 or 90 percent of the most stocky clays is silex. As I have before observed it is present in vegetables - a grain of corn contains silex, alumine, magnesia, & lime - there is more silex in rye & oats than wheat. It is from this circumstance that burnt straw is used for polishing mirrors: the very very small particles of silex contained in the straw are very hard & consequently make the finest scratch for polishing we can obtain. Quartz is pure chrystallized silex - this obtains the name of diamonds sometimes as Bristol, Bagshot diamonds &c. - when coloured it forms a variety of mock gems - purple quartz is the amethyst. Flint is nearly pure quartz - when the steel is struck again the flint, the the greater hardness of the latter break off very minute bits of the metal, wh are ignited by the friction. That is is [sic] the case I know from bad experience, for one day when striking a light one of the burning particles got into my eye, & lodged in the cornea; I was obliged to be for some time under the hands of an oculist & part of the metal still remains in the lodging it has chosen. Chalcedony is less compact than quartz - it is formed in the cavities of trap rocks; I send round specimens of it, as also of cornelian, opal, onyx, sard & sardonyx - the colours of cornelian are the effect of artificial heat. The lines and branches imprinted on this inopal are metallic. I might relate a pleasant incident of a gentleman who had a snuff box made of this stone - to his great surprise it gradually got larger, & at the end of some time was twice the size it was when purchased - the truth was the metal had expanded by the constant heat of the pocket. Here are so [sic] Egyptian pebbles - what are called Scotch Pebbles are not really pebbles; by pebble I mean a piece of stone which has been rounded by the action of water - now these Scotch stones assume their round from from the cavities of the rock into wh they have been poured whilst in a fluid state. I send round a specimen of the French Bahrstone; its excessive hardness wh is owing to the quantity of fine silex renders it invaluable for mill-stones - it abounds about Paris; in England a pair of mill-stones made of it would cost £60. Its hardness is such that no mechanical force will split it; the artifice by wh we effect our purpose depends upon the principles of capillary attraction. A number of small holes are bored in it, and willow tubes filled with water are inserted in them, the capillary attraction brings the water together through the ends of the tubes inserted in the stone, & this splits the sullen mass. It is from this same principle of capillary attraction that a mushroom is enabled, as is frequently the case, to raise up a flagstone of a hundredweight. Gunflints are chalk flints; will it be necessary to send round specimens of these? Flint cannot be melted by any artificial means, but there can be no doubt nature has the power of doing it. When however chalk is added to it, we <u>can</u> melt it. These chalk-flints have been taken from a kiln, where the heat has vitrified the silex & surrounded the stone with a coat of glass. With the addition of soda flint melts into glass.

Having now gone through the most important earths we proceed to the interesting subject of chrystallization.

Chrystal in its primary signification, why need I mention this to such an audience, means ice - it was by ancients applied in a secondary sense to those masses of quartz which are still called rock chrystals; for these resemble ice in colour, in transparency, in brilliancy & it was the prevalent idea that such rocks would melt if brought into a warm climate. The Modern Mineralogists have perverted the term chrystal still further from its original meaning. In the language of modern science a chrystal is any mineral that has a regular external appearance accompanied by a regular internal structure. It need not be transparent. Chrystallization is effected both by fire & water - melted metal will chrystallize as readily as a solution of Glauber's salts - chrystals are found both in the cavern pervious to the water, & in the mountain pouring out fire. Nothing is requisite to chrystallization but a liberty for the particles of matter to move freely among themselves and settle as they will. Several of these observations must at present be obscure to the beginner, we proceed therefore to render ourselves more intelligible.

If we take a chrystal and examine it, we shall find it split in certain directions & not in others. The Abbe Hauy has, by a continually paring of the sides of chrystals in the directions in wh they would split, reduced all chrystals to 5 primitive forms. His argument was then as follows: "I assume (for this I think a likely hypothesis) I assume that, for instance, the primitive chrystal of calcareous spar to be that to wh I can ultimately by paring reduce all calcareous spar chrystals. Assuming this I proceed to erect a theory wh if correct may be demonstrated mathematically. My idea is that when this spar is in solution it deposits its primitive (rhomboidal solid) chrystal - the solution however is not all exhausted so it goes on depositing more - however, suppose it weaker, suppose more water in what remains than before (& that of course there must be) the solution thus weaker, will not have strength enough to lay upon the six sides of the rhomboidal solid plates equal to the present superficies - they will be smaller every way - hence this process proceeding and the solution getting continually weaker & weaker - at length a 4 sided pyramid will be erected on each of the 6 sides - hence the figure of the primitive chrystal will be completely changed - to see if this be correct I will try the experiment making the solution constantly become weaker -". He did this, & found that by altering the strength of the solution he could make his chrystals what shape he pleased of those wh (for instance) calcareous spar assumes. He reasoned the same way concerning a solution continually increasing in strength - with the same result & the same confirmation of actual experiment. These he calls the increments & decrements of a chrystal. He then proceeds as follows, "Now since I have determined the primitive forms of each chrystal I may mathematically compute how *many different secondary* shapes each chrystal may assume by the increment or decrement of the sides. Thus fluor spar, being primitively an octohedron, ought to have so many variations - calcareous spar, being a rhomboidal solid, so many; let me consult the book of nature & find whether the same number of variations is written there.". It was - the number his mathematical computation gave was in every case exactly the same as that wh nature afforded. This was clear demonstration of the truth of his system; & so clearly did he see into it & so convinced was he of its accuracy, that when a mineral we have before mentioned, Arragonite, was shown and it was objected that it bore a form such as calcareous spar never could wear according to his theory, he boldly declared it was not, it could not, be a carbonat of lime, they had analyzed it wrong, let them analyze it again. They did so, and found he was right - it contained a little strontian.

The exactness with wh chrystals are formed is beyond imagination. In the angles there is not the slightest variation in the same kind: take two chrystals of fluor (for instance) and you will not be able by Dr. Woolaston's [sic] goniometer (wh you see it before you, is so wonderfully constructed that the lesser the angle the better it acts) to detect the slightest, no not tho 1/10,000 of a degree, difference between the angels. It is an exactness of wh we can have no conception how it exists; art, art, how art shrinks before it! So much for the external form, concerning the internal structure little needs to be said. It is sufficient to observe that the parts of a chrystal are similar to the whole, a cube is made up of little cubes & so on. Smash a chrystal on the ground & you have broken it into a number of chrystals similar to the large one; break that one again & the same thing occurs. Here then mechanical division stops; here is a line of demarcation beyond wh the knife of steel can do nothing: we must then have recourse to a more piercing instrument, the knife of mathematics. To enter in the long series of arguments by wh the following facts are proved, neither time nor my ability nor the nature of these lectures would allow; I shall therefore briefly relate them without any attempt at proof. It is discovered that the integrant molecules wh make up every the least piece of the chrystal are figures of three kinds; the primitive figures are, it was before observed, 5 - the tetrahedron, the cube, the hexhedron, the octahedron, the dodecahedron. The 3 forms of the integrant molecules are the simplest of the solid figures, & this we might naturally expect, the tetrahedron, the pentahedron, the cube. Now these integrant particules are still of the same substances as the whole mass - thus the int. part. of calcareous spar is still carbonat of lime - & that is compound - these integrant molecules therefore must be divisible into the constituent molecules - & these are discovered to be either tetrahedrons or spheres - most probably the latter - if so, it is a wonderful reflection that that form wh belongs to the bodies wh. are greatest in nature, should also belong to the smallest.

We proceed to investigate the cause why there is any such thing as chrystallization. Let us suppose the molecules which constitute the mass to be magnets possessed of a north and sout pole. That this is a probable hypothesis will presently be shown - now it is evident that, since the poles of two magnets have reciprocally an attraction towards each other, two particles of matter wh lie adjacent to each other will not be still on their deposition till they have wriggled themselves into such a position that the north pole of the one shall touch the south pole of the other & vice versa - we are now reasoning ont he supposition that no external motion disturbs their free action - & this we before stated to be necessary for chrystallization - these two particles now become one will proceed with any other two become one in the same way, till the whole mass is thus united - this will account for the similarity of the parts of a chrystal to the whole - there must in this case be a regular external form & a regular internal structure - thus we observe that on the supposition of the agency of magnetism the effects desired is produced. That magnetism will produce this effect may also be shown by throwing a parcel of magnets into a bucket of quicksilver - they will wriggle about as if uncomfortable, nor cease their action till their poles reciprocally join. We have now advanced so far as to show that magnetism is one of the causes that are able to produce chrystallization; but this is not enough, we must show it to be a probable cause, a cause wh is eligible from many others. To make this clear I must step a few paces back, & show that magnetism attends on electricity. It is not long since _____ [sic] a Swedish chemist while passing the electric through a galvanic wire observed that a magnetic needle which happened to stand above it instead of pointing to the north pointed to the east; he placed it below the wire it pointed to the west; he placed it parallel with it, it pointed to the north. He tried this experiment with the common electric wire, & the same effect was produced. He then published an account of this without attempting any solution. Sir H Davy on reading this statement tried the experiment with common needles instead of magnets - & found that those above & those below the wire were both turned into magnets, with this difference; that the north pole of the one was at the same extremity as the south pole of the other & vice versa. Those needles that were parallel to the wire were unchanged. Here he left it - then comes Dr. Woolaston [sic]. "A wire of electricity" says he, "is attended by a volume of magnetism which revolves round the wire - this will account for the phenomenon observed by Sir H Davy - for it is plain that the stream of this magnetic atmosphere will enter the needle that is below the wire at the different end to that by wh it will enter the needle that is above the wire - no wonder then that the poles are the reverse - the needle that is on a line with the wire will not be entered at either end by the magnetism first - the stream will pass through the whole needle/magnet transversely & not ......[? thrill] through it from one pole to the other; we may easily conceive therefore that it need not be affected." He then proceeded to show by the test of actual experiment that if a revolving stream of magnetism be artificially constructed it will have the same effect on the magnet which was observed by the Swede in the case of the electric wire. He placed four magnetic needles so as to represent the sides of a square - with the north pole of the first next to the south of the second & so on. Thus a revolving stream was clearly made - he then held a magnet over these four needles it turned to the east; under, it turned to the west - parallel it pointed north - he held a common needle over, it was turned into a magnet - under, the same effect but with the poles reversed - parallel no effect produced. I have said enough then to establish my point that magnetism does accompany electricity; wherever the electricity exists frequently in nature, magnetism does too. Nōw it is known that electricity is <u>every where</u>, nature abounds, nay more than abounds in it; it produces a thousand effects in the most common things; it is said to be the cause of chemical combination; as far therefore as I am carrying the universality of electricity, <u>so</u> far do I carry the presence of its attendant magnetism. Nor does the evidence for the presence of magnetism in bodies stop here; it does not depend on this proof from electricity alone; observe this chrystal, see how it refracts a double image of anything submitted to it; consider the polarization of light from what does it arise but from the particles of matter crossing each other, and taking different directions from the agency of magnetism; here is an additional proof taken from Optics; from the discoveries of Newton, confirming the conjectures to which recent phenomena in electricity have led us. Surely then we may safely decide on the universality of magnetism. The case therefore stands thus; an effect exists which it is known may be produced by a certain cause, & this very cause we discover every where in nature, & more conspicuous in some of those very substances in wh the effect exists. This is the very basis on wh the system of the heavens, those discoveries, the great boast of the mighty mind of Newton stand; surely we may be content to rest our assertions on the same foundation on wh our knowledge of the motiȯn of the planets is supported.

Many chrystals are electric - we may distinguish from their having their extremities different in shape; one of these is the pole of negative, the other of positive electricity. To know when a mineral is at all magnetic we must have recourse to a stratagem devised by Hauy. Without this expedient you very frequently cannot detect it. For instance, if I present a stone I suspect to be magnetic to a magnetic needle, it will not turn it unless its magnetism is greater than the attraction the needle has for the north - place therefore a piece of iron at the north pole of the needle and equally attracted towards the north & the south it will swing round to the east &

remains there so equally poised & so hesitating between the two attractions that if the suspected stone contains the least magentism it will be sufficient to turn it to thė right or the left. An [sic] similar expendiėnt is made use of at sea to prevent the magnet wavering, as the rolling of the vessel throws the guns &c to this side or that; the compass-box is coated with iron & thus the magnet equally attracted all sides is deaf to the iron wh would fain allure it to accompany its shiftings. There are three species of pseudomorphous chrystals, or those wh are composed of minerals wh should not chrystallize in the form they exhibit. If during the chrystallization the water be disturbed, the chrystals appear as if they were half turned round, as this model will show - these are called by Haüy hemitrope - they are common in fluor spar - metastatic are .... [sic].

The Metals. It is a question how the metals were produced. It seems certain they are of later date than the rocks in which they are found; but how did they get into those rocks in the manner we see at the present day. They are found in fissures, the mass seems to have split, & the metal some way or other to have deposited itself in the chasms at the time. Now the two favourite theories the Neptunian & the Plutonian each explains this circumstance suitably to its own views. "The metal has been deposited from above from an aqueous solution" says the Neptunian. "The liquid metal has been forcibly ejected up from below by the agency of fire" says the Plutonian. Unfortunately for the former supposition there are some ores which have no communication whatever with the upper parts of the rock, the fissure stopping before it reaches the top - unfortunately for the latter there are some wh have no communication whatever with the parts below the rock, the fissure stopping before it penetrates to the bottom - unfortunately for both there are some fissures which are stopped from above & below, wh neither extend high enough to allow of the metal's deposition nor deep enough to allow of its injection. Hence it not only is, not always by aqueous action, not only not always by igneous, but, it is sometimes neither by aqueous or igneous. I explain the formation of mines by supposing that before the great shock wh threw the metals into their present abodes, they were diffused in minute grains through the substance of the rock, but that the convulsion that ensued had the effect of squeezing the mass like a sponge, & consequently the metal was forced together into those chasms wh the same convulsion had occasioned. This has happened at many several times because coats of metal are sometimes found like many different stuceoings [sic] on a wall - sometimes also coats of spar are interposed. It is a most providential circumstance that the metals are lodged underground in the manner they are. Supposing they were on the surface of the earth & could be obtained without labour the first thing an invading army would do would be to destroy the mines just as now they destroy vegetation. In this way metals wh are necessary to man's living with any thing like comfort, without wh there could be no art, manufactures, navigation, commerce, or discoveries, would soon perish & man be left to barbarism. Cornwall is cracked across as this map presents in the most surprising manner - you see it is not confined to one fissure - many run parallel to each other & to the equator. It has been attempted to explain this by supposing that the earth when getting dry & firm would be disposed to crack as we see moist ground do every day, and that its centrifugal motion wh has a tendency to flatten its poles and increase its girth round the equator would cause it to split in the direction we see in Cornwall. The oldest of metals is Tin - lead & silver are also old - gold is not.

Gold is so ductile that a cube of it, whose dimensions are 1.1/4 may be beaten out into leaf sufficient to gild a silver wire that will go round the globe. It is remarkable for its freedom from oxydation, at least the heat of fire is not able to oxydate it. Not so the heat of the sun or the electric spark, either of wh are powerful enough to make it combine with oxygen.

This seems to point out some connection between the sun & electricity, & other experiments render such an idea extremely probable. Gold is generally found in the neighbourhood of the line. There is a remarkable contrast in aspect to place between it & silver. Gold is found in warm latitudes, in low levels, in sand & gravel, in grains; silver in cold countries, in high mountains, in the rock, & in ore. This however seems to be purely accidental, since no inference seems possible to be drawn from it. It seems probable that gold formerly was in lofty situations & inbedded [sic] in the rock but that the diluvial action has washed down the eminences, crumbled the solid substance of the mountain & carried it down to the sea, the gold being heavier remaining behind with some fragments of its native rock reduced to gravel. Gold seems to have been more abundant in former days, and it seems rather difficult to assign a reason for this. The Israelites seem to have obtained it from Sofala on the coast of Africa opposite to Madagascar, or even to have ventured round the Cape of Good Hope to the Guinea coast, wh supplies us with gold at the present day. It is observable that the time may come when it will not be worth while to procure this metal, as it is only accomplished with great labour; but it is the labour of savages & their labour is cheap; suppose them civilized & it will be not more worth their while than it is worth the while of the Portuguese to extract the gold from the sands of the Tagus.

Platīna or Platĭna, for you may call it wh you may call it wh you please, is the heaviest of metals; it does not rust, or contract & dilate from the temperature of the atmosphere - hence it is invaluable for pendulums &c wh require a very great nicety of parts. Its strong reflecting power renders it very useful for the reflector of telescopes - for glass will not do on account of the double reflection wh is given from its upper & lower sides - whereas metal presents only one surface to the eye. Platina has very great ductility. Dr Woolaston [sic] has spun it out into a wire only 1/10,000 inch in thickness. It is found in South America & a little in Spain, in the shape of very small grains as you see in this vial.

Silver has an astonishing avidity for sulphur - hence in the mines it is generally found in the shape of a sulpburet - (so is lead & copper) its fondness for sulphur is the cause of its tarnishing - for tarnish is nothing more than a coat of sulphur wh the silver has attracted from the atmosphere - the same is the case with the silver egg-spoon. I send round specimens of red silver, antimoniated silver &c &c.

Mercury has this peculiarity in its history in common with tin, they are both found in very few places in the world & then in very great abundance. There are only 4 quicksilver mines as yet discovered. In them it either appears native or else in the form of a sulphuret, when it is called cinnabar. Mercury is of great utility in the extraction of gold or silver from the ore on account of its great partiality for those metals. Suppose the ore is an alloy of gold & copper - this is melted and made to pass upon mercury - the lkatter uniting itself with the gold of the melted mass forms what is termed an amalgam. Thus the gold & copper are separated. It is easily [sic] to separate the mercury from the gold on account of its volatile nature - expost the amalgam to the fire - the lighter metal goes off in steam & the more solid remains at bottom.

Lead is a peculiar metal in several respects. It is hardly ever found without some portion of silver. The _____ess [sic] of ________ [sic] has a service of plate made of the silver extracted from her mines in ______shire [sic]. Lead will not alloy with iron; nor can it be beaten closer than a certain closeness - its particles cannot be made approach each other nearer than a certain proximity.

Copper is the most sonorous of metals - hence its use for bells, gongs, trumpets &c - silver however is often added to soften its harsh sound - hence the epithet of "silver" to "sound" - "silvertongued" &c.

Tin - when a metal is alloyed with tin, its ductility is destroyed - this curious property possesses in so surprising a degree that its fumes alone are able to render gold, the most ductile of the metals, as brittle as glass. Indeed it may observed [sic] as a general rule that alloys are brittle if the component metals are ductile & vice versa. Tin is used for the back of mirrors - a plate of tinfoil is spread on the glass, then quicksilver is poured on, and the affinity of the two metals causes them to unite. Tin in its natural state is an oxyd - it is found in very great abundance in the sands of Cornwall (it is to speak of a thing too well known to mention the mines) - it seems to have been washed down with the rocks in wh it resided from the tops of mountains by the force of the diluvial action. The manner adopted by the miners to separate the metal from the sand is simple enough. It is placed on platters & shaken under water - this motion causes the heavy particles of the metal to fall to the bottom of the heap, while the lighter grains of sand are carried away by the rushing force of the stream. There is in Cornwall (or rather was) a mine of tin worked under the sea. At the distance of two or three miles from land they let down an iron chimney, about six feet in diameter. A steam engine was employed on the shore to pump out the water; men descended, dug into the gravel, & began to work the mine with only a few feet of earth between them & the sea. The gravel easily admitted the water though, and they were obliged to make use of hurdles plastered with clay to keep the mine tolerably dry. This went on some time, the richness of the mine compensating the hazard & expense. When they had no occasion of working it, the machinery of the steam-engine was stopped, the chimney was filled with water, & so it would remain for months. One dark night however an unlucky ship ran aground & destroyed it - & since that time the probject has been abandoned.

Iron is the most abundant of metals - its incalculable use is not to be known except by its absence; it unites excellences of every kind; it is the hardest of metals & next to tin the lightest. It approaches nearest of metals to our idea of omnipresence, it is not confined to the mineral kingdom; vegetables possess it in abundance & so do animals. It is discovered in the hair & the blood; Dr. Clarke found it in the petals of roses & conjectures that the beautiful colour of that flower is owing to its presence. Iron is found in various states. These drawers contain abundant specimens of the marcasite, the homatite [sic], and the loadstone &c &c. The loadstone is rarely used now for the purposes of magnetism; for it is discovered that an artificial magnet may be rendered much more powerful than any natural one; indeed the loadstone has the power of making iron much more magnetic than it is itself. The iron we use comes from Norway. Steel is iron hardened by the addition of carbon. At present a way is discovered of softening steel & hardening it again wh promises to be of considerable utility in the arts. The only use to wh it has as yet been attempted to be applied is in the engraving of plates for bank notes. An American gentleman offered an invention to the committee wh seems to promise the greatest advantages. A steel plate is engraved with the form of words whatever it may be - a steel cylinder of the same length as the breadth of the plate & the same circumference as the length of the plate & is made to pass over the engraving; of course it retains the marks of the engraved plate in relief - this is hardened - other plates of steel are softened & this cylinder is rolled over them - hence they have all the marks of the engraving cut in them, & when hardened answer all the purposes of the engraver - thus it was found that at the expense of <u>one</u> engraving by this mechanical process an unlimited number of plates might be produced each fit for stamping off notes - they could therefore afford to expend a very large sum in [sic] the original plate & make it a most costly engraving & very difficult to be imitated - they tried this - & were on the point of producing the notes - by chance an engraver saw the plate and imitated it immediately so perfectly that one was not known from the other. Hence the plan altogether failed, not in the apparatus of the steel plates but in the original engraving; & it seems now completely demonstrated that there is no engraving so ingenious, so costly, or so laborious wh the necessity & application of the forger cannot copy. The steel of the Damascus sword blades is hardened by mechanical means - a number of thin strips of steel are hammered together till they adhere to each other. The Damascus blades are so famous that to relate any particular instance of their sharpness might seem superfluous, the marvellous nature however of one anecdote is too irresistibly tempting to be omitted - a Turkish offender was ordered to be beheaded - when on the scaffold the executioner instead of producing a regular & formal discharge of his painful office kept flourishing his Damascus blade in front of the prisoner. The latter at last became impatient - "why do you delay" said he - "to inflict the sentence of the Sultan?". "Oh do not make yourself at all uneasy," replied the skilful man, "your head has been off these two or three minutes - shake it & it will fall off" - He did so, & the words of the executioner were verified!

Of all states in wh iron is found the most interesting & most mysterious is when it is detected in those stones which are seen to fall from the sky. Meteoric stones contain native iron, nickel, & sometimes earths, such as magnesia. These were once supposed to be the produce of volcanoes; they are however authenticated to have fallen in every part of the world - how surprising then that there should be so many volcanoes wh are situated in regions no one can discover! Besides, their analysis gives always the same component parts, & always <u>different</u> from the produce of burning mountains. Some have supposed they came from a lunar mountain, & calculating on their ejection with a velocity half as great again as that of a cannon ball, they might do so - but the curve they describe is incompatible with such a notion. These stones do not sink above two feet in the earth - they would not penetrate deeper though they came from the moon; the resistance of the earth as a mass is so exceedingly great. It has been supposed, & with great reason, they are generated in the atmosphere. Their component parts may have been volatilized by heat, & have ascended up into the air, till an electric cloud met them, depriving them of the caloric, caused them to condense & fall to earth again. The thunder & lightening that attends them & their appearance, wh at 100 miles distant presents the same size as when close at hand, favour the idea of electricity & gradual condensation. However all the astronomers & philosophers reject this probable hypothesis; "it cannot be thus, the curve these stones describe is incompatible with such an explanation". The way then we must account for them is to suppose them the fragments of some smashed or exploded planet. It has long been observed that between Mars & Jupiter (I think) there is a vacant place as if the planet to wh it belonged had been destroyed. Sometime back three very small bodies one of them so small that its superficies is not greater than the county of York were discovered between the very two planets, & Piazzi formed the idea that they were the fragments of the broken globe. This opinion received considerable weight from the agreement of his à priori calculations with a succeeding discovery. "If" reasoned he, "there is a fourth fragment of my supposed plant, it must - I know by mathematics - move in the same plane as the others; I will therefore set my telescope in that direction in wh along it can be seen". The event justified his prediction; a little after eight, as regularly as any stage coach, the little planet was seen driving up. Hence it is the present opinion that an heavenly body has been exploded, split into four parts wh now traverse the space formerly occupied & that very many minute pieces, wh did not adhere to either of these four, are wandering through space with vague unsettled unhappy course, now whirled round one planet, now round another, till they happen in the midst of their vagaries to venture too near the centre of attraction & then they fall down to the surface of the attracting body. A quick motion through the air will produce the fire that attends them. If a match be violently thrust down an hollow cylinder the compressed air will be sufficient to set it on fire - & their curve is precisely that wh a body in such circumstances would describe.

Zinc and the inferior metals ....[sic]

The Salts. The salts have been divided into the three classes of metallic, earthy, and alkaline - of these the last is the most important division. 1 The metallic salts are four in number - mineralogically blue, green, white, red vitriol - in chemical phrases sulphat of copper, of iron, of mercury, of cobalt. 2. The earthy salts are only two and these are also sulphats - the first of alumine, or common alum, the second of magnesia, or common Epsom salts. Of the latter it may be noticed that it covers in great abundance those immense plains wh constitute the deserts of Siberia - & there is little doubt it is formed from the atmosphere - sulphur is known to be in the air, that it frequently holds earthy & metallic bodies in solution is also pretty certain; & the mention of magnesia leads the mind back to consider those wonderful stones wh one hypothesis conceives generated in the atmosphere, actually contain a portion of that earth. 3. The alkaline salts are numerous - I shall mention the principal - saltpetre, or more accurately nitrat of potash, is a most abundant salt. There is sufficient proof that this also is generated in the air; in a warm climate, for instance India, new ploughed fields are covered with it; it forms upon old walls & buildings; it was in this way the French collected it at Saragossa for the manufacture of gunpowder. The walls of the Pigmarket are frequently coated with it, & Dr Kidd has published an account in the Philosophical

Transactions of its formation on the sides of his room in this Museum. It is evident that the stone of the wall is not a material in its formation, for a length of time discovers no diminution of it - besides, we know that the constituent parts do frequently exist in the atmosphere. It has one peculiarity, it will not form on any stone but limestone. Sal-ammoniac, or muriat of ammonia abounds in the neighbourhood of volcanoes - and M _____ [sic] has mentioned that the Chinese obtain it from the craters of some mountains in the sesert of Tartary. He then observes that the existence of craters on a spot wh is 3,000 miles distant from any sea refutes the hypothesis which affirms sea water to be necessary to an eruption. Natron or carbonat of soda is found in abundance in the lakes of Egypt; it is imported into England as a material in making glass. Muriat of soda, the common salt of our tables, is a substance every where dispersed. On the top of mountains, in the sandy desert it is alike present. In this we discern only a fresh proof of the kindness of Providence, for salt is a substance wh all animals like & wh is beneficial to all. In our food we like it for every thing; our meat, our vegetables are boiled in salt, our butter & cheese are flavoured with it; it is on the table at breakfast, dinner & at night. The reason why it is so beneficial is one wh may at first startle; those, who have been accustomed to look upon salt as a preservative against natural decay, may be surprised to learn that it promotes digestion by hastening putrefaction. The truth is, salt in a large quantity is antiseptic, in a small, septic. It were needless to observe that the most famous salt mine in the world is at Cracow. Of this place a number of fables are circulated - it is true indeed that there are some dwellings & a chapel cut out of solid salt - but that there are towns & villages & a population that never saw the light of day, is altogether false. Why should they not see it? There is always leave & a way to ascent on the Saturday - the modē of ascending is rather uncouth to be sure, but it is still perfectly safe. When we were last year, they put us all together into a kind of net wh they then began to pull up - consequently we were all immediately thrown one upon another like salmon in a drag & in this state we were drawn up. However this is nothing to the strange manner adopted at Hal [sic] in the Tyrol for descending from one level to another. I should not call it strange, it is so dangerous. Two smooth cylindrical poles of wood parallel to each other join the upper and the lower floors - the person, who wishes to descend, places himself astride these - he holds a candle in his right hand & a rope in his left & so he slides down the poles. This exploit we performed last year - the eclat however, wh might have attended us for intrepidity, was considerably diminished on our discovering that a great name, Queen Caroline, had accomplished the same feat when she was in the Tyrol. Salt may be obtained from the sea in cold climates by cold, in hot by heat. The sea water is exposed to the air in open vessels; the heat in the one case evaporates the superfluous moisture - the cold in the other freezes the fresh water - & what little water remains is easily subtracted by boiling.

The Combusibles. Of the combustibles coal is the most mysterious in its history. We cannot understand how, when, it was formed; how, when it got into the situations in wh we now find it. That all coal was once vegetable is certain - & the remains of these vegetables wh are still visible, point out the most simple species that can be conceived, species wh no longer exist, wh must have been swept away by innumerable floods & buried beneath the surface of the earth. But the most wonderful circumstance is that coal is found on the summits of mountains & in situations below the level of the sea. How did they gain these situations? What floods could cast them on the top of mountains & bury them there? Will you say that the mountains were afterwards thrown up? How then could these land plants grow at the bottom of the sea? One thing is certain; they are not in their original situations - the strata are edgeways & the roots of the vegetables have been violently torn off. But these are geological subjects. England contains more coal than the rest of Europe put together - hence the flourishing state of her manufactories. France is very deficient in fuel - we have therefore no cause of apprehension lest it should ever in any degree rival us in manufactures. The Americans however have discovered coal mines in the mountains behind them, & it is a subject of very serious consideration whether they will not one day rival us with such a treasure - particularly as we export our coal, a circumstance wh ought to be instantly stopped, a circumstance wh will be heavily felt & bitterly lamented before the expiration of an hundred years.

Amber is principally obtained from the shores of the Baltic. It is a fossil gum. The Turks buy large quantities at Venice; their reason for doing so is not altogether known, but it is supposed that it is burnt before the tomb of the Prophet of Mecca. Sulphur is too common to need description; it abounds in the neighbourhood of volcanoes. But it is nearer home than that - it is present in the atmosphere as was before observed - and in many vegetables as greens & turnips - it is very much in the white of eggs. The Diamond was conjectured even by Sir I. Newton to be combustible from its peculiar power of refraction - the other precious gems are formed from a solution in water.

APPENDIX 1.2

TWO OF BUCKLAND'S LECTURES & RIDE TO SHOTOVER, ELECTRICITY, 1825

Manuscript exercise book (M.S. GSL M/N143) in Murchison Papers, Geological Society of London Archives

Oxford

Lecture of my friend Professor Buckland which I came to attend (from Town) with himself.

June 7th 1825

On Springs

The lecture room at the Museum being arranged - a globe in rilievo suspended - maps around it & models ready (viz. preparatives of ½ an hour) the Professor began pulling on his gown & talking from the corner of the room as if in conversazione having previously sucked 2 oranges - then sat down whilst illustrating his first point & afterwards taking his largest black board to reach all parts of his Museum he entered more vigourously [sic] into his subject & soon assumed his wonted eloquence & his wonderful fluency & ease of speech.

He first alluded to his last lecture in which he had explained how springs issued from the points of junction of a hard stratum of clay with a porous soft superstratum - hence in Shotover Hill & in Cumnor Hill sections 2 set lines were observed because there were in those hills two ranges of these alterations of porous upper beds resting upon impervious or clay beds

thus

[section sketched in]

Since it is clear that to drain a section of two ... [?] strata one trench at a proper level below the lowest of the porous beds viz the coral rag would draw the upper strata - observe this attenuation of strata in the escarpment of the Hills in the London road from Oxford beginning at Wheatley & continuing to Nettlebed Hill where the Chalk is perfect - beautiful arrangement of providence in these sloping strata by which percolation & stoppage of water is regularly effected so that no great distance can be travelled in search of some sort of spring - this the Professor illustrated by a hard board to represent the clay with a covering of bran to represent the porous superstratum - or horizontal the clay holding the water and would become one swamp, but being sloped & channelled out into diluvial gutters & from them washed into valleys of denudation - springs constantly occur at every check or point of junction - see ... [Cossieu's?] Map of France - how the surface is swept out into circuitous vallies & offering a beautiful variety of soils for agriculture.

Then comes the Query - from where does the water come? Old Woodward - famed at Cambridge supposed great chasms and a central abyss of water acted upon by heat which producing vaper [sic] forced it upwards & that meeting with the cooler strata & air it was condensed into water. This was an absurd theory - 1st as water cannot descent thro' impervious clay neither can it ascent or force its way jpwards - 2nd Dry seasons are invariably followed by dry springs - here Buckland alluded to the Henley spring or Thame (which he pointed out to me on our journey) which had been quite dry during several dry seasons - rain therefore he concluded to be the only source of land springs.

Moore's Almanack of this year states a slight shower to weigh 100 tons (of water) - curious to reflect on the capability of the atmosphere to support such a weight - hence we may conceive the weight to water carts & the great expense necessarily incurred in watering our streets.

Evaporation

The exhaustion of the Mediterranean attributed to this cause ... [?] to-day its constant influx - vide Dr Halley calculation of evaporation - the quantity of dew easily ascertained by hanging out clothers - drying them and gauging the quantity of water - in this county or America the average quantity of dew is equal to 5 inches of water per annum. In England the total quantity of rain 36 inches - America 50. The evaporation is equal to 13 inches & the remaining moisture is therefore taken up into vegetable circulation.

The globe in rilievo & suspended aloft was whirled about to show that 2/3 of it was covered with water. This is the great source of moisture - and the hotter the atmosphere the more water is found. Lima was adduced as the place of all others most abundant in prolific & exuberant vegetation requiring & containing the most water & yet no rain ever falls there. This is owing to the power of the sun - even in our country observe the heaviest dews in the cool evening of the hottest days (Christ Church Meadows was the Professor's example) the hot atmosphere held the water particles in solution - but withdraw the sun & they are precipitated by the cold of Evening - hence marble weeps in heat - moisture is condensed on the cold windows of your carriage - & hence ponds upon summits of chalk are kept constantly supplied by precipitating & condensing the collected dews - a score of trees around the high ponds on the Hampshire Downs act like the ... [blushes/bristles?] on our face in a fog they collect & precipitate the moisture & prevent evaporation - (allusion to Wadham College which previous to the cutting of some trees was a swamp - & hence in the climate of Germany is confused by cutting forests. [sic - no closing bracket]

In the antediluvian world little is said of rain - probably it never was required - watered by mists - Curiosity of Patriach's &c. &c.

Switzerland

Glaciers - Sources of rivers

Bogs

Swollen in winter by rain - shrinkage in summer by drought & evaporation - hence the surface falls &c. House not visible over in their wet state may be seen across them when shrunk. Took a sponge - wetted it & compressed it on a sloping board - compared every calcereous hill to a great sponge - the rapidity of discharge is equal to the rapidity of their absorbtion - hence Chalk absorbing so rapidly is dry in 6 or 8 weeks - observe the bridges at Stocksbridge & Winchester (whence the tops of arches just permit the ducks to bob their heads & swim under). These if flooded would be washed away - but in these strata there is no annual rise because the water percolates away rapidly as fast as it falls.

Dry & wet streams alternating B. ridiculed as being dependent on Caverns of water.

General Supply

By conversion of Sea into fresh water - drew an analogy between their change & that of blood of the Body - the latter aerated & purified by the lungs - the former by heat the atmosphere being the lungs of the great body the ocean - hence a constant renovation - & probably the very same quantity of water now as at the first period after creation - a drop of water used by the brewer - drank by an American - passed thro' him into earth at Philadelphia evaporated again & once more becomes the original drop of water.

Dr. Townsend - Section of Strata

Lansdowne Hill - springs all the same principle - hence the bulk of population always upon secondary strata.

Bath - supply affected by the demand - hence always full on Sundays - passes by Batheaston horizontally.

What is the cause of Heat in certain things? A chemical union will produce it as in mixing sulphuric acid with water & in Bath water there is a trace of sulphur & sulphate of Lime - but how account for Bristol hot springs which are quite pure? or Pfeffers Baden & many others. Most probably rationale is Galvanic action viz. perpetual contact of unequal bodies in strata or places under great pressure.

Aix la Chapelle - sulphur scraped off. See Watsons Chemical Essays.
Cliffs of set on fire by [sic - gaps in original].

Anecdote. experimental - Himself - Bath at Aix-la-Chapelle heard under water the talking of friends above - hence fishes may hear - tho' without ears they have a peculiar gelatinous pulp - (silence in fishing to Chantrey who was an auditor & an angler) - therefore he the Professor must be a bad performer.

Baths of Lenk in the vallais - patients in dress sitting up to their necks in hot mud - eatables floated about to them on little cork trays - stewing process.

Carlsbad extreme heat - issues from Granite carbonate but no Sulphate of Lime probably owing to volcanic heat.

Geisers - illustrated by views - alternately a boiling mountain - or a naked crater - 2 plates of it - siliceous tufa found - ... [deneatic?] uses but water - Salmon from the adjacent cold streams already boiled when they accidentally swim into the hot rivulet

- Sir G. Mackayie's Iceland

Bakewell referred to - supposes volcanic heat within forces up steam - better explanation required.

Return to Springs - London Basin

If gravel only upon the London Clay then numerous springs near the surface - the gravel being the only porous stratum - hence at Finchley Common no springs upon the surface because there is no gravel - hence so long uncultivated - new boring is better understood.

Refer to Philos. Transactions - spring back of Holland House Uxbridge road - 60 to 70 feet - much of water with a quantity of sand to fill the hollow - clean out - fill again - at length seen clear.

Wimbledon Hill 463 feet.

A well now may be sunk in every London House for £1 per foot - bore 6 inch diameter.

Section of Bishop of London's well at Fulham & the rationale of its rising more at high than low water of the Thames - no proof of any communication thro' the London Clay at the bottom of the river & springs below that clay - but accounted for by the small filtration & communication thro' the upper bed of gravel when the river is at high water having a greater pressure upon the quantity below causes the spring to rise some feet.

The great reservoirs of water at the vast beds of Plastic Clay enveloping the London Basin - recollect always how much friction water has to encounter & how much zigzag opposition - no doubt an adjoining great brewery would diminish supply of private house.

In Lincolnshire - east - 60 or 70 feet of Diluvium to penetrate.

Beauty of inclined strata recapitulated - as in the Golt [sic] of Cambridge - by boring to the level of junction of the porous bed & clay from where the spring first rises, you certainly obtain the same rise of water.

Finis - 2 oclock

Angel Inn

- -

Lecture Buckland. Oxford June 8th 1825

Rivers

Rain the source of springs & rivers - carried by them to sea - & reproduced in same quantity, by evaporation. This process of nature he compared to the artificial mode of boiling off the salt in sea water & producing fresh water. Rivers carry off the waste water & are in fact only gatherers to convey superabundance to the ocean - quite a mistake to suppose that springs fertilize the soil - if not carried off by natural or artificial drains our surface would become a swamp - incorrect simile introduced by certain divines of animated nature drinking at the streams - here B. quoted Scripture "he maketh ... [fat?] to descent from the clouds" - see Mr Townsend's book for springs in primitive countries - exhibited old Pack's Map of Kent intersected by a thousand rivulets like threads - or resulting an ignition by wax. These rivulets act as drains to carry superabundant water to the Thames - here we see the advantages of denudation in thus having 100 [sic] rivulets instead if it by the numerous breaks & inequalities of surface however needs may take their size in primitive state they all flow over secondary strata with the Lea & notwithstanding all the steep escarpments they meet with - still there is always a valley offered to their course. These have clearly been ... [affected?] by diluvium & denudation - see the 6 rivers which rise in the oolite & fall into the Thames. This river had it [sic] carved and fashioned its own course ... [aided?] by a slight elevation passed have almost without confinement have run to Cambridge - but no smack thro' the high escarpment of chalk - hence the absurdity of endeavouring to account for valleys in which rivers flow by existing causes - vide Table of rivers with their rectangular heads & the extraordinary resistances they pierce & traverse - Map Rivers & Mountains near ... [Madrid?] at 3 s. + 6d.

Alluded to the course of the Thames in its gorge at ... [Easley?] - the gap at Guildford - Godalming - Weybridge -

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- -

Ride to Shotover Hill with Professor Buckland June 8th 1825 Oxford.

On quitting the town at the distance of a few hundred yards trotted off to one side & looked at a gravel pit. It exhibited rounded flints (the nearest of which must have come from Birmingham) together with pieces of rag & shells of ostrea - probably the latter mixed from the clay below.

All the valley of Oxford consists of the blue ... [clunch?] clay-gravel scarce upon it - only whased here & there by diluvium ... [rerolled?] our sections - passed over Common - full of young cricketers - all the strata now immediately in front around & above as far as Headington to the Quarries at Ballington Common consist of Coral Rag & Calc. Grit - on the sloping ascent to Ballington Common Buckland marked to me the straight line between the Oolite or Coral Rag and the Clay where water flowed out not being able to descent thro' the latter & produced a wet rushy ... [glacis?] down to a small rivulet - one drain at the junction of the Coral Rag & clay would drain the lower land by catching the descending water - the small rivulet never could have been channelled out by the wretched rivulet which on the contrary had enlarged the higher part by accumulating mud & forming a peat moss.

Rode over Ballington Common & examined the Coral rag quarries - scarcely any mould or vegetable covering to this Common.

Ascended Shotover Hill by Horsepath Brick ... [Thilus?] & Quarries & next came to a fine clear section of Kimmeridge Clay which had been cut down & quarried out to arrive at a bed of oxford [sic] oolite or the regular stone of the county. In the Kimmeridge Clay found - much black Ammonites - Ostrea - slate & with pyrites - small bone mineralized - called Owl's heads - same name in old Plot vide Oxfordshire.

Sections of the Kimmeridge Clay on each side of this road. The quarry of Oxford oolite is far below the section - presently about 50 to 70 feet of escarpment of Kimmeridge Clay above it. Ascending still higher we came to a quarry of Aylesbury Lime Stone - picked up specimens of it

w. Ammonite. numb. - large double headed ferruginous stones (Lapides testiculares of old Plot) in the road - ...... [peredition?] of water has this Aylesbury Lime Stone & from the Red Sand above it evident up the junction with the Clay below as in the coral rag & Oxford church but the back of the hill.

Ascending the sand now becomes slightly ferruginous & on the summit of the hill it was highly so. We were now on the great red sand plateau of Shotover & looking Cumnor with its solitory church presented a top covered with the same sand. The valley of Oxford and town intervening whilst to the .... [gap for direction in original] the line of the red sand hills extended to Bedfordshire by & - [sic. spaces in original], with vallies of denudation between - the day most clear & lovely so that to the south of us we saw the whole escarpment of the Chalk Hills called the Chiltern - by Itchen Church to - then seen from Wiltshire to Cambridgeshire - observe the notches & breaks in the way for passage of rivers - causes thereof - diluvial action. Along the summit of Shotover to the section of the ochre pits where I observed the highly ferruginous sand stone on top - dwindling away at about 12 or 14 feet with into a non descript [sic] sand stone which Buckland described as common to all functions & a piece of which I brought away only as a caveat emptor on future occasions - the creamy coloured unctious clay with white variety & lastly the yellow ochre - hence the dip of Iron Sand Stratum, was very apparent & B. observed that it was so rapid towards us to disappear entirely under the Thames not reappearing till .... [gap in original] Consider this line of dip as at right angles to the line of escarpment viz. from Shotover to Cumnor Hill - observed the square frames as it where of iron including the sand thus [thumb-nail sketch in text here] - peculiar to the red sand. The metal may be extracted from this sand & has been worked in places - a beautiful small valley of denudation with farm house - tress water &c gave the Professor the opportunity for dilating on the great advantages of his diluvium - by this denudation a hollow was made otherwise we should have had an uninterrupted line of infertile sand stone from what is now two opposite hills of it only - the cultivated valley presents every variety of soil & useful clay - the surface is increased - man's wants supplied - the rain is collected - it trickles down the valley as rivulet - by the junction of the Porous stone & Clay springs are formed & there is a sheltered & well provided asylum for Man.

The position of the multitudinous utterly overthrown by these invincible & unerring examples in the secondary strata (where alone the crowd of population is) - existing causes quite insufficient to have carved our vallies - tho' there are appearances of many having been formed by disruption & earthquakes yet all have been modified afterwards by diluvian action as in the chasm of the Avon at Clifton - the Professor here extended & practically confirmed his position established in the lecture of this morning & yesterday upon shrimps & rivers - looking to the N.W. we observed the chain of Hills which he had described as the backbone of England from whence the rivers descended running East & South.. This chain of Hills viz. the Cotswold [sic] looked very like a gradual & slight elevation of the immense plain west and north of Oxford whereas in fact their height is considerable but being on the reverse side of the escarpment it does not appear. Whereas turn round to the chalk Escarpment on the S. East of the Chiltern hills - & there observed the sharp angle - the lofty hill the notches & the chasms thro which the Thames & other rivers carve their way - at one view you perceive how impossible it must have been for any river to break thro' such a height of hill when by turning in another direction the elevation of a few feet only would (in the case of the Thames for instance) have conveyed it along by Bedfordshire to Cambridge.

Descended reexamining - how - .... [ruin?] of the Oxford oolite from Quarry at Horse path - roads made of it friable & destructible nature - followed down well laden with specimens by the Wycombe road to Oxford.

N.B. Septaria in the Kimmeridge Clay - of greyish blue colour.

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APPENDIX 1.3

"NOTES TAKEN BY ME AT DR BUCKLAND'S MINERALOGICAL LECTURES, AT OXFORD IN 1832. J E JACKSON LEIGH DELAMERE. 1871"

Manuscript notebook in Geological Museum Library, London (Institute of Geological Sciences): Accession No. IGS 1/635

[Inside front cover]: Buckland's Mineraological Lectures. February & March 1832.

First 2 lectures missed - the course began Feb. 14.1832.

Lect. III

Tuesday 21. Feb.

Review of last lecture: knowledge of My essential for many purposes. If makers of laws had understood it 200 years ago, there wd. have been no tax on coals - none on stone. London wd. have been built of stone, & not of brick. The official trustees of B. Museum wd. not have been cheated in repairs of Memnon, & at length have asked, if there was not some way of making granite, + public taste requires knowledge of sciences, - useful for improvements in Arts & Sciences.

Growth of minerals. 1st by apposition - *no vascular apparatus, no fluids as* animals - quarry glass produced by sulph. acid separating lime from shell or bone, + rope surrounded by crystal from Geneva. Sanday stone given by Mr C Bigge. + alabaster, beautiful collections of specimens in Jarratt's cases at Radclyffe [sic]. 2. - Laws of crystallization influences by electricity & attraction - 2d. way - as agates, outer coat formed first. Buckland's scull [sic] without brains - or porous nightcaps - particles penetrate porous coats of agate; & finest are found in ye centre:- opal & carnelian are porous & suck up water - colour can be changed. Minerals once formed will never be changed, except by ye action of some external chemical force.

Mineralogy ye Alphabet of Geology, + Labrador, false name for opalescent felspar, whole mountain of it in Norway.

Simple substances differ from simple minerals. S.M. may contain many elements, s. substances are elementary substances - compound minerals, made up of more than one mineral - knowledge of S.M. necessary to know rocks that make up 1/3 of whole Earth - (gold from Wicklow) - powder of lime for white-washing or quick lime corresponds with rust. Gravitation & affinity nature of unknown. Native Iron, only found in Meteoric Stones - native lead, & tin, only found in combination - made transparent by oxygen - 54 or 55 elementary substances - alkalis, elemeny. & Earth's with metallic base - oxygen constitutes ½ of every substance. Water, fluid mineral like mercury - will remain solid at certain temperre. for ever - 3 forms, vapour - solid - or fluid. Anhydrous gypsum + Water of composition + water in black flints. When separated by action of heat, they become opaque, as in cells, in opal or selenite or bits of mosaic glass. Water, compound substance: is in charcoal. Oxygen, a mineral. Every ton of limestone gives ½ ton of oxygen. Hydrogen 2d. ingredient of water - firedamp - ochre yellow, turns red in ye fire + white sand; an additional quantity of oxygen being imbibed by iron colouring in sand, - burning is oxidation, a new chemical union is formed + cause of heat animal, according to Sir J Herschel. Slow combustion produced by carbon of blood coming in contact with oxygen inhaled in air into ye lungs - most brute of form of matter has been subjected to laws of mathematics.

23. Feb. Lect. IV

Oxygen called a Mineralizer. Iron found in combination with different quantities of it - in ores of Elba, specimen of much & little ox. at ye same time: brilliant parts of ye ore where little oxygen is; that iron wh contains ye minimum possible of O. is called by French "Feroligiste" (ὀλίγος) . O. also mineralizes tin & copper. Another mineralizer is Carbon. M.B. Combustion means oxidation: a new chemical union. Iron may be made to burn like a firework, by thrusting a piece of mainspring (is best specimen) into oxygen.

Colour of blackness not essential to Carbon - diamond white, ox. united with carbonate of lime & iron, produces white. Nil loss or annihilation in Nature, (see Herschel, page 40. 41) - particles, say from a candle dissipated in air, or absorbed by plants (Quantum of Nature never diminished) eaten by oxygen, oxen fat yields tallow, rursus [sic] fit [sic] candle, may come round in a fortnight. Houses at Bristol destroyed ye other day, only destroyed to the present generation not lost to Nature: may at this moment be undergoing conversion to trees or any thing else. The question that used to be asked, whether there is the same quantity of water now as at ye Conclusion of ye Creation may be answered thus. The identical particles have changed: are undergoing eternal circulation: but ye amt. of water is ye same. We call the Thames, of Caesar, still ye Thames, but there is not a drop of water ye same, yet tis ye same river. The beard that we shave every morning is the same, but not ye same identical hairs. Carbon in plumbago, or black lead, = name incorrect, for there is not a particle of lead in it: ye proper name is carburet of iron. Carbon with copper, makes malachite. Carbon in chalk, out of 10 lbs of chalk is 1 of coal - ye chalk is converted into gas, & precipitation by voltaic battery produces carbon. Chalk is converted into gas, & precipitation by voltaic battery produces tube with black precipitate - can never be substituted for coal, in case of failure on acct. of cost - 1/8 of all limestones is charcoal. - ch. in all shells, skeletons, vegetables. Theory about ye limestone being produced from animal substances is false & very reverse is ye case: for carbon is found in primitive marble antecedent to animal life.

Phosphorus, in boxes: in fluids of vegetables - must be kept in water else combining with oxn. it gives out heat & light. Rank poison. Fire-King did swallow this but immediately went out, tickled his throat with a feather & threw it up. The other things he did not swallow. Ph. to be traced to earliest creation, elements of minerals antecedent to animals into whose composition they enter. Coprolite, phosphate of lime derived from food of ye animal. Whether animal on vegetable food, either derived it from the sea or air. Phosphate of lime in crystal of fluor. & Buckland's thumb - ye only difference is ye age, the thumb was not 50 years old. Apatite [its name from deceiving first Professors] contains Ph. It is found in most ancient combinations with several things, in most ancient veins, in most ancient rocks.

Sulphur - raw, or living near volcanoes - state of passage into selenite. Crystal of S: scarce - combined with gypsum, iron, lead, copper - found in most kinds of grain, wheats, rye, maize - & cruciform vegetables, cabbage &c.

Fluorine, "fluo." - blue John.

Iodine - takes particles of iron, or steel filings. Discovered in making saltpetre of Paris: not known xx [sic] yrs ago, found in sea plants, rock salt, silver ores from America - salt springs of England by Daubeny, not yet in land vegetables or animals + acts on glands & goitre; it having been recollected that burnt sponge & baths of luca the wise had recourse to cure goitre they were analysed & iodine was found.

Lect. V

Earths - metallic base and oxygen - e.g. potash give balls bright as silver, wh. when cut have ye 4 properties of metals.

Ythria [?], zircon, glacine [?] thorina not very important Earths. The 4 bulky ones are Lime, Silex, Alumine, Magnesia. Defn. of E. dirt, whence sweeping of streets. Stratum on a Dr. of Medicine's head - chalk why clean at a foot under ye surface - ye dirt, caught by superficial soil as epidermis of any dirty animal = difference betwn. limestone: metallic lime & quicklime (a metallic oxide) carbonic acid burns out of limestone in ye kiln. This & calcium make up limestone - water being thrown on burnt lstone, ye caloric of fluidity is thrown out, and it becomes hydrate of lime: hair or sand is thrown in to act as nucleus, lime wraps round it & returns nearly to its original condition - old mortar useless, wd fuse.

Plaster of Paris is lime with sulphur - gypsum always soft; takes impression of nail. Plaster, gypsum burnt, water thrown out (mason's trick of leaving lime, dangerous) - wherever carbonate of lime is, there is effervescence!

Barytes, sulphate of fine crystal in Museum - Carbonate of B. ratcatcher's stuff.

Strontian found in Argyle [sic] lead mine - Carbonate, & Sulphate of Strontian.

Magnesia, causes greasiness in soap-stone - meerschaum - serpentine - agalmatolite (or lard-stone) - a certain quantity in all limestone. Magnesian limestone produces powder & shot (round balls). Epson salts crystalize within cavity. Fuller's earth, is clay plus magnesia - put a lump of clay in water - if it falls down & dissipates: t'is fullers earth. E. of magnesia in meteoric stones ∴ magn. not confined to this world.

Silex: crystallized. German name is quartz - ½ oxygen ½ silicon (base of silex) with alkali, it wd. make jelly: "I'll give you flint soup any day - forms agates, & skeleton chalcedony. Little silex in rain water & sugar cane ∴ in plants, in cooper's rush (file rush) - in epidermis of all grasses, must be soluble, we can't imitate it, you may shave with silex. Wootz. (Dr. Pearson wrote abt. this see P. Mag. 1829.), razors to be bought of Pepys: won't rust, because silex in it.

Alum - suplphate of alumine - alumine, basis of all clays, precious stones - non pure. All earths, if pure wd. be white.

Lect. VI

Carbonate of lime, yields charcoal - alabaster, sulphur.

Dean Jackson's statue in Ch.Ch. of marble, or carbonate of lime wd, if it weighs 2000 lbs, give 200 lbs of charcoal. The alabaster statues of Lyttelton Brothers in Mag. Col. wd. give 200 lbs of sulphur, being sulphate of lime or gypsum. Shells burnt on west coast of Ireland to give lime - no phosph. of l. as bones. Lime not from animals for where did they get it - ab eterno? No - they can't manufacture it, it must come from some other source than animals themselves, for these was once a time when there were no animals, ∴ from food. Carbonate of lime forms 1/8 of Earth - many things in ye creation not exclusively for use of man: for they existed before man, but they have been rendered subservient to his uses - *lime most useful to man: for* without it, no bones, no building.

2000 lbs of water yield 2 lbs of lime. Between Rome and Tivoli, Sir H. Davy put a walking stick into a pond: & in 4 or 5 months found it thickened to a gate post (all water contains a little carb.). Lime encrusted from springs, in fresh water deposits, says Dr. Wollaston.

Chalk, either deposit from sea, or submarine discharge, springs pouring down sediment. Dr. B. of former opinion.

1st form of lime, combined with Acid of charcoal. Marbles, ye best Chantrey ever had was used for late kings bust & Canning's statue. 2 faults in M., sand holes (wormeaten monument of children in Lichfield C.) & veins, see Macculloch 1st. Vol. Trans. Geol.. - How to tell Parian from Carrara. Parian course grained - flakes of light - may tell ye age of statues & fragments. Parthenon built abt. time of discovery of Carrara, B.C. 400 - ∴ almost all Parian statues are anterior to that date. Venus de Medici's of coarse grained, Apollo Belvedere fine. Decay of Elgin marbles caused by ye stone containing laminae of mica & other impure matter wh. wears out, as ye marble of Glentilt [sic] in Scotland. Pentelu marble used at Athens for ye same reason that Headington stone is employed at O. because it is nearest.

Agrigento, Palermo, Syracuse, walls built of shelly-stone: shells beautifully preserved. Moss once grown upon stone t'is safe, does not decompose. Way of rolling large columns xi feet broad, excavated & rounded in ye bed, wheel built round ye stone, no difficulty in transporting largest blocks.

Red marble in Derbyshire in magnesian limestone belonging to Duke of Devonshire prettier than rosso antico - & in Devonshire. Slabs near Weymouth like ammonite called Melburg marble. In ...... [?] ch., Purbeck stone columns. Cotham, i.e. - landscape marble - bust supporting Ld. Grenville in B. [? N.] C. library of Oxfordshire marble - black marble "Lucalline" being much used in his villas.

March 1. Lect. VII

Dolomite (from Dolomieu, who first analysed it) consists of carbonate of lime, & carbonite [sic] of magnesia - flexibility of one kind caused by heat. Flexible kind of sandstone. Dol. in Sunderland - but magnesian limestone to be expected anywhere. Sulphate of lime without water, vulpanite, Vulpini. Lumachelli, light in it reflected from pearl of shells, as ammonite, or others in ye stone.

Alabaster, oriental - carbonate of lime & strontian. Sarcophagus at Sir John Soame's, Lincoln's Inn Fields wh. ye British government was too poor to buy for £2000. Cone in cone, ye characteristic of arragonite [sic] satin spa of Cumberland, probably oriental alabaster in a fibrous state. "Flos ferri", false name; not a particle of iron in arragonite. (The gypsum of ye Ancients was lime, γη εψηθεισα).

Gossamer like formation of st. in Eisenertz in Styria. Beef in Dorsetshire nr. Purbeck, formed in ye cone in cone manner, an imperfect attempt at crystallization ye grain of ye beef is vertical, whereas ye rest of ye beef is horizontal. Iron is also found in ye cone in cone form.

All carbonates of lime break up into rhomboidal form. The Abbé Haüy maintained arragonite to be not common carbonate of l. ye crystal being different. .... [? Shomlyer] by more correct analysis found it contained strontian. Best s specimen of Arragonite is tomb at Sir John Soame's [side note: "Triumph of theory"].

Alabaster pipe. Case of alabaster built by a worm.

Pearlspar, carb. of lime & carb. of iron - other name Siderocalc, crystals form all on one side. Styrian iron ore ye best in Germany, being already steel; as it contains carbonate of iron - as being combined with an acid & some earth, t'is called a mineral salt, the salt is properly only that which is soluble in water.

Apatite. phosphate of lime. ... [?] the crystallized from bones of men.

Selenite or quarry glass, lime & sulphur: a lump of S most probably was back bone, or some other bone of an icthyosaurus.

iiid. Form of lime combined with Fluorine, Fluor, Blue John: Zinc Black Jack. Fluor (fluo) found naturally in copper ore of Swansea. A green fluor, supposed phosphorescent, in Cornwall & Devonshire: called χλωροφανε- a stone covered with it by a gentleman in Siberia - phosphorus of dead whiting, Buckland read newspaper by light of, in a back kitchen. Fungus in Mines of Dresden.

Strontian, sulphate of & carbonate of.

Barytes, or Terra ponderosa, in Cumberland. (N.B. Chantrey says 12 cubic feet of marble and granite weigh 1 ton - of Portland stone 14 cubic feet, minus few lbs). Brainstone of Terra ponderosa in Derbyshire. (Roman cement made of London clays).

Bologna stone, native + artificial - steeped in water & then combined with gum. Crystal beads on rosaries - coloured quartz, either amethyst wh. has peculiar optical properties or cairngorum [sic] wh. when genuine is nothing by smoky quartz - ye others are nothing but yellow crystals of Brazil quartz. R. crystal often contains other substances, as mineral of titanium, fibres like hair.

2. Crystals are found in Bagley Wood, rolled. Pebbles of silex found in ye lime kilns glazed over - also vitrified by lightning which has also formed tubes of sand; e.g. in museum at Dresden.

Aventurine, natural, is a peculiar kd of quartz = artificial.

Rose Quartz. Chrysoprare. [sic] French mill-stone or Burr, 2 of ye worth £60: (premium offered by S. of Arts for discovery of, in England) cellular surface of stone best for grinding, for there is always an edge, grind as long as you will - like Elephant's tooth. This stone will float for ye same reason as an iron boat - manner of cutting mill stones, see Herschel, pag. 48.

Thin Plates of fossil wood, jasper &c, (Allanbank, Berwickshire: written in wood plates) fixed in glass to be examined by microscope. Potato stones from ye Mendip Hills. Flints are not necessarily formed upon a nucleus, a shell or other thing some times serve for one, but they are generally nothing but knobby irregular concretions - the same result once appeared in ye cooling of a mass of ground flint, mixed with some thing else into a creamy consistence, wh. became full of lumps at Wedgwood's pottery.

Menelite, fr. Paris - no chalk in America, nor Turkey for ye ... [? am.] come to England for flints & in T. they use agates.

Hyalite or Müllers glass, formed in Volcanic rocks, a proof of solubility of silex in water - fine specimen from Auvergne.

Chalcedony - Box agate - agate quarry near Perth, about 1 in 10 good. Fortification, form of, depends on ye form of ye cavity, consists of a no. of bands of jasper-quartz: & chalcedony. B... calls agate a simple mineral - contains sometimes animal or vegetable matter. Jasper formation of: a pond dries up in ye summer; & is cracked, if ye cracks were to be filled up with any other kd. of fluid, wh. was to harden, t'would be analagous to J. = thus nature forms septarians, pure limpid substance of chalcedony builds up cracks in Jasper. Trees bored by teredo, filled up by do. Oberstein famous for agates - Antigua for fossil wood; better than Hungary - even touch wood fossilized in A. (Teredo grows very fast - several inches in 80 days.) Head of a palm tree: process of petrifaction not exactly understood - chalcedony of nail colour is called onyx, of flesh colour, Sard - of both together, Sardonyx. ∴ used for cameos, though really cameo is derived from cama, ye shell used to imitate ye Sardonyx; (3 or 4 different bands of calcedony cut into head of Nap. Bloodstones or Heliotrope (drops of blood in cameo at Paris are Saviour's Scourging) oxide of iron causes variation of colour. Flakes of lead, rare. Thus Mantuarun: in ye late row [?] at M. ye Duke put it in his pocket & ran off - story of M. antony [sic] - & man who buried valuable cameo in Egypt. Chalcedony is semitransparent - Jasper opake [sic], a little clay makes ye difference. Mocha stones brought from, but not found there. Ribbon stones, mountain of in Siberia: Egyptian pebbles: cat's eye, Fibres of, are of asbestus [sic]. Blue chalcedony at Lyme Regis. Shells converted into Jasper at ----- [sic] nr Exeter only. Series of opal flints passing from dark to white show silex modified by action of fire. Specimen at a place on ye bank of Rhine. Sibgebeit, or something like that [sic]. Jasper made at Dudley, compact brick.

Lect. X

The species of zeolite most worth remembering is ye Mesotype. Pyroxene, formed whilst lava is in ye act of cooling. Milschelich of Berlin made artificial pyroxenes, they are also found in ye slag at Merthyr Tydfil, therefore they are produced by fire, & if they are, other crystals may be. At Andernach on ye Rhine conglomerate is found to turn to pitch stone, and lava at ye top - pitch turns to phosphorus, ph. to granite - best pitch from Meisson [sic] nr. Dresden. Crystals of zircon found in lava in France, Puy en Velaur(?) [sic]. Sahlite in Hebrides. Garnets of all colours are from fire: Leucite, white G. - slatey clay in basaltic dyke in Isle of Anglesea [sic] turned to crystal of garnet ∴ garnet is older than ye rock in wh. it is found, for ye other thing accommodate themselves to ye shape of it. Grenalite or Staurolite, found generally with Cyanite (to be pronounced Kyanite, to distinguish it from Syenite) in ye Alps.

Schorl (from name of town Schorlau, in Saxony, (old name for many prismatic crystals is now confined to black tourmaline. Tourmaline, plates of, used for eyepieces in optics: polarization of light - black at Dartmoor - red & green together enclosed one with ye other. Red, valuable piece given to Ox. Mus. by Drummond ye Banker worth £60.

Topaz used to be called schorl: name from island Topazos in ye Red Sea. The old way of setting topazes, in a cross, ye best, being most like ye form of ye crystals. White topaz substituted for diamond in watches - made pink by heat. Beryls, made in Limoges, mended with - another name, is Aquamarine, Hornblende never in rocks of equeous origin - formed in Syenite, (Syene in Egypt). Cleopatra's pillar & pillars of pantheon at R. made - not of granite - but of granite plus hornblende, best of all materials for mending roads; what workmen call a d - d [sic] ill natured rock. Labrador hornblende, iridescent. Actinolite green: pistachiolite ? [sic] vesuvian: axinite from its fitness for hatchets.

Lapis lazuli - azure Arabic wd. for blue, gives ye famous ultramarine to painters. Kneller's beards indebted to L.l.

Lect. XI

Paste jewels may be detected by application of tongue, or knife = steel won't scratch chalcedony or quartz: silex will = things of equal hardness. Plus velocity will scratch one another.

Alumina: forms about 1/3 of all clays = with sulphuric acid forms alum - is got nearly pure by filtration at Newhaven. Silex however forms greater part of all clay. Without clay, all other earths useless. There wd. be no vegetation: no animal life. For 1st, it gives tenacity to ye soil: the sands of Africa & New Holland are sterile for want of clay, whilst those of Norfolk have been made useful by ye addition of it. Again, without clay, there would be no springs: clay has this remarkable feature: it will suck in water, every drop that it can get, till it is saturated, & then will take no more, nor part with that which it has got - hence ye process of puddling in dams & canals.

Specimens of earthenware used by ye Savages of South Sea, & of Wolvercot [sic] near Oxford. Same kind of utensils: sling balls like egg in shape = flint knives ..... [? laces]. The bits of white in old sepulchral pottery either roasted at a fire or baked in ye sun are supposed to be small pieces of bone: collected from burnt ashes of skeleton & mixed up with ye clay. London clay ye best for bricks: ye yellow L. bricks ye best; they contain a little clay & some lime & are reduced almost to state of glass. Roman pipes of imperishable material.

[Side note: "Brongniart, ye French Geologist, Keeper of ye Sèvres porcelain manufactory: gave 2 lectures on ye history of pottery."]

Wavellite consists of alumine & clay, & a little phosphorus.

Ruby & sapphire are chemically ye same - ye purest state of clay: contain 98 pr. cent Turquoise, alumina (tinctured by copper) nearly in a state of purity.

Spinelle [sic] Ruby from Ceylon ½ ye value of ye diamond - (ye emerald of silex). Emery is course Ruby & sapphire. "Teleseine" French word for sapphire: signifying "perfect". Corundum from E. Indies, insipient sapphire, "adaman spar". Felspar, 1/3 of granite in greenstone: & (2/3?) [sic] of porphyry, & in all rocks of igneous origin, fusible with potash, infusible without it, is made into crucibles, pipe clay = used innocuously for bread - a mere "caput mortuum", ship load taken coming into Portsmouth during ye war, for use of French prisoners. Felspar only in one case, white. The colour of granite depends on colour of Felspar. Vesey's door steps: of red granite. White felspar in base of Chantrey's statue of Pitt. Andalucite, crystallized Felspar; also got at Innspruck [sic]. Chiastolite, makes gr. letters.

Magnesia, chief ingred. of porphyry - beautiful spec. of porphyry from Cornwall.

Jade - extremely hard, used by savages. Lemnian earth, piece of quackery in time of Homer - γη Λημνια, terra sigillata - sold as a cure for ye plague - also lapiz nephriticus - cure for diseases of ye kidney; made up in shape of one, according to old notion, that identity of shapes had certain sympathies. Plinys emeralds were green magnesian earth, he mentions 12 kinds - amianthus, white & brown silky, vegetable silk, asbestus coats of for firemen - fibrous kind used for wicks.

Meerschaum pipes, cont. good deal of magnesia. Potstone used for vessels by Esquimaux - chrysolyte softest of all precious stones, crystals of olivine in meteoric stones, wh. contain, iron, nickel: & ye earths - hence these exist elsewhere than in our Earth.

Mica of all colours - red makes red snow in ye Alps - black - generally, silvery white, lanterns in Russia, divisible into 1/300,000 pt. of an inch. (Hutton's Mother's [?] Recreation) - when charged greatly with magnesia, is called <u>talc</u> wh. was useful purple by ye Romans - talc is soft & flexible: mica resists pressure.

[Side notes: "Chrystallography." Illustration of ye process of crystallization. Rainwater in a phial saturated with Epsom salts: allowed to stand till cool: take out ye cork - t'will instantly crystallize: if not stir slightly. It gives out heat during ye process: & ∴ ye bottle is warm to ye hand."]

Lect. XII

In passing from a fluid to a solid state every substance assumes one of a definite range of mathematical figures: this range is limited by ye manner of apposition of <u>similar</u> figures. The object ∴ is to get to know what <u>one</u> form is, & then it may be known a priori what ye series of combinations may be. The important thing is to find the primary form.

Take a crystal of carbonate of lime, t'is divisible into infinite small crystals, all of one form - rhomboidal - this dividing is called Cleavage. The 500 secondary forms of Carb. of lime are only so many packings up as it were of ye primitive form - putting together in different attitudes & combinations so many similar bricks, only ye brick in each case is of a different material (all of course of ye same mat. in ye same crystal).

Haüy ye Abbé, who almost originated crystallography, having formed his theory maintained that arragonite wh. had hitherto been classed under carbonate of lime by analysis, was from its primitive crystalline form, not strictly so. The chemists insisted upon it being properly classed. I don't care for your chemistry, go and try again. It must be as I say. They repeated analysis more carefully, & found it to contain strontian + primitive form depends upon ye original form of ye particules: wh. are brought together by a kind of vitality - viz. electricity or polarity - with ultimate particles they are magnets, & have poles & move freely. Iron to be considered frozen, as ice, of wh. ye natural condition is water: t'is only a question of temperature - crystal of sugar candy. Professor of Divinity's dessert furnished crystallized orange in a glass, another specimen from Vice chancellor's table, & a third from Archbishop's table at Bp. Lloyds consecration. Spec. of Tin ore ½ crystallized. In Tin of common use there is very little of ye real metal, thin plates of iron are dipped in tin: & imbibe it, as a coat tail dipped in a pan of grease.

Crystallization takes place under ye influence of fire. In bottom of furnace: at Merthyr Tydfil; charcoal. Crystals of Feroligiste in volcanoes. Keys are Herculaneum ½ crystallized, glass melted, crystallizes in ye passage from solid to fluidity. Reaumour's porcelain, old bottles from Castle espty. Billiard balls in Fire of London - crystals of arsenic on walls of flues, caloric cause of fluidity.

Definition of a crystal. "A Body having a regular external form, & a regular internal structure". It need not be transparent = there are opake as well as transparent C. = & a regular external form is not enough, for Causeway pillars are externally regular - lines on surface of a quartz crystal as great to a flea as ye steps on a pyramid to us. [Side note: "See Herscell.] The primitive form may be ascertained by cleaving: when you have arrived at that point at wh. ye crystal will only give off plains parallel to its surface, i.e. lateral laminae, there remains ye primitive form. Tin has many combinations. Quartz 14 or 15 Carb. of Lime, 500. Wollaston & ye diamond at Rundell & Bridges. D. is cleaved in a particular direction: he resold it for 150. Lead & salt, cube, prism form: Faraday's discovery last week electricity by magnet. Buckland's illustration of magnetic attraction of particles: bag of fleas each with N. and S. pole. The principle of crystallization applies to aqueous & igneous solution alike.

Lecture XIII (Rather miscellaneous)

(Day of Wilson's election for .... [? Sansin's] chair

If Paley had been a geologist he wd. not have commenced his Theology as he does, for he would have known that a stone mt. not have been there for ever: it mt. have been a coral once formed by an animal: since rolled by a deluge. Geology assists ye argument of Paley - atoms in water move about, we don't know how - globe with copper wires on ye meridians a needle points at same ∠ as on ye real globe ∴ heat of ye sun daily, sufficient cause to account for magnetism .. Increment & Decrement.

"Replaced" (as "undone" & "abortion" in Botany means what never was done) means never placed, i.e. wanting, one slice off. Bevel, 2 slices cut off.

Having reached ye primitive form, not at end of ye story by any means. Prin. form, is made up of molecules integrant, of constituent molecules: each constituent of elementary mol.

Tableau of Crystals

5 forms:
- Secondary
- Primitive ------ 5 { 4, 6, 8, 8, 12 }
- Integrant Molecules —— 3 { 4 Pr... (couldn' read ye word); 5 Prism....; 6 Parallelopiped }
- Constituent do.
- Elementary do.

Modification of Secondary alias "Rogues, imposters," not genuine crystals:
- Pseudomorphigal. (e.g. sand carried along with carb. of lime, as ye plums in ye pudding)
- Epigene. "Got by carbonate of zinc out of carb. of lime!" to use terms of ye Racing Calendar!
- Hemitrope - or "arrow headed" - ye crystal cut in 2 as it were & turned ½ round - selenite - Montmartre
- Metastatique = whole turned round.

Lect. XIV.

All earths except silex are metallic oxides, + we are not used to think of ye importance of metals, any more than of ye using of ye sun: but we shd. presently feel their absence as his light, if ye servant shd. wake us some morning, Sir, it's ten oclock but ye sun has not risen. The most essential is Iron. With utensils, man wd. in spite of his boasted superiority fare little better than irrational animals. The next question is, what general privision is made for ye appropriation of metals.

Strongest case of final causes, in the distribution of certain metals - 2 M. enter in ye composition of organized beings. Iron & Manganese. - Iron in every inch of Earth - in blood, demonstrably. Another class of M. useful to man but noxious to vegetables, viz Copper. If C. was as universally distributed as iron, ye whole Earth wd. be poisoned. Sulphate of Copper poured round ye root of a tree destroys it - Do. Lead. Accordingly such metals are laid up in repositories for ye use of man alone, in Cornwall they are shut up as it were "in the cellar" - & ye door is unlocked by ye steam engine. The veins there of no define [sic] degree of obliquity; from 45° upwards - being below ye surface, they are out of harm's way and require a little ingenuity to get at them.

18,300,000 lbs in 30 years produced by Copper mines alone.
2,200,000 lbs per ann. in England by Coppr, Lead & Tin.
2,000,000 do. ---------------------- Iron alone.

[Side note: ' "Records of Mining" by John Taylor, ye eminent Engineer']

4 or 5 millions of persons employed by working of metals. If they were annihilated tomorrow, *that No. of people wd. die of starvation*.

No one definition of a Metal. The most important quality is malleability, many have not. 32 metals in all: but some of ye more recent ones not above ½ a lb. has been discovered altogether.

Platina. Native found in grains, used for crucibles, foil, wire - used for forging gold coins.

Gold, Nat., generally in grains.

Silver, do. in lumps.

Copper, sometimes dendritic.

[Side notes: "Molybdēna." "Platīna."

Properties of Metals

1. Fusibility Different metals fuse at different temperatures, e.g. mercury, iron. Simple metals melt less readily than compounds. Soders Cuff at Bath sell spoons of base metal, that melt in hot water, often employed to play tricks upon old Ladies.

Workers in metal eminent from Tubal cain [sic] to Brunel downwards. [Side note: Mr. Mawdsley, Mr. Rennie."] The Ancients put a Blacksmith in cotu deorum. Mr. Mawdsley, who died last year (?) [sic] Immensely [sic] rich, was a common blacksmith, picked up in ye Borough by Brunel. Mr. Rennie once worked at the anvil. Travelling afterwards with a nobleman in Scotland, ye carriage spring broke. R. got out and mended it himself with his coat off, at ye next forge, & his Noble Friend, very courteous hitherto, never spoke to him again.

2. Metallic Lustre, not in ye same manner in Earths. Mica, par exemple [sic] dull if cut vertically, Metals lustrous in whatever manner cut, a plate of metal the 100,000th. pt. of inch thick is still opaque, ∴ another property.

3. Opacity. A thin leaf of gold foil 1/300,000 inch thick held up to ye light transmits ye green rays - this property of O. possessed by all.

4. Weight. All heavier than water.

5. Hardness. "It may shock your feelings to say, that metals are not hard, a knife will cut iron: (specimen handed round, a poker with a ring cut by B's

knife - a Chantrey knife,) a softer m. + velocity will cut a harder one - charcoal to iron fit steel [sic].

6 Elasticity, depends on hardness & increases with it.

7. Malleability, (spoken of in last page.)

8. Ductility - on wh. malleability depends, platina by Dr. Wollaston drawn to wire 1/3,000 inch thick.

9. Tenacity - wire of iron supports 500 lb. wt. on this, ye principle of iron bridges, wires there certainly of tolerable thickness: but they do not support ½ of what they will bear: that they may last ye longer. Iron worth all ye other metals put together in pt. of utility.

Difference between --- Uret & - ate terminations - Uret combined with actual substance - ates with acids, eg Carburet of iron - iron with charcoal - carbonate of lime, with carbonic acid, not substance. Sulphuret of copper, copper with downright sulphur: not sulp. acid. - "∴ Remember! -- ates with acids!"

[Classificatio on opposite page]

Tableau des etats dans lesquels les metaux sont trouvés (particulierement fer.).

1. Native -- as Meteoric
2. Oxydes [sic] ------------------------------------ combined with ox.
3. Sulphuret --------------------------------------- sulphur
4. Muriatic -- chlorine

Acids

5. Salts. soluble

Acids. 1. Carbonic

insoluble

2. Sulphuric

Metallic Acids, ie ye metals play ye part of Acids.

1. Arseniate
2. Chrome
3. Molybdēna
4. Tungsten

Lect. XV

Veins in Cornwall of different ages, the oldest are of tin, ye 2d lead, 3rd class "Cross Courses", contain no metallic deposits, but rubbish, 4th. injected with porphyry. Probable cause of injection: fire acting upon water, causes infilteration [sic] from below, - illustration of ages of veins in common pebble with quartz veins crossing each other. Veins of another kind, where foreign matter is injected (pink striped drawing). Another mould in wh. metals are found is in grains dispersed bodily through mountain masses, as of porphyry.

Another where they are found contemporaneous with mud in a liquid state: lumps of clay from Dudley, cracks, filled up by infiltration.

Noble Metals, are those wh. will not combine with oxygen. Whereas if a vessel of molten lead be exposed to ye air, the oxygen enters into comb. & surfaces covered with kind of dross: artificial litharge - lead too is generally found in sulphur. The Noble M. won't do this: they wont contaminate themselves by coming in contact with foreign substances as ye Baser sort of Metals do - gold coin of age of Alexr. as fresh as when coined. Gold when pure does not ring. The sound is caused by ye copper in alloy with modern coins. The pure gold is quite flexible & soundless. Silver greedy for sulphur, wh. turns it black, but this does deface it permanently.

Base Metals oxidate by fusion & exposre. to air. It is difficult to say by what principle M. shall be arranged as N. or otherwise. Let ye law of ye arrangement 1. readiness of combining, 2 readiness of parting with ye oxygen. But the affinity of M. for ox. varies, as also ye disposition to part with it. The Best work on ye Precious Metals, by Jacob: who from his situation has had access to documents of authority. 4 Periods he makes of M. - 1. Before Augustus 2. Aug. to discovery of America, 3. From D. of Am. to 1809. 4. 1809 - 1830.

Iron more valuable than Gold in ancient times. In Denmark, gold mines found with iron edge, (? could they cut with gold edge) just as our knives, 2 plates of iron, & one of steel. In Siberia 1,000 little furnaces containing bits of copper & gold, discovered. Must have existed in ancient times of wh. we have no account.

In Europe, Russian Asia and America (of ye other A. and India we have no data on wh. to calculate) produced annually to money value 10,000,000 of G. & Silver - (2½ of gold) (- 2 m. in America) - great quantity of money lost every year. ½ of all gold discovered from beginning of ye world lost - much buried, some found in year Buckland was born near Lyme: buried at landing of D. of Monmouth - a "crock" of money found Leigh: little while ago nr. Lyme. Tutbury Castle, 1831 + plate at Clifton buried under cabbage beds, as time of Bristol Row.

The annual loss, by conversion into trinkets, plating silver (by rolling bars of silver & copper together) unknown to ancients &c, &c amounts to 5,000,000! S. increase annually.

[Side note: "story of breeches maker & taylor, --- Chantrey's battes [sic] & detonating balls. -- Jekyll & snuff."]

Electrum, was ore of gold alloyed with 1/5 of silver = in Pliny.

No silver in modern coins - silver utterly tasteless ∴ used for forks, ½ of whole quantity of silver used in spoons & forks.

Gold not easily volatilized - dial of St. Mary's oxidated by lightning. No acid will affect it but aqua regia. Silver & gold pack better than gold & copper, principle of Heero's [sic] crown.

Mica particles on leaves - in sands - mistaken for gold sand by Boyle, found often in mouths of rivers flowing from mountainous country.

N.B. never work a gold mine yourself - let some one else do it & bargain you for 1/10 of his receipts.

Johnson's play of Alchemist [sic] founded upon ye circumstance of King's proclamation that he would pay all his debts.

Russian platina coins foolish - when p. comes cheap, t'will be forged at Birmingham. Jamisson's [sic] tables of mineralogy. Sulphuret of silver, rare, red silver.

Relative values of money, returned to what it was at Trojan war - 7½ to 1, lowest 15 to 1. 100,000 horses a tribute to Rome treasury in reign of Augustus.

Lect. XVI.

[Side note: "Mr Symons of Ch.Ch. presented last wk. a most valuable collection of minerals to ye Oxford Museum - 20 or 30 or 110 gs. each, "beat ye B. Mus. hollow", W.B. Sir John Soan announced at ye end of his lectures, in London his intention of leaving his house in Lincoln's Inn Fields, open to ye public."]

Lead represented in Chemist's shops by hierogl. of Saturn: it devours all other metals, lead put in with silver. In purifying silver, or gold, a cupell [sic] small vessel made of bones, very porous, used. L. devours ye other m. & S. or G. remains in form of a button at ye top. L. tarnishes, does not oxyde [sic] - not ductile, becse. not compressible - litharge. L. unites with silver hence liquation [sic] of Copper. In ores of lead containing silver, if ye grain is course, ye quantity of s. is small. Silver found in all lead, exct. that of Bleibery. T'is worth ye expense of separating. Mrs. Beaumont & Pitt - she had a complete service of silver plate made from her own mines. Boasting of this to Mr. P. he wd. not understand her, but constantly answered, Really, Madam, if you had not warned me of it, I should have thought it was silver! L. alloy with all metals, exc. iron - more fusible when with tin than alone. Soder galina fused, makes glazing of pots. Printing types of lead & antimony. L. in paint, - never found native, - case certain of l. in volcanoes, exception; not tenable. Most common form in wh. l. is found is with sulphur, cubic crystals of lead with sulphur - alias "potter's lead", or Sulphuret of lead. Sulphate of l. is brown. Carbonate of l. white - made up of black & blues i.e. black carb. - blue lead - why white is produced, reason unknown. Metallic oxydes with lead, chromate, arseniate, molybdenate (separated on tray by ------- [? stripes].)

"Slickensides" in Derbyshire - pipe veins - rake veins. Sorex at all Souls Coll. roof eat holes in ye lead. Judge Blackstone's acct. of it in MS. bought with ye lead by B. for 3½ crowns. England richer than all Europe in iron & lead - Europe than all ye rest of ye world - while France produces 60 tuns [sic], E. gives 250.

The 1st used by mankind Copper, in pt. of ductility & tenacity it ranks next to G. & S. Combines with almost all metals. Phoenician tinkers in Port Meadow reliques viz. spear heads, saws &c dug up there - also unwrought bars & pieces just turned out of ye mould - do. in Cornwall, ancient coins forged; exc. patina covered with green. Vyvyan's [sic] Cop. works in Swansea - tin brought over, coal taken back, copper shot, dropped from greater height. £2 million in 2 years from 1 parish. Ores. 1. Native, oxyde, carbonate of, (malacite - colour of mallow - mine belonging to Demidoff of Florence) - blue carbonate "mountain blue" earthy carbonate chrysocol. used as soder πολλη by ancients. Sulphuret of C. irridescent - caused by oxidation. Cast load of iron thrown down Parry's Mine comes up copper - what at bottom charged with copper - cow bone, green, having lain within range of water holding copper; hence Volga turquoise. Real T. also indebted to copper for its colour. Gelon [sic] Mine, crystals of sulphuret of copper in carb. of L. built Buxton - arsenic in copper. The History of Tin lies in a nutshell - found in one form only - oxyde <u>stream tin</u>, pebbles of oxide of tin - probably the only ore found by ancients - how washed: principle of centrifugal force, heaviest remain, lightest fly off. Treadmills in ancient use, see plates in Agricola de re matallurgica - use of tin, for bronzes, & covering of iron plates - <u>latin</u> or fer. blaze.

Lect. XVII

Iron. The lightest of all metals exct. tin - the most tenacious & ∴ ye most useful. Never native, exct. in meteoric stones. Savages instead of it use shark's teeth, wood, or bits of meteoric iron. The king of one of ye savages islands made a fortune by letting out for hire an awl made of an old nail! picked up on ye shore.

Specimens of Esquimaux instruments. Iron found every where almost. Bloomery. Roman iron founderies in woods. Aetite or Eagle stone: sand & clay originally one mass by certain chemical process, iron separates, forming shell of hollow stone. Rust acts as cement, attracting some substances - old horse shoe. I. in plants - animal blood. I. differs from other metals in possessing this remarkable property:- viz. it admits of a change of state: The original bar, or pig of iron, in its metallic state, is soft = brittle. Before it can be converted to ye purposes of cutting instruments, it must be made malleable, wh. is done by taking out ye charcoal, by hammering, or rolling. The sparks that fly from ye anvil are chiefly charcoal. Thus it becomes ductile - but requires to be impregnated again with charcoal, slightly, 1 in 300 pts. - w. it has undergone these processes it is called "cast steel". Carbon in cast iron pipes forms a crust protecting ym. from rust. Woots razors contain silex. Pepys sells ym.

[Side note: "Abridged Phil. Trans. 1795. Page 580. Dr. P.]

New improvement in furnaces.

Hot air to be collected from ye furnace chimney, if forced by ye bellows instead of cold, to supply oxygen for combustion, will save fuel 1/3 of - & will also produce more iron - ore, lime, & coal, thrown together into furnace. The ore used by ye ancients was most likely common oxide of iron, as ye argilaceous ore requires *lime for* a *flux*, *wh*. was probably not known. The supply of coal without sulphur at Merthyr Tydvil causes ye great iron works of South Wales to be centred there. Swedish & Spanish iron better than English, because they use charcoal - reason: white iron ore has charcoal present. Anchor made of faggots of bars, bound by wires of iron - & beaten together: that if one bar be weak in any pt. it may be counterbalanced by others - gun barrels, of old nails.

White carbonate of Iron, with carbonate of lime, found in Styria - Alps &c other names: "native steel". Pearlspar.

Magnetic ore: most important. (Davey's Gilbert ......[?? gaoled]).

Ferroligiste - i.e. with least possible quantity of oxide, next purest ore to Meteoric Stone - bright metallic plates. Crystals of it dispersed through a mass of loose white volcanic stone.

Haematite "bloody red powder. rich ore, but harsh often forms stalactitically: burnishing stones for gold or pottery wares.

Manganese gives gloss to iron ore. M. ye next most abundant metal to iron.

Round nodules of clay containing fern leaves.

[Side headings: "Marcasite pyrites."]

Marcasite: name of pyrites when used as gem - for court swords &c - all crystals of this fall to pieces if not protected.

Ink chemical name of Tanno-gallicate of iron - for it consists of three things. Tannin - gallic acid (or acid of gall nutts & iron. This gallic acid *in ye oak* buried underground in bogs unites with sulphate of iron there, & turns ye wood black - sulphur found in vegetables cruciform, cabbages, turnips, &c. & in trees. Boat hook stuck by Buckland's father into a tree: covered with crystals of sulphur.

Cupid's wings, sold to ye young ladies at Lyme, compressed crystals of sulphate of iron? [sic] specimen from Muirkisk, Ayrshire, in circle like ½ crown with radiations from centre, as crystallizn. in ye Wavellite.

Chromate of iron - chromate acid in painting got from it. Arseniate of iron.

In Meteoric Stones are found, Iron, Nickel, Chrome, Silex (in great abundance)

Magnesia, Lime .. [sic] cannot come from ye Earth, for the Iron is native - never known on earth. Difft. opinions, - 1 that they are fragments from volcanoes of ye Moon. If ye force of ye volcano is only 3 times as great as that of cannon ball, ye stones would be here in two days.

Vagabond fragments wandering thro space - causing peculiar electric phenomena - no cloud when they fall: but they excite electric action by velocity of descent - become red hot by resistence of ye air; fusion takes place on ye surface - little cavities bounded by subangular margins made when bits scale off, chips & fragments of large stones called shower of stones. Lambotin a Frenchman made his fortune by selling a cartload of pieces. One fell at Lanton nr. Bicester 2½ yrs. ago - always seen when red hot at night, people dare not go near them at first - buryed [sic] by force 1 or 2 feet in ground.

Another opinion is that they are fragments of a planet. That ye minor planets Ceres Vesta &c are themselves pieces of a larger planet: & that there are chips.

Comets: found to be nothing but masses of vapour, transparent, = ye density slight, & if they were to approach any body, wd. do it no great harm.

There is to be a whacking C. in 1835.

The 3 important ores of Iron then - are 3. I. Meteoric. II. oxide of iron. III. White carbonate.

Lect. XVIII, & last (March. 31)

1½ hour long

Of the minor Metals, or as they are sometimes called unjustly, semimetals, there are some that Buckland has never seen. All that has been found of them together wd. not fill a hat.

Zinc, highly electric: from its unoxidating qualities is recommended for pipes under eaves of houses, tanks, &c: & so is used on ye Continent.

Manufactory, at Namur. But in England, lead being cheap, & great reluctance to any thing new [sic] it is not so much employed. The objection to it, is that it is not malleable at a low temperature. Sulphate of zinc in Derbyshire called Black Jack, or Blend. [sic].

It volatilizes [sic] in ye fire: fluccalent form, called Lama philosophorum. Sheets of zinc may be bought. The metal highly crystalline. Is not often found in iron mines but elsewhere is common. The difference betn. zinc & lead externally is easy to be distinguished, moisture retained on zinc, from breathing on it, than on lead.

Yellow crystals of zinc. Carbonate of Z. (deposited stalactitically), is ye lapis calaminaris of ye ancients, is mentioned by Aristotle & Pliny both mineralogists to a certain extent.

Carbonate of lime is converted into carbonate of Zinc. This, ye most important ore of zinc, used for making brass. Sheets of copper, are laid over several pots placed in a row; & ye fumes of ye zinc burning in yse vessels are absorbed by ye plates of c. Mosaic gold, Prince Rupert's gold or Mola[illegible] τσφατα are all alloys of copper & zinc, without a particle of gold. Bronze not malleable except in Chinese gongs. Zinc useful in all bell metals. Brass kettle less dangerous than copper, yet brass ones require to be watched, for a green rust forms upon yn, of poisonous nature. "Native brass" were copper & zinc (?) [sic] are found in combina., rare. Ships, sheeted with copper, not to protect them, but to kill & poison off ye marine animal & vegetable adherence. The misfortune is, that copper rusts exceedingly fast in salt water, but as galvanic action stops ye action of an acid, e.g. on a penny exposed to acid, a galvanic shock would stop he process, it was thought that nails of zinc would by contact with copper prvent oxidation. Copper screws in lock gates at Lpool. unrusted. Zinc burning most brilliantly is used in fireworks with Iron & Antimony.

Molybdena. Neither common lead nor black lead (which is charcoal & iron: not a particle of lead), comes from Catfell in Cumberland. The best plumbago (black lead) in ye world is also from Cumberland - most acceptable present in going abroad. Molybdate [sic] of lead, from Carinthia, straw coloured. M. found in flakes in syenite of Cumberland, as plumbago in [sic] nr. Vienna.

Nickel - constantly found in Meteoric stones, name origin of unknown: "Nick name" probably given by ye miners who discovered it: it gives ye colouring matter to chrysoprase, which is found only in one place in Silesia in serpentine rock. It is becoming very scarce; & is ∴ imitated very successfully. Man in St. Clements sold a necklace of false for real ch. ye other day. B. went & made him disgorge. The real may be distinguished from false, by being cold to ye tongue, whilst ye artificial is warm.

Bismuth, most fusible of metals. The composition of which ye melting spoons were made is 5 parts of lead, 3 of tin, 3 of bismuth. T'is always found native, as Gold, has little affinity for oxygen as Silver, is most dense next to Silver & if ductile, wd. rank next to S., in alloy, is valuable: has curious property of giving fusibility to minerals that have it not; whilst it diminishes ye fusibility of those that have it. So does sulphur. Sympathetic ink is solution of Bismuth. Skimmed milk is also sympathetic - how to cheat ye post office, by writing on edge of newspaper. Also pretty style of drawing. The trees in a landscape being done with common Indian ink, & ye leaves in solution of bismuth, they may be made to appear before a winter fire, = away from it; ye landscape is bleak.

Antimony. Name from its antimonastic qualities, having been used for poisoning monks - most useful as a medicine = circular pill going through a family! before the metal became common.

It crystallizes in rays - plumose A. + a gives sonorous property to bell metal, = used chiefly in printing types. Flowers of antimony - if in state of ignition, it be poised over ye table it will break into little stars or young comets, as quicksilver into spheres. A. formed at the basis of all the experiments of ye Alchemysts [sic]: which tho' ridiculous, laid ye foundation of modern chemistry. It is rare in native state the great mass is sulphuret of A.

Arsenic, rare in metallic state: common form is ye sulphuret - found native, said to be, in sulphurets of silver - abundant in copper. Fumes of A at Swansea spoiled vegetation on tops of ye hills, action a law, justifiable. Oxyde of A white form sulphate of a., in Cornwall. The acid of Ars. or Arseniate, combined with lead, iron & copper. Auri pigmentum, or .. .. [? or pigment] combin. of sulphur & A. = when red, is called Realgar, from volcanic countries, sometimes imitated, but may be detected by smell. If real A., there should be a smell of onions, when t'is burnt, - ∴ though in case of a supposed suicide, the absence of that smell wd. decide against poison having been taken, but presence of ye odour would not positively satisfy; for ye person might have eaten onions. But it wd. dictate ye necessity of further enquiry.

Chrome, - commonly found in Chromate of Iron (*gray speckly*) ye acid is separated from ye iron, & united with lead, for paint yellow bright - shd. be looked for in the Serpentine of Cumberland & Cornwall, "look for it". T'will make yr fortune.

Tungsten, dull, like quartz. T-ate of lime, & iron.

Uranium, a beautiful green. Uranite, oxyde of U. & ox. of cop. pitchblende, Cornwall.

Titanium, found aritificial in slag in bottom of furnaces. In crystals of quartz needles & threads of oxyde of titanium. "Rutilite", - useful pigment for porcelain at Sèvres.

Co'balt, not Cobo'lt, - £60 to £80 a ton - lilac colour, called "smolt" or "sapphire", used in tingeing [sic] paper, as Indigo for linen, & particularly Bank notes. Specimen of slag, of burnt Bank notes - get some at porcelain manufactury at Worcester.

Manganese dendritic in cracks of stones, as drop of iron on a pitcher - common - gives gloss of oxyde of Iron round black globe - gives rosy tint to Rose Quartz (from Kapnic) - and useful in bleaching linen. Valuable mines nr. Exeter. Wadd, in Derbyshire, light as sponge, floats. Earthy smell, lies in red sandstone "dash look sharp for it", blue colour in glazed [sic] from a furnace, caused by mang.

[Side note: "Something not in books - False amethyst"]

N.B. on surface of chalk strata, at bottom of hollows, is stratum of clay loaded with M. - brownish colour. False amethyst is Quartz coloured by M. - is used in colouring glass, & is called by Haüy "Glassmaker's soap" - it destroys colour in other substances - giving col. to colourless - great source of oxygen = of igneous origin in veins of porphyry. Ye effect of sublimation = any where in O.R.S. sandstone and elder rocks, it may be looked for. "If you see a black powdery place in any hedge or ditch, where a sweep seems to have sat down: try it - say nothing - go & buy ye field - you'll make yr. fortune".

Rhodium, discovered (with 2 or 3 others by Wollaston called semimetals as wanting malleability) in platina, used lately for points of pens. The microscopic chemistry of Dr. W. taken up by no successor.

[Side headings: Inflammable minerals. amber]

The inflammable m. belong to chemistry & geology, rather than mineralogy. Diamond Coal Bovey (pronounced buvey). Jet. Amber nothing but fossil gum, easily imitated, except those pieces that have a cloudy appearance. "Buy them" = found after storms in great quantities: 5 s. per oz. - in Prussia, curious as indicators of hot climates. Lizard of Lord Northampton's no doubt false - much burnt at Mecca for incense, resin as ....[?] in catholic churches.

Salts, sapid soluble, not mineralogical: alum melts away - they belong to Chemistry. Miny has to do with solid things, - rock salt may perhaps be admitted in a Cabinet, = consists of soda & chlorine.

APPENDIX 1.4

"NOTES FROM DR BUCKLAND'S GEOLOGICAL LECTURES. THESE WERE TAKEN BY ME AT OXFORD IN 1832. J E JACKSON LEIGH DELAMERE WILTS. JUNE 1871"

Manuscript notebook in Geological Museum Library, London (Institute of Geological Sciences): Accession No. IGS 1/635

Dr Buckland's Geological Lectures 1832

(only ½ a course - in consequence of ye Philosophers Congress at Oxon in June.)

(Map & section of Basin of ye Rhine by Von Deckel of Bonn.
Geology of Poland (by Omalius d'Halloz)
Montereaux, Fossil Conchology of Poland. 219 Regent Street by Bailliere 10s/-
Shells of Paris to be bought chez Lambotin 30 Rue de Bussy
Phillips's Geology of Yorkshire
Wytham (& Nicol)
Lindley & Hutton Fossil Flora
Brongiart's Prodromus.

"Dr Buckland - May 22

Lect. 1

Books recommended. Conybeare. Miller's Crinoidea (fine specimen of analysis.) Lyell. (Fellow of Exeter) his book excellent for those who are read in Geology: hard for beginners. Theories in 1st volume have not Buckland's assent, & are not sufficiently proven. For general readers, Cuvier's theory will do.

Density of Earth as to 3/4 to 1, of water, i.e. 4 globes, + 3/4 of same size as E. of water in one scale wd. be necessary to balance it, or 2½ of P S?

Its shape, flat spheroid, just what wd be produced by rotation of fluid, it probably was once in a state of fluidity, that fluid being produced by igneous solution. - 180 places where fire breaks out.

Formation. defined by Cuvier & Brogniart - a collected mass of beds, "exhibiting materials." - The beds must have deposited not all at once, but without interval of any great change during one era as it were - Formation illustrated by Professor Boobee's section. and
Weymouth Section from Chalk to Lias
Primary. Secondary. Tertiary. Quaternary.
Geology of Poland well known. Flat plains of Russia & Poland, of Quaternary formation.

Animals of Duria antiquor found not below ye Lias.

Tropical vegetable remains and even footsteps of Tortoises (in Dumfriesshire) in Sandstone below that: the R. Sandstone, not much developed in England.

Coal Formations included by Buckland in Transition Series.

Ye climate in tempore vegetabilian foss. must have been too hot for animals. Primary slate deposited by hot water; mt. be called "hot water beds". Granite not stratified: not prod.d. by water, & cd. not be: but injected as by modern volcanoes; & crystallized. Iron pyrites at Weymouth if exposed to wet, & coming in contact with bitumen takes fire & produces slag; not lava, nothing to do with volcanoes.

The Earth was likely enough, at one time, a red hot star - became cool by radiation - in hottest period no remains of animal or vegetable - ascending to cooler times, as fresh coats or strata were deposited, like additional wall or coat of bricks round a furnace. We find ultra-tropical vegetables - all ye remains "gigantesque" - ascending still. It became gradually cooler & cooler, we get on to animals, & finally to present temperature.

Astronomy tells us that ye present equilibrium of heat was arrived at, 2000 years ago, (all changes of temperature extend to about 25 feet, none 40, under the surface of earth) - no loss of central heat for there has been no dimunition of ye Earth's diameter (as there wd have been, things shrinking and contracting as they become colder) which is known by ye length of ye day of which we have in time of Hipp. (ocrates) - or (archus?). [sic] P. Soldani from one ounce of sand, extracted 10224 nautili! weighing 181 grains & some ammonites. In Dirt bed in isle of Portland - cycas - zamia, tropical plants, found growing on dry land:- yet, ye surface there has 1000 feet at least under water, since they grew. Reeds on coast of Yorkshire, ye same - ∴ ye surface of ye Globe must have moved up & down, as carpet on stage to represent sea, and ye gazeious matter in ye E. wd. be sufficient to do this.

10 Formations in Basin of Paris.
See Horsley, in sermon preached before Human Socety - vol. III, 39. 1816 & Glegg in Stackhouse
De Luc's hypothesis not to be maintained.

The present state of E. cd. not have been produced the Deluge, nor 2dly, in the interval betn. Creation & Deluge, - there is not sufficient time so that Buckland offers choice of 2 ways, i.e. 24 hours each, - or 2dly keep these days, if you please, & yet 2 first verses of Genesis still allow illimitable time - "In the beginning - when was that? Ages, & millions of ages ago:- the heavens & ye earth were created and ye earth was without form & void & dark - then we have ye Spirit hovering over it, to introduce a new state of things, & to furnish it for ye use of man.

This explanation, is not only not contrary to Scrip. but assists ye critical explanation of it - & suits the a priori feelings.

Lect. 2

The object of the course of Lectures, is, to give an account of the different staates of our planet as a receptacle for animl. & vegb lift.

1st state: as a molten star without life of any sort in it or on it. This is an important fact, in a theological view. The assertion that there is no proof of a beginning - no trace, but that things have gone from an eternal succession of causes cannot be disproved by any physical reason but by Geology. G. gives not only an account of a period, of non existence of life, but of several beginnings - a succession of creations [not in ye sense of the word, in which a new generation of one species may be called a creation, but an introduction of new species and genera.] The earliest state of things was the simplest, & as the globe assumed its new successive geological features, classes of vegetables or animals less simple, & more complicated were introduced. They are not to be called more or less perfect, for perfection is relative, & every thing is so, *more or less, according to* its adaptation to the circumstances in which it is found.

The earliest geologl. condition then, was an undulating groundwork of granite: produced by ye passage from a fluid to a solid state.

At Claremont in France, volcanic rocks pierce ye granite & come out above them.

The next, or transition, deposited by action of hot water sweeping off surface of granite: the ingredients of Granite being found in great abundance in them. [Were they decomposed graanite, afterwards

consolidated as ye surface of the present strata by action of ye air?]

Ejectments of lava or "dykes" (approximating in some cases to granite) in constant succession, from times of original granite, through all overlying strata to a period more recent than coal, then appear to have come tranquil times.

Animal & vegetable life, coeval. The earliest animal is ye Trilobite & an analogous animal has been lately found by Capt. King, feeding on seaweed. The history of ye creature may be found in a 4to. vol. Brongniart & Desmarest. Histoire des Crustacées.

The eyes, on high optical principles, like those of lobster & crab, indicate ye operation of ye same mathematical mind at that early period, as now.

The earliest plants were also ye simplest. Algae. Ferns: Lycopodacea - our respect for a Fern-bush ought to be raised by reflecting that it is one of ye oldest created plants. Tree ferns found on ye Continent: small here. Lychopodia, a creeper, on Shotover, but analogus to the fossil L. wh. is huge. Equisetum, Canna, gigantic all.

From wh. ye common inference is that the heat was immense.

Lepidodendron: the scales (causing ye plant fossil, to be called at Newcastle, Fossil Salmon.) served as points for insertion of small leaves, as spines of echinus.

Such was ye state of vegetation during the Transition period, in wh. for convenience sake coal is included by Buckland - because ye limestones separating ye coal from lower beds, is so much harder than ye more recent beds.

In ye Val d'Orsin, Switz. blocks of granite & vegetables torn up by action of water, from ye surface, are all jumbled together in transition beds.

Tropical fern growing in island of Ischia: but we are not always to trust such appearances for botanists play each other tricks. Russian plants set at Abbotsbury, ye other day, may deceive some future Geologist.

The next series, ye Carboniferous, is characterized by Coal.

The next, Red Sandstone, by Salt and Gypsum. *quantities of brine* springs in this formation: Salt being useful for digestion, & being supplied to ye body by muriatic acid, it is a wise provision which has placed Salt, within reach of every body on ye globe, procurable either from ye sea or land. The Esquimaux get it, by freezing ice from saltwater: for ye ice of saltwater, is not salt, but fresh: & ye brine is deposited.

Oolitic Group, characterized by Saurian animals only one little wretched Mammal found - viz. a kangaroo Rat, or opossum, at Stonesfield. The vegetable & shells in O. differ from those below it.

Tertiary formation. When this began to be deposited there was by this time a considerable quantity of land, wh. had been manufactured at ye bottom of ye sea & forced up. Large freshwater lakes, contaaining happy palaeotheria &c: ye sea coming back put an end to their pleasures - changes of fresh & marine again. Last, was marine - extensive bed, called "Crag" found at Bordeaux - Italy & Sicily, in beds from 1, to 2,000 ft. thick. The Shells of it approximate to modern ones - & of them catalogues are a-preparing.

Diluvium. The question of ye Noachean deluge is still "sub judice" - a discovery of human bones wd. settle ye point - if discovered in strata of former ages, wd. destroy ye Mosaic account of creation. (?) [sic]

Lect. III

Addison in Spectator (543) had some notion/foresight of the regularity and order which has been since his time been traced in ye apparent confusion of ye world - its anatomy, he perceived, might admit of dissection.

The world in its earliest state, being molten, no matter, of what substance; & surrounded by a coat of ocean, as an orange pulp, is by ye peel. The elasticity of ye vapour caused by water coming in contact through some crevice, in contact with ye fiery mass forced up ye hills.

Exeter conglomerate ye detritus of porphyry.

For six or 7 periods, ye mechanical action of ye waters of ye ocean, not of rivers was excited, & the produce was ye Secondary formation, occupying 3/4 of ye present surface of our planet. The animals lived in the commotions & disturbances, were Rough weather fellows.

The Mendip Hills were lifted up before the Alps at ye mouth of ye Rhone + judge of age, by ye material.

M. Elie de Bowmont [sic] some years ago laid down a rule, the truth of wh. is now abandoned: every modern writer attacking & tearing poor Elie, that Parallel elevations are contemporaneous, & contemporaneous elevations, parallel. This is now proved to be so, but it deserves to be called a splendid general doctrine.

E. de Bowmont & Du Fresnoy are now employed by ye French Government in preparing a Geological Map of France, after ye model of Greenough's.

The Red Mark is ye decomposed red felspar in porphyry.

We may observe that regard was had to prospective utility at the time of ye earliest injection of metallic veins - all metals are diffused in veins, except Iron & Manganese - m. if found every where - black hair on man's head, - pebbles - &c.

All other metals are found in veins, & all below the coal, or limestone just above it. The veins were cracks formed during raising of granite.

Fossils often so well preserved, that their species are more easily distinguished than recent specimens - especially in ye case of fossil wood.

Lect. IV

History of Oolitic animals by Professor .... [? Solfütz] & Question whence came the lime necessary for ye shells of crustaceous animals in older rocks, wh. contain (little or) no lime - in beds betn. secondary rocks tis found: in some from the decomposition of animals, as oolite often of shells, but where did the animals get it from? From vegetable - & whence did ye vegetables get it? from ye land - & how did it come onto ye land - by volcanic springs, of wh. an instance may be now seen at Auvergne (Wollaston first suggested the idea) at Claremont a spring is at this moment building strata - walls - bridges; & encrusting fruits - jackasses.

The whole country there is extinct volcanic.

Corals, wh. build only in hot climates, get ye lime from ye ocean vegetables perhaps, wh. derive it from ye sea, wh. is supplied underneath by volcanic springs.

The Lasus Naturae of Dr. Plot abound. The answer metaphysical, is that according to it, ever body wd. have every form, whereas, each body has its own, & only its own, distinct & specific. Physically - in ye fossil world, there seems to have been analogous purposes - the same diseases & ye same remedies - parasites as ye lettle pholades - lithodomus &c in ye coral.

Fossil barnacles attached to fossil wd. from Lyme.

The Earliest animals - cartilaginous, [sic] not containing any, or little lime - Starfish, Shark, Tortoise. The red sand stone Tortoise marks. Gent. Mag. 1828. 163. Chantrey & Buckland, & Duncan of Ednburgh. "What a fool?! - on ye 2d. box being opened - says Chantry, I know who's fool now. The marks then of tortoises in red sandstone being acknowledged. Where is ye tortoise - no bones found. Teeth cannot, because he has none. The bones are found elsewhere. But says B. they are Scotch tortoises travelling South! They are found close to Firth of Forth. The better reason for their not being found, is, that red sandstone has no lime to preserve them in & has not ye capacity of preserving animal remains. Casts generally found: the substance of ye animal having been decomposed.

Lect. V

(Someone gave this day to ye Museum a piece of Roman brick from Stonesfield with ye impression of a Cat's paw - made during ye soft condition of ye brick.)

Convenient passage in Art of Poetry often quoted by Buckland but not to end as Horace does Et sic mentitur! He has often been laughed at & ye truth of this doctrine called into question. "Come & look" say I. They won't look; so I tolerate their incredulity: whilst my evidence is such that I do not beg their assent. I demand it, I defy opposition. I challenge them. I dare them to doubt it.

Doubt that ye stars are fire!.

Referring then to ye picture distributed through ye class, it seems that at the time when ye greater part of ye world was sea, ye Lords of ye creation were lizards & crocodiles, rigged out for sea; the fossil Tortoise & Turtles, are distinguished by ye elongated fins, that make ye difference betn. ye recent land & ye sea Tortoises & Turtles. In Freshwater formations, are Freshwater Tortoises - & also there are Terrestial Tor. They lived in very warm times; & being underwater Conybeare has called then Enaliosauroi - no Saurians above chalk - not much below lias, ∴ they are confined to oolitic - a few have been found in new Red Sandstone (Muschelkalk). Above ye chalk ye animals of Tapir form.

From ye lithograph, then ye world seems to have been a slaughterhouse. The arrangement by which is presented ye natural death of most animals, a humane & merciful one. When we see a pike eat up a carp, we say, "poor carp" - but forget to show ye same compassion when we have one dressed at our own table. Nor do we ever say it of ye beasts - pigs, sheep, chickens, geese, ducks &c. If ye law of nature is, that all must die, there is no cruelty in ye ordaining a violent death to ye majority - lingering death thro pain, weakness or accident are prevented. If an animal hurts itself it is probably taken up the same night by one of nature's policemen - ye carnivorous animals, so that great suffering rarely occurs in nature. What wd. be ye consequence again; if animals were all of one class & not of many different genera, destructive of one another. Supposing, all were deer & eaters of grass? Nothing by pauperism therefore there includes a violent death apprehension, & fear. A fish eats a good dinner - gets a hook in his mouth, pulled out & bagged in a moment. No pain - he does not dislike it. Therefore ye arrangement affords natural pleasure to ye eater & to ye eaten.

Did fossil animals do this? Class of scavengers, Hyaenas, eat bones & garbage, far preferable.

Lord Cole gave a specimen to ye Museum here of an Ichthyosaurus who died of indigestion & was actually found with a quantity of faecal matter in his inside! The scales of fish, like grape stones, & cherry stones are indigestible vide human coprolites in ye .... [?] &c. Coprolite: this is ye name of ye fossil faeces - corresponding in form to injected faecal bag of recent sturgeon. "These I made myself, says ye Professor! Remains of a saurian 4 feet long, inside another. Like sharks they bolted their food - & have a long pouch to put him in.

In richis of a head 6 ft. long would entrance 6 undergraduates, or at least 3 professors or Heads of Houses.

Megacephalus - a kind not yet described.

Crocodile at Whitby, with snipe beak, like ye Gavial of ye Ganges.

How do I know that Icthyosauri were marine animals. Look at his vertebrae - they are concave on both sides attached to one another by membranes containing elastic fluid, to assist flexion. Man at Wantage used one for a shaving-pot! From this, we discover that they lived in sea, & used their tails for rudders & also that they cd. not come on land for smash would have gone his back!

The eye of ye Icth. ye largest in ye world. Defended by scales with artichoke leaves - 1st to protect it from immense pressure when going deep into ye sea, & also to save his having a black eye at every wave - ye nostril close to ye eye. [thumbnail sketch here].

Another provision perhaps to contract or enlarge ye eye as birds do - eye of a whale small but toughest thing in nature against pressure.

Junk, a fragment of fossil.

Again ye construction of his jaw remarkable. It is made on ye principle

Plesiosaurus - betn. crocod. & tortoise - neck as long as body. Doctrine of Geoff. St. Hilaire [sic] of developement [sic] - one speciies formed from another - e.g. crocodiles from ichthy. or ples. - thus an animal in less complete form by exertion of .... [? appitency] assumed new improvement of shape. (Lyell answers this well.) All that can be done in this way, is only modification of species, egg warmed more on one side than another will produce a deformed chicken, monstrous this side minute on that. Keep your foot or finger in a chinese shoe or a vice ∴ will never gain its usual size. but you cannot change organs or introduce a new idea. Yet 1/3 of continental philosophers are of this school.

In France, & Sussex, only a saurus found, from its size classed Megalosaurus. 40 ft. long, 7 high.

Observe ye construction of its Teeth, - it has a sabre shaped cutting edge inwards - sharp & serrated within - but blunt & rounded on ye outside. Here's cutlery! When young (remedial provision a Scotchman's dirk! ye young teeth may be seen in ye draw) - the tooth is a thrusting sharp pointed sword. Old, a single edged sword for cutting. What did he cut? Crocodiles, dragons - or he mt come on land.

<u>Iganuodon</u> [sic] - ye discovery of belongs to Mantell. Head of femur (large as a shaft of an Elephant wh. Cuvier said must have been 16 ft. high) When shown to C. he at first said, t'was a Rhinoceros, but it may be a lizard! Teeth of this herbiv. anim. made exactly on

pattern of pincers for tearing off wood. Now if appetency [sic] begot these teeth in ye crocodile - then in the iron it begot ye pincers. Specimen from Super. of ye toe of an iguann. wh. must have been 1,500 lines of ye bulk, (not necessarily ye length) of a modern lizard - ex pede itenalem [sic].

Lect. VI

Dragons in middle ages of Geology, as well as in ye romances of historical Middle Ages! + plenty of bivalves (& spirifers), but no oysters in ye older Secondary rocks. Lizards, tortoises, crocodiles most numerous Lias but not of ye largest size. In ye Tertiary rocks, all cease exc. tortoise & crocod. : - not a trace of ye larger saurians: in lieu of them Tapiresque Quadrupeds. The lowest shells are marine. Thus Freshwater shells are found lying betn. marine beds, is not extraordiny. seeing that now-a-days it is not uncommon for Freshwater to drive out ye salt water in lakes. Stonesfield was probably a margin, where land lizards drifted down to ye sea, & fell to ye bottom - lizards are also found, analogous to bats, at ye bottm. of ocean. with cookchafers [sic] beetles of which ye fed - ye dragonflies: ye dragons ∴ eat ye dragonflies.

Diffent kinds of lizards. Brevirostris, Longirostris, named by Cuvier. Megalonyx at Lyme, with 3 or 4 claws, not only for hooking onto rocks &c. but also for walking. In ye fossil L. ye 4th. finger only is elongated - had a Tail. Some must have been as large as turkeys.

Out of a rejected block at Bonn, P. Goldfuss struck out a new species of lizard Maprocaphalus. "These are not Fancy Birds". They are rightly classed with Lizards, becse. in all points in wh. they differ from Birds, as well as from Bats, they agree with Lizards. They are not ye same as ye draco rotans: for he has only extended ribs. The teeth (wh. no bird in the world has). Ye "os carrè" at ye junction of 2 jaw, round (?) [sic] - bones of ye neck, ye ribs, ye pelvis, ye hooks, ye metatarsial bones (?) [sic] agree with those of ye Lizard. There are various proportions in claws of Lizards but in all ye penultima bone of ye toe is ye longer, ye antepenultima ye shortest - so in ye Pterodactyl, but not so in birds. In ye 4th Finger of ye Lizard, is ye largest no. of bones. Ye antepenultima,& ye one before that, being ye shortest: so in ye Pterodactyl. Flying fox from ye Ternet islands.

Reptiles herbivorous (& iguanodon herbiv.), found in earlier periods so Mr. Miller of Bristol found his iguanod [sic] eating forced kidney beans in the hothouse. *The dragon of Wanttey [?] once omnivorous.*

The Lizard Dynasty was put a end to by ye Chalk, (beautiful sharp edged speciments from ye Portland, of Quainton of icthyosaurian vertebrae).

Ammonites Belemnites. Nautilus.

Of amm. ye are 3 or 400 species, none recent, nor in ye Tertiary rocks.

Belem. began in Lias end in chalk.

Nautili began at ye beginning & went through to recent times. Their shell is less complicated than that of Amm. (a little diversion concerning Sepia, to illustrate ye history of Ammons. is necessary.)

Cuttle Fish is Sepia is ye highest of ye Molluscous animals (Pen & ink fish). The ink bag when dried is Indian ink.

The Icthyosaurus eat Sepia. "How do I know? - I gave a piece of Coprolite to be analysed by Dr. Prout: what's in that, said I - "Can it be Sepia! said he. To be sure it is said I. This also teaches me another thing. When ye Sepia is frightened, ye squirts out his ink. This fellow has not squirted out his, ∴ he was not frightened, ∴ he was killed suddenly without being aware of it. Probably he was choked by mud, died, & was buried before putrefaction commenced, as icthyosaurs themselves mt. be, & as haddocks are bemired by thousands in Scotland. Now Sepia has a parrot beak: so has ye fossil. Now ye ammonite & naut. have been supposed long time to be a kind of sepia - ink-bag-less - because they wd. not want that kind of resource, when they had a shell to retreat to. Nature is not <u>prodigal</u>: she is very oeconomical. Rumfins, an old writer, asserted that ye Sepia was ye inhabitant of Nautilus Pompilius. Every body laughed at him. Sailors say, tht ye Sepia is often found in the nautilus shell now, but that when ye shell is caught, he jumps out & escapes, ∴ he is only a parasite - or tenant at will.

Within ye last 6 weeks however a Sepia has been taken in ye shell & so ye matter is settled & ye shell is in ye College of Surgeons. Rumfins is right, he had arms & beak & no bag - and so we find the naked & shell-less sepia only has no bag. Ye Sepia without ye inkbag could crawl upside down having a double bill he could float on his back & grub up crabs & then lay hold of them with his tentacles - ye hollow chamber of ye shell acting as a float to buoy him up.

Ammonites, begin at earliest periods - change as they go up. The 3 oldest accidentally have been named after ye three professors, Henslow, Sedgewick [sic] & Buckland, "of wh. Professor Henslow is more simple than professor Sedgewick, & professor Sedgewick is more simple than Professor Buckland!" A. end with chalk.

In ye nautilus, a curve meets 2 rt. angles. In Amm. ye shell is thinner & ye transverse plate goes backwards & forwards - locked in. The exterior of ye A. is rugose each furrow being a bridge providing mechanical strength. The Naut. is simple in ye exterior.

How can philosophers say that one (of their 300 species) has proceeded from another by natural descent, when there is to be traced throughout a constant affinity to some great principle. Paganini performs 300 or 400 convolutions & distributions, yet observing one tema as ye groundwork. It mt. just as well be said that this is owing to an affinity between ye Fiddle & fiddlestick, and not to ye skill of ye performer. The will not admit ye action of mind.

Different kinds of chambered shells.

Scaphite coiled at both ends. Hamite, at one; wh. is often found broken off. Baculite, straight. Orthoceratite of gigantic size. Turrilite, & all having siphunculus connecting inner chambers with outer in wh. ye animal lives. Belopteron a connecting link betn. ye Belemnite & Sepia.

Lect. VII.

Animals of ye Tertiary Period. If ye history of ye Secondary strata is due entirely to ye English, that of ye Tertiary is due wholly to ye French. Basin of Paris unknown 25 years ago. 1/3 of Earth covered with Tertiary strata. Curious extract from a work by Demaillez, who disguises his name by transposition, making it "Daillemez": one of those philosophers who maintained that Men were once Fish, & went through a series of tadpole metamorphoses till they arrived at their present degree of perfection. "If I was a King of France, says he, I wd be a philosopher King, I would set my subjects to work, to dig down into ye bowels of ye Earth: & if they found a fossil city with fossil Frenchmen so Daillemez shd. be ye First philosopher in ye world." Now changing ye terms, this is quite true. Institute for French-men ichthyosaurs & plesiosaurs: & there are fossil cities, Kings &c under ye city of Paris. "If I were to dig down through Dr Daubeny I shd find not a fossil professor & a fossil clay, and a fossil universe, but classes of other animals, belonging to different epochs." - alter ye terms then, & ye theory is true. According to Elie de Boumont [sic], & Lyell, ye paroxysms of nature have been more violent in ye tertiary than in ye 2dary periods. Agst. this point of Lyell, B. protests. The conclusions are forced further than ye premises will warrant. + (Maria Graham describes subsidence of 150 miles of Chili coast 4 or 5 feet by an earthquake! Tertiary Basins in different pts. of Europe. Paris, ye Rhine, described by Von Deckel of Bonn; in a good map & section. Poland by Omalius d'Halloy.

1000 feet at least of Lacustrine Period - ye dignatories of ye Earth in those days, web-footed as Tapir.

The lowest strata of Tertiary contains driftwood forming ye Blackheath coal - & coal of Corfe Castle. Terrestrial & Freshwater remains not only always to be looked for in Freshwater deposits - dead dogs washed down rivers will be mixed when ye water is brackish with oysters. At Stonesfield certainly a marine deposit, are found animals of Earth or opossum, air, & Freshwater.

Volcanic region of Claremont described by Scrope. Basaltic cap over freshwater shells in limestones. Fossil ducks eggs - rats, "....." ["insipid"?]. This district was once lacustrine, was then covered with lava, & since, has been subject to a great inundation wh. has removed ½ of ye basalt. But what inundation? Scrope says rivers. Buckland, diluvial. This is a good country for seeing the difficulty if not absurdity of Scrope's doctrine. For ye water has removed what? Tertiary! Some of ye latest deposits! There cannot have been time for that. B. cannot see how ye action of any river, from eternity itself, can have had such effects: much less than in space so limited, as ye time when these tertiary strata were deposited. No Secondary

Rocks here, but ye Tertiary is deposited on ye very granite. It may be asked, then why are not the secondary, being on ye granite & tertiary here, of ye same age. - Because the organic remains are totally different.

"Stock paragraphs" of newspapers speak of cows grazing at ye bottom of ye Sea - they are ye lamantin or dugong - warm-blooded animals with lungs that come up to breathe ye air at ye surface, for cold-blooded animals by means of ye gills can breather in ye water as fish. These dugongs have given rise to ye story of Mermaids. (Duncan's picture of dugong with comb & mirror.) rib of lamantin in a village church nr. Wantape sent home by a Jesuit many years ago. Their ribs solid, not marrowy, can be found as it is, at Bourdeaux [sic], in company with ye Morse [?], a cold-blooded. - "dayman"?

Cuvier collected fragments of bones & entire bones from Montmartre, & filled his house, then set to work & by aid of Comparative Anatomy, arranged them. His account of his feelings, as if he were in a charnel house. He has made out 7 species of Palaeotherium there. In all there are 10 - of Lophiodon 12 - Altogether 50, or 60 different species of animals! Also a marsupial. (Within last few months, an opossum in New Holland, & recent Trigonia (or a shell as nearly like it as possible) not known to exist before, have been discovered & sent from Hobart'stown. The opossum exactly corresponding with that of Stonesfield. That ye Stonesfield spec. is an opossum fragment is certain, for the teeth being very small have 2 fangs on ye molars, wh. no reptile has, & each has 5 or 7 lobes like none now found exct. ye opossums.) The tertiary marsupial is ye Salir ? [sic] That it is so, is known by its having 2 additional bones of pelvis, for support of marsupial bag.

From ye specimen at Stonesfield: then we learn, that of all ye warm blooded animals, ye Marsupial was created first. Their mode of uterogestation, is certainly the most simple, viz. extrusion of foetus when abt. ye size of a mouse.

Cap. Murchison who discovered ye fossil fox was himself a great foxhunter once.

I sat next Hugh James [1795-1838, theologian and founder of British Magazine] at ye Lecture today: he was much amused.

Lect. VIII

Quaternary animals.

The country from Liverpool to Lancaster covered with the quaternary strata. Extinct species of Elephant found in gravel pits all over ye world, differing from both ye recent species, ye Asiatic, & African. And is found even in America where no recent species exists, - all to be referred to last universal innundation - (whether ye Mosaic innundation or not, will not say), also 7 or 8 species of Mastadon, there being no recent one.

The sources whence the remains of this ara [sic] are derived are 4.
1. Freshwater ponds (viz. large tracts once covered with freshw. lakes). In Thorne waste Mr Vernon has found tyger, lion, hyaena with 16 or 18 species of recent shells.

2 Sea. In ye crag of Norfolk, a marine deposite [sic] are found

Elephant - deer. Val' d'Arno crowded with hippopotamus of 4 or 5 species.

3. Dens of wild beasts.
4. Fissures containing particularly carnivora & ye animals persued by ym.

These then are 4 depositories of quaternary animals agreeing 1/3 of them with recent animals.

Beechey; animals at North Pole, died at ye same inundation correspond with others dug up in front of St. John's Coll.; leg of one, in Oxon Museum, wh. Cuvier saw, & said must have belonged to an Eleph. 16 ft high, - higher than ye lecture room.

Of Rhinoceros 7 or 8 species - co-extensive with Elephant. The Rhin. found in Mr Gell's cave [Dream Cave, near Wirksworth, Derbyshire] must have been brought in by deluge.

Mastodon less abundant in Europe: found in large quantities in America, in situations in wh. they almost seem to have been lodged since ye great inundation that produced quaternary deposits. Mr Crawford [sic] having missed his ship was left to wander abt. on ye shore (in Ava) during wh. time he discovered 2 new species of M.

It may be called 1st cousin to ye Elephant = ye name from mamillated surfaced teeth.

Megatherium brought lately by Mr Woodbine Parish, consul at Buenos

Ayres [sic]. The most curiously constructed animal under ye Earth - haunches - femur & foot immense, between Sloth & Anteater, but nearer ye Sloth. (Dé..... [?] to history of ye long-armed & paroisseux Sloth. Simplest teeth possible, like mill for crushing, such as no other animal has, hind feet armed with claws set on at rt. angles. Fore feet quite a lazy-tongs for creature that has been most profanely & blasmephously [sic] abused as a Bungy beast by Buffon, & all naturalists not even excepting Cuvier: but his toits is most admirably adopted to his profession. Waterton who has observed ye habits of ye animal himself in American woods, is ye only naturalist who has fairly treated ye Sloth.)

Megatherium's teeth, like a sugar mill - & his general construction exactly contradictory to that of ye Elephant. The exterior of ye El. is heavy; & rests upon his forefeet, whereas in ye Megatherium the fore-part is slight, but his posterior, magnificant! There must have been tuns [sic] of muscle. His haunches served him for a perpetual camp stool, on wh. he sat - reaching up to boughs of trees, & hooking them down to be crunched. The Sloth sticks up in ye tree, & when he has eaten all that he can of it, goes to another, perhaps crawling over ye ground, but often going from tree to tree. The Megatherium sat on ye ground - no tree cd. bear him, a horse in an orchard will squat on his haunches & eat ye apples. When Professor Sedgewick saw ye claws of this Megatherium, on ye floor of ye Geological Society rooms he said. He knew what it was - it was ye fossil remains of Old Scratch! The only bone (pelvis) of this animal in Engl. was sent to Oxon. Mus. by Late Duke of York.

Another animal - a young Scratch - covered with Mail, called Megalonynx, quite a discovery of Woodbine Parish's.

There are also lots of small fry - such as were found in ye Kirkdale Cave - 4 ways by wh. these caverns became filled with bones.

I. The animals were dragged in by hyaenas: Col. Sykes found in Paboo a shoulder of a camel - jackass bones &c: having shot a hyaena at ye mouth of ye cavern. They hunt in packs & unite in dragging beasts much large than themselves to ye hold. They eat their venison high-stinking - & not only ye flesh, but bones - they will eat each one another, a hyaena at ye Cape kept by Mr Clarke - eat [sic] his own brother. All these facts were assumed by B. in his Rel. Dil. a bone of a hyaena has been found in a cave polished by rubbing, as corners of stiles in Wales, by being rubbed by greasy leather breeches on latter end of ye Welshmen - one polished by feet of goats in a cave in Sicily. Also large quantities of Album Graecum in balls, left in ye cloaca of ye den, bearing ye actual form of pinch of intestines, in act of being extruded - ye same of ichthyosaurian faeces: by wh. B. can tell what was ye shape of ye gut of the anim. Tons of dung at Lyme R. These facts may seem ludicrous, & unimportant. But says B. they are not so - "I made £500 by my book: & ∴ as a mere matter of pocket they are important !"

II. They were drowned & washed in.

III. They retired there to die: as bears do. 200 bears remains in one cave in Germany, and

IVthly, They fell in through fissures.

Lect. IX

Fossil Vegetables. Robert Brown (late Keeper of Sir Jas. Banks's museum, I believe) is ye first Botanist in the world. No one knows him in England, so retired are his habits. But in Bohemia Count Strahnberg ? [sic] to whom Buckland used always to send his fossil flowers to be christened, for he cd. get no one to do it in England told him that R. Brown's work on New Holland flowers wh. unfortunately had been burned at ye publisher's, was translated into German &c: & was regarded on ye Continent as the very highest English authority - he is now at British Museum.

Phillips's Geology of Yorkshire is illustrated by a great no. of plates. The Transfer Lithography is a new & cheap way of striking off drawings so that you may have 100 of yr own done for 20s.

Brongniart Jr. ye most accomplished Botanist in France, as his father is a first rate Geologist.

Astis also of Doncaster, published a book called "antediluvian phytology" wh. B. Recommends, tho' it is not of the same authority as others.

There is ye same indication of a graduated decrease of temperature from ye earliest times, in ye vegetable as in the Animal World. They abound in older rocks. For ye resumé of fossil plants in ye different strata: see Brongniart's Prodromus.

He says there are 50,000 species of known recent plants, & divides geological ones into 5.

1. Actual. 2 Quaternary. 3. Tertiary 4 Secondy. 5. Transition.

The Linnean System fails us in arranging fossil plants & Geologists are obliged to have recourse to a new method. Examination of ye structure of fibres of wood &c., by placing small thin slices on plate glass, under ye microscope.

Of Vascular Cryptogamous plants there are 1700 species of which 222 are found in Transition. The most familiar of this class are ye Ferns.

Of Gymnospermous or Coniferous - found in Tertiary strata: B. does not know of their having been found in ye coal - a piece was subjected to Lindley, of which he said that ye transverse section, agreed very well with that of deal, but ye longitudinal section differed. This latter is a common match if examined with high microscope, shows every fibre to be made up of a number of little globules in rows.

Of Dicotolydenous 32,000 recent, none in Tertiary.

The differences betn. ye Dicotolyenous, & Moncoty. are coincident throughout ye plant through ye bark - trunk - leaves - root: all of which distinction is as equally apparent in ye fossil plants as in ye recent.

Out of 50,000 recent species of plant, then there are in all, fossil 550 already found - probably in 40 years - hundreds & thousands more will be classified.

There is a Flora peculiar to each Geol. ara [sic], some plants begin at ye beginning, & go through to ye end some are confined to a single epoch.

1. Transition rocks 9/10 of wh. that have been found are Cryptogamous, whereas of recent species only 1/30 of ye which are. The are gigantesque. Lycopodium 50 or 60 ft long, equisetum 6 inches diameter & many yards in length.

2. In Secondary Cycadeae chiefly abound. In bed of mould under Portland stone are trunks of cycas & Zamia - agreeing in peculiarity of Buds, & internal structure. The Cycadeae begin & end with the Lizard dynasty: the climate is found to have been answered [sic] nearly to the Tropics.

3rd.

4th Period agreed nearer to actual vegetation, ye climate like ye present Mediterranean clime. Montebolia prolific in fossil plants. The proportions & genera of dicotolydenous plants nearly ye same as now.

The Theory of M. Brongniart draws from this graduated decrease of heat is pretty & may be true. eg. Looking to ye Grotta el Cane nr. Naples we find that where carbon is supplied abundantly, vegetation goes on with great rapidity - as in dunghill. He says that in the time of these gigantic plants, that Carbon was more abundant than now: that it has diminished gradually till ye air has arrived to ye present condition of our atmosphere, abt. 1 per Ct. of Carb. All animals breathe out carbon. If you want to put out a candle in a barrel of gunpowder, breathe on it through a long paper tube: before your breath is exhausted, the candle will be out. As these animals yield carbon, plants take it up & feed upon it, so that Animals & plants act as contradictory forces, & ye more you feed a plant with it, ye fatter it will get. Look at a cucumber in a hot-bed.

In these days then we are speaking of, there was too much carbon for animals to live. Well, does this agree with ye story told by ye strata? Yes. There were none! not even reptiles. Except marine anim. as fish, molluscous, wh. wd. be quite safe under water.

In ye next period, thus ye carbon becoming less every thing becoming Tropical - vegetation is less gross & ye character ye animals is changed - crocodiles &c. come in. B. wd. like to try an experiment upon a lizard, or crocodile: how much carbon could he endure - if he cd stand 5 per cent of carbonic acid gas, this wd. illustrate ye theory.

What then is become of ye Carbonicacid gaz [sic] ? it would radiate as heat will: it won't go back into ye Earth, whence it was sent out in quantities by volcanos [sic] - he disposes of it thus. It went to make the Coal.

Thousands of forests swallowed up ye carbon. Coal is known to be a mass of vegetable matter - as truly as a dung hill is made of straw. There ye carbon remained. The air foul with 8 per cent of carbon was purified by ye profitable conversion of vegetables into coal.

Syrmgodendron - marked with pipes; & scales to wh. were attached prickles as on recent cactus.

Lepidrodendron - exists only in form of Lycopodium. Conites Bucklandii - But when does Palm begin? & Tree Ferns end. The Palm is monocot. - & ye northernmost point of growth is Sicily, when indeed it is a dwarf. They have been transplanted to Italy. Palm begins after Coal. Chemnitz stone not in coal, each tube contains hexagonal star.

The dinner we eat, & ye instruments we eat it with are connected with this most remote period. Between the beds of coal, wh. cook our meal, lie beds of clay containing quantities of iron. The great bulk of ye iron got in England, comes from ye mud that buried the forests of those days! The Romans cd. not get this. The limestone beds accompanying ye coal, serve as a flux for melting out ye iron.

June 7th

OTHER MISCELLANEOUS NOTES BY J E JACKSON IN BACK OF THE NOTEBOOK

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[1] France

A rivulet that turned a mill suddenly disappeard [sic] under ground & re-appeared some yards off: leaving the mill helpless.

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[2] At Lucerne

Boulder cave shown - basins worn by stones

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[3] Imposition practised by ye Jesuit Roderick, upon the tip top Dr. of Wurtzburg, Adam John Besenger. His book in Latin "Lithographia Wurceburgensis Joannis Beringer" 1767".

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[4] Pachydermata, of various extinct genera, &c found in great quantities in Tertiary, & 1000 diff. kinds of shells.

Cuvier made up skeleton of a tapir species from fragments of bones, &c published his book before the animal had been found. His description of himself in a charnel house & angel's trump.

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[5] Capital jelly in antediluvian bones. B. proposes to treat his friends with some in commemoration week.

N.B. Never eat jelly abroad - made of all sorts of rubbish, mules &c.

bodies in grave decompose, & solve into gas - nothing whatever left.

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[6] Hyaena emits white secretion from glans near anus: & devours it as "butter to his dog bread" to aid digestion of bones.
(Dr Sykes at Cape of G. Hope)

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[7] <u>Buckland</u>

Sterno - costal stays! borrowed from st. cost. bones on stomach of plesiosaurus - like double row of buttons on an old ... man's [?] waistcoat, on & venison ... [?] - as carrée - quadratus).

In caricature of his beasts, one made spouting out water with his mouth open.

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no rhinoceros found fossil.

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a plesiosaurus like a sea serpent run through through a turtle.

That we are all descended by gradual perfecting from Crocodiles &c disaproved.
Ichthyos. - croc. - & ples. - are found coeval. not one following ye other. The Frenchman St Hilaire has never been able to change one animal into another only alter ye amount of development. Eg. by application of heat or cold can alter size of particular limit of chicken but never is changed chic. to duck.

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[8] advice - never to try & persuade ye world of a new theory - persuade 2 or 3 of ye tip top ment - & ye rest will go with ye stream, as Dr B. did with Sir H. Davy & Dr. Wollaston in case of Kirkdale Cave.

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[9] bones when first discov. in caves often as soft as touchwood.

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[10] Look in the lowest part of caves for bones & sound with hammer, when it rings hollow - under stalagmitic floor.

Elephant bone found in New Holland - all in the dark. Animals diff. from every other part of ye earth.

3 kinds of caves. 1. where prey has been dragged in by hyaenas, & other anim., not bears. 2. when beasts have fallen in down chasms, as at Ld. Feversham's, & in Derbysh. 3. Bear caves in Germany. inundation since deposit of bones has swept all down to lowest hole.

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[11] Neither amm. nor nau. found above ye chalk nor in transition.
difference between nautilus & ammonite.
1. Nautilus tucks up his tail &c that you cannot see it - but the point of ye A's tail is always visible.
2. Wonderful serrated sutures lock work in ye ammonite.

Pipe from outer chamber runs through all curves.

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both inhabited by sepia. Story in Buffon of wonderful ......
[? poulpe] attacking ye Ville de Paris.
Balistes armed with ...... [?] & hair tripped.

Spirifer shell - iron [?]
bufonite: in palate of fish's mouth - wh. with spines - & teeth, on some .... [?] found - they being ye only long or enamelled parts of cartilagenous animals. αναπανθα.

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400 species of ammonite.

Many fossil genera of extinct animals

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orer and boree carniverous τραχηλοποδες
erbiferous [sic].

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wh n an oyster is dead ye shell opens - a muscle keeps it shut, th natural position being open & ye animal dying ceases to use ye mus le.

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[12] Domestication will make carnivora, herbifera [sic], & herbiv., carniv. & both together.
horses in S. A. eat hard beef. Cats & dogs eat veget. food & meat.
P. bear in natural state will eat any thing, anim. veget. or min. is

a gentleman of his work like .... [sic] (Buckland).

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[13] Planaria (found at Red House Battersea)
The Hydra of ye ancients - described in Literary Gazette. May, 1831. - read in Globe of Saturday May 21.

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[14] (The following Notes were made by me the morning after a Lecture given by Dr Buckland on the Megatherium at Oxford. June 1832. J. E. Jackson (of B.N.I).
Leigh Delamere, June 1871!

1832.

Dr Buckland lectured in ye Music Room on the last evening of ye Meeting of ye B. Association for advancement of Science, held at Oxf. June 18 - to 23 -, upon ye Megatherium.

"3 claws on forefeet - 1 on hind, cd. scratch a ditch at once: capital ditcher & drainer. "Mr Brunel (who was there)" eyes him & says I shd like to have gone in "My Tunnel?" No, Mr. B. he wd not suit you, he's a bad Tunneller. "Covered with an elytron, as armadillo, to defend him from dirt & dust in a hot sandy country. Feeds chiefly on roots - & young shoots on extreme branches of trees - snout as tapir. Pelvis "Mr Clift, loaded with glory & honours had "crept through it: & so came into ye world a 2d. time thro' ye pelvis of ye M.!" - "Old Scratch", B. "wd. be sorry to be ye husband of a wife with such claws." Snout like a Tapir. Teeth only for grinding potatos [sic] & shoots of trees, & kept yourselves sharp by use more as a knife, plate of steel in centre of 2 plates of soft iron.

Ld. Northampton during a speech during this Evening meeting mentioned "politics". Dr B. rose again & amused ye audience by explaining "what were politics of ye Megatherium." "He lived on roots, therefore he may be presumed to have been a Radical. He cd. not dig deep holes, only scratch, so he was not Broughmonger: his Teeth were "Tricolor". (Mr Clift of ye Hunterian Museum had painted his Teeth of 3 colours). - "& all who witnessed his enormous behind must agree, that no one was better fitted to be ye Premier of a broad bottomed Administration."

Eulogy upon Cuvier: all sons of science allowed to subscribe to his monument. Only one passage in his immortal works to which B. wd. not assent - viz. that, wh. accused ye Sloth of being awkward sans aucune compensation. Mr Clift & Waterton had redeemed his character & justified it by his conformation.

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[15] 1832

Mr Brunel stated in ye Theatre at Oxford, that observation of the mode in which ye Teredo works under an operculum, when boring, suggested to him the idea of his shield in ye excavation of ye Thames Tunnel: & he resolved upon ye practicability of ye scheme, though it had been previously tried in 1808. If he had to begin again he wd. make it larger & nearer the surface of the bed of the river.

I heard Brunel say this.

J. E. Jackson. Leigh Delamere
1871

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[16] Keep along ye line of dip not along ye line of bearing - (across ye furrows - not up one).

Crops up - escarpment
sloping precipice

Formation - identity of time & circumstances let alone substance.

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4 miles lowest depth - not on direct line even 1/4.

World from its spheroid shape one in a state of fluidity - igneous fusion for water insufficient to produce such effects

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Fault: caused by sinking of strata - going plump bodily down.

Thundering noise in wells at Bath.
(Drumming well at Oundle. B.P.A. 11.262)

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[17] Aylesbury Ducks = always more forward in season. Dr. B. says, the women give the drakes brandy, & keep the hen on ye nest, several weeks by feeding her with gin and keeping her in a state of constant stupidity ∴ pulting eggs after eggs, she being drunk the whole time till she is nearly reduced to a skeleton. The young ducks are then fed upon some glutinous matter boiled out of bones & (I forget what else).

Dr. Buckland's Lect. 1832.

JEJ. 1871

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[18]

Artesian wells - from Artesium (Artois) natural fountains - bored thro clay arrived at porous strata (Lord Holland's).

John of Bologna's Mercury mt. [might?] stand on one leg & blow water from a pipe into either Rhine Rhone or Ticino, from a peak nr. Glacier of Rhone.

Napol. intended to join Rhine & Rhone by a cut from Neufchatel to Geneva Lake.

All great rivers pass thro narrow gorges "Eclus" - Rhine, at Bingen: once closed & all country under water, as was ye case with country from Bale to Bingen - they rise in primitive rocks - pass over transition - out.

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A NEW REVISION OF THE PLEISTOCENE MAMMALIAN FAUNA OF KIRKDALE CAVE, YORKSHIRE

by PATRICK J. BOYLAN

(Read at Hull, 18th October, 1980)

CONTENTS

SUMMARY

Kirkdale Cave, discovered in 1821, has a special place in British palaeontology, as William Buckland's first, and classic, fossil hyaena den. Since Buckland's time there has been no comprehensive re-examination of all the surviving mammalian fossils from this important site. Hitherto the Kirkdale species list has apparently shown puzzling anomalies, including a mixture of cold (glacial) and warm (interglacial) species within a single thin cave-earth.

All of the surviving Kirkdale Cave material that could be traced has now been re-examined, and a revised faunal list is given. Eighteen species are identified, four more species are doubtfully recorded, and twenty-seven rejected as erroneous or synonyms. The latter include *Homo sapiens*, *Ursus spelaeus*, *Mammuthus primigenius*, *Rangifer tarandus* and *Coelodonta antiquitatis*. The material is indicative of a single, homogenous faunal assemblage, which includes *Vulpes vulpes*, *'Panthera'* cf. *leo*, *Crocuta crocuta spelea*, *Elephas antiquus*, *Hippopotamus amphibius*, *Bison* cf. *priscus* and the interglacial rhinoceros, *Dicerorhinus hemitoechus*. The assemblage is attributed to the climatic optimum (Zone II) of the Ipswichian interglacial.

I. INTRODUCTION

In June 1821, John Gibson of London was visiting north-east Yorkshire when he saw fossil bones and teeth in road-metal at Kirkbymoorside. These were traced back to a small quarry by the side of the Hodge Beck, Kirkdale (SE 677856) in which a small cave had recently been discovered. The cave contained enormous numbers of fragments of bones. During the next few months, excavations in the cave earth by Gibson, William Salmond of York, Rev. George Young and John Bird of Whitby, Rev. William Eastmead of Kirkbymoorside, and others, yielded large collections of teeth and bone fragments in which the remains of hyaena, 'elephant', rhinoceros, hippopotamus, and various speeies of bovids and cervids were found.

In November 1821 William Buckland, the Professor of Geology and Mineralogy in the University of Oxford, learned of the discovery and began working in the cave. He was already familiar with the great German bone caves and with the techniques which Esper, Rosenmuller and Goldfuss had developed during the previous forty years of excavations (Boylan 1967c). Disagreements soon arose between Buckland and the previous excavators, especially Young (the latter gave the first public accounts of Kirkdale Cave in letters read to the Wernerian Society of Edinburgh on the 15th and 29th December, 1821 (Anon. 1822)). Conventional thinkers wavered between the ideas of Young, who considered that the deposits of the cave were the result of the Universal Deluge described in the Bible, and those, such as Eastmead (1824), who held a Woodwardian view of nature and considered that the Corallian limestone in which the cave was found was itself 'Diluvian', and therefore argued that the deposits of the cave were therefore 'Post-Diluvian'. While at Kirkdale Buckland wrote that the floor of Kirkdale Cave was '. . . entirely paved with the Bones and Teeth of Hyaenas, many of them polished and worn by the trampling of their successive generations. . . . How they the bones got there is not easy to be conceived unless they be either the wreck of the Hyaena's larder, or were drifted in by the Diluvian waters' (North 1942, p. 97). Buckland's most important contribution to Pleistocene mammal studies was his novel hypothesis that the cave had been a hyaena den in 'pre-Diluvian' times. Buckland's accounts of the cave and his revolutionary interpretation of the cave deposit (Buckland 1822 and Buckland 1823) had a very great impact on scientific cave exploration in Britain, and was widely discussed throughout Continental Europe and North America as well (Boylan 1967c, 1977).

Fortunately, the discovery of Kirkdale Cave occurred at a time when local scientific societies and museums were rapidly developing in Britain, so that many of the specimens were preserved in public collections. At both York and Scarborough, the first donations to the Museums were series of specimens from Kirkdale *presented by* Salmond and Buckland. At Whitby, specimens from Young's collection, including items from Kirkdale figured by Young and Bird (1822, pl. 17), were amongst the foundation donations to the Whitby Philosophical Society Museum, and a series of typical specimens from the collections of Salmond, Gibson and Buckland, were among the first items given to the Hull Museums. The main part of Buckland's collection from Kirkdale was given to the University of Oxford, and helped to form the basis of the University Museum; a few specimens still in his possession at his death were auctioned, and were mostly bought by the British Museum. Salmond, who was reputed to have the largest collection of Kirkdale specimens, gave large numbers to the British Museum, the Yorkshire Museum, York, and to the Royal Institution (from where they went to the British Museum). Gibson's collection was divided between the Geological

Society of London (from where they were transferred to the Geological Survey Museum), the British Museum and the Royal College of Surgeons Museum, London. Buckland also gave specimens to the Bristol Museum and the Woodwardian Museum, Cambridge (now the Sedgwick Museum). Small series of specimens were sent to the Edinburgh Wernerian Society Museum by both Young and Buckland, and a few items from Young's collection found their way to the Hunterian Museum, Glasgow, through the collection of Thomas Brown of Lanfine and Waterhaughs. Further specimens have found their way into public museums from private collections, but an analysis of contemporary accounts (particularly the interesting estimates of populations by Eastmead 1824) shows that a large proportion of the specimens has been lost.

Despite the historical importance of Kirkdale Cave there has been no modern comprehensive review of the mammalian remains from the cave, although there have been some revisions of individual groups and species. Indeed, because of the disagreements between the original discoverers and the subsequent rivalry between private collectors, it seems unlikely that the accounts of Buckland (1822, 1823), Young (1822), Young and Bird (1822, 1828), or Eastmead (1824) were based on truly comprehensive surveys of the material discovered in the cave. However, the list of species alleged to have been found has greatly increased so that more than fifty species names have been cited, compared with the eighteen noted by Buckland. The most recent detailed review (Rutter 1963) includes twenty-five species.

Also, the more recent published lists contained puzzling anomalies when compared with the faunas of other British fossil mammal sites. In particular, two distinct faunal groups appeared to be represented: a 'warm' interglacial fauna, and a 'cold' glacial fauna, although the cave deposit was reported to have been homogenous and less than one foot (300 mm.) thick at the maximum. It was clear that further minor revisions, without a comprehensive survey of the material, could add little to our knowledge, therefore every collection that could be traced has been examined, as has the whole of the significant literature. Unfortunately, the large collection at the Royal College of Surgeons, and those at Hull and Bristol were all lost during the 1939–45 World War. However, more than 1,250 specimens that are recorded as from Kirkdale Cave have been examined, and a systematic review is given below.

Only an abridged synonymy is given and, in particular, references to Buckland's first account (1822) have been included under his more extensive account in *Reliquiae Diluvianae* published in 1823, and reprinted in 1824. Since Young and Bird (1822) have priority over Buckland (1822), no injustice is done and identical repetition is avoided. References to Dawkins (1869) and Rutter (1963) are only given when they differ significantly from those of Dawkins (1867) and Rutter (1956) respectively. Similarly, the provisional faunal list given in my historical review for the Yorkshire Philosophical Society 150th Anniversary (Boylan 1972) is only cited when it differs from the present paper. The various species have been arranged in three groups: (a) species confirmed in the present study; (b) doubtful records; and (c) erroneous records.

II. SYSTEMATIC REVIEW OF THE MAMMALIAN FAUNA

Abbreviations

AMS	Archaeological Museum, Scarborough
BMNH	British Museum (Natural History), London
GSM	Geological Survey Museum (Institute of Geological Sciences), London
HMG	Hunterian Museum, University of Glasgow
LM	Leicestershire Museum and Art Gallery, Leicester
OUM	Oxford University Museum
RSM	Royal Scottish Museum, Edinburgh
SMC	Sedgwick Museum, Cambridge
WES	Wood End Natural History Museum, Scarborough
WM	Whitby Museum
YM	Yorkshire Museum, York.
(unreg.)	Unregistered specimen(s)

(a) Species confirmed in the present study

Order CARNIVORA
Family CANIDAE
Genus CANIS

Canis cf. *lupus* Linnaeus **WOLF**

1822 WOLF or DOG, Young & Bird, p. 276
1823 WOLF, Buckland, pp. 15, 18; pl. 13; figs 5 & 6
1828 WOLF, Young & Bird, p. 300
1846 *Canis lupus*, Owen, pp. 123-5
1867 *Canis lupus*, Dawkins
1890 *Canis lupus* Linnaeus, Woodward & Sherborn, pp. 325-6
1907 *Canis lupus*, Lydekker
1909 *Canis lupus*, Reynolds, p. 10
1956 *Canis lupus* L., Rutter, p. 420

Material. *SMC*. D.20848 (canines); *WES* ?2020/39/1 (3rd lower milk premolar); *YM*. 605 (canine); (unreg.) (right mandibular ramus with M1).

Remarks. The presence of a large canid, corresponding in size to that of *Canis lupus* is confirmed by the specimens noted above, and by Buckland's figure. It is sometimes difficult to distinguish between the teeth of wolf and of juvenile hyaenas, and there is therefore a slight risk that wolf remains may be overlooked in a large collection of hyaena teeth, but it is clear wolf was quite rare, and no more than one juvenile and one or two adults are represented in the surviving collections.

Genus VULPES

Vulpes vulpes (Linnaeus) **RED FOX**

1823 FOX, Buckland, pp. 15, 18; pl. 6; figs 8, 9, 10, 11, 12, 13, 14; pl. 10; figs 9, 10, 13
1828 FOX, Young & Bird, p. 300
1867 *Canis vulpes*, Dawkins
1885–7 *Canis vulpes*, Linn., Lydekker, pt. 1, p. 132
1890 *Canis vulpes*, Linn., Woodward & Sherborn, p. 326
1907 *Vulpes vulpes*, Lydekker
1909 *Canis vulpes*, Reynolds, p. 10
1956 *Vulpes vulpes* (L.), Rutter, p. 421

Material. BMNH. 55 (O.O.) (right mandibular ramus, complete except for incisors); *GSM.* GS 322 (canine); *OUM.* (unreg.) (2 incisors; 7 canines, 7 cheek teeth; mandibular ramus fragment, left humerus; calcaneum; astragalus); *YM.* (unreg.) (right mandibular ramus with canine and 5 cheek teeth, imperfect right mandibular ramus with P2., 3., 4., & M1).

Remarks. All the remains appear to be of *Vulpes vulpes*, which is therefore the second most common carnivore. Traces of at least four individuals appear to be present in the surviving collections.

Family USIDAE
Genus URSUS

Ursus cf. *arctos* Linnaeus **BROWN BEAR**

1822 BEAR, Young & Bird, p. 276
1823 *Ursus spelaeus*, Buckland, pp. 15, 17; pl. 6, fig. 6
1828 *Ursus spelaeus*, Young & Bird, p. 300
1846 *Ursus spelaeus*, Owen, p. 90
1867 *Ursus spelaeus*, Dawkins
1869 *Ursus arctos*, Dawkins, p. 194
1869 *Ursus ferox*, Dawkins, p. 194
1890 *Ursus spelaeus* Rosenmuller, Woodward & Sherborn, p. 391
1890 *Ursus arctos* Linnaeus, Woodward & Sherborn, pp. 388–9
1890 *Ursus horribilis* Ord., Woodward & Sherborn, pp. 389–90
1907 *Ursus arctus*, Lydekker
1907 *Ursus arctus horribilis* (?), Lydekker
1956 *Ursus arctos* L., Rutter, p. 421
1956 *Ursus spelaeus* Rosenmuller, Rutter, p. 421

Material. HMG. ?V.5611 (molar: the preservation is unlike that of typical Kirkdale specimens).

Remarks. Bear remains were very rare in the Kirkdale deposit (Buckland 1823, p. 17; Young and Bird 1828, p. 300), and I do not believe that any of the bear teeth seen by me are from Kirkdale. (The imperfect canine tooth in the Whitby Museum, referred to by Young and Bird (1828) is presumably *WM. KC.* 30 which is labelled 'Bear' but is a fragment of the lower canine of *Crocuta crocuta*.) Reynolds (1906) lists *U. spelaeus*, *U. arctos* and *U. horribilis* as recorded from Kirkdale, but specifically warns that the details of his distribution table are simply taken from the literature and that he has not necessarily confirmed the determinations. In the circumstances, therefore, the only real evidence is the canine figured by Buckland (1823, pl. 6; fig. 6) which is similar to those of brown bears from a number of British Ipswichian sites, which Kurten (1959, p. 75) considers to be a distinct sub-species: *Ursus arctos taubachensis* Rode. Until recent years the classification and taxonomy of brown bears were in an incredible state of confusion, with more than 100 specific names being available for what is here regarded as the single species: *Ursus arctos* Linnaeus (see Erdbrink 1953, and Kurtén 1957).

Family MUSTELIDAE

Genus MUSTELA

Mustela cf. *erminea* Linnaeus **STOAT**

1823 WEASEL, Buckland, pp. 15, 18; pl. 6; figs 28, 29; pl. 23, figs 11, 12, 13
1828 WEASEL, Young & Bird, p. 300
1846 *Putorius ermineus*, Owen, pp. 116–8
1867 *Mustela erminea*, Dawkins
1890 *Mustela erminea* Linnaeus, Woodward & Sherborn, p. 368
1890 *Mustela vulgaris* (Erxleben), Woodward & Sherborn
1907 *Mustela erminea*, Lydekker
1907 *Mustela nivalis*, Lydekker
1912 *Mustela erminea*, Reynolds, p. 12
1956 *Mustela erminea* L., Rutter, p. 421

Material. None seen.

Remarks. In the absence of the Kirkdale specimens, which have not been traced, we have only Buckland's figures with which to identify the remains of the small mustelid found by Salmond. However, the mandibular ramus figured by Buckland (1823, p. 23, fig. 13) measures 22 mm. in length, even though it is apparently not quite complete. A lower jaw length of more than 22 mm. almost invariably distinguishes *Mustela erminea* from the smaller weasel (*Mustela nivalis*), (see, for example, Corbet 1964, p. 32) so there it is likely that Owen and subsequent workers were correct in considering the specimens to be too large for *M. nivalis*.

Family FELIDAE

Genus 'PANTHERA' Oken

'Panthera' cf. *leo* (Linnaeus) **LION**

1823 TIGER, Buckland, pp. 15, 17; pl. 6, figs 5, 6, 7
1828 LION, Young & Bird, p. 300
1828 TIGER, Young & Bird, p. 300
1845 *Felis sp.*, Owen, p. 32
1846 *Felis spelaea*, Owen, p. 32
1867 *Felis spelaea*, Dawkins
1867-72 *Felis spelaea*, Dawkins & Sandford, p. 194
1869 *Felis leo* var. *spelaea* Gold., Dawkins, p. 194
1885–7 *Felis leo* Linn., Lydekker, pt. 1, p. 57
1890 *Felis leo* Linnaeus, Woodward & Sherborn, p. 348

660

1907 *Felis leo spelaea* Lydekker
1956 *Panthera leo* (L.), Rutter, p. 422

Material. BMNH. 51(O.C.) (2nd right metatarsal), M.40368 (proximal end of 4th right metatarsal), M.44021 (molar); *OUM.* Q.2175 (left Lower M1); *WES.* ?2031/39 (imperfect astragalus); *YM.* 581(upper P4), (unreg.) (4th right metacarpal).

Remarks. At least two individuals appear to be represented in the collections. One of these is markedly larger than the present-day African lion: the upper premolar in the Yorkshire Museum could not be examined or measured in detail because it is largely covered with stalagmite, but it is at least as long as the largest example figured by Dawkins and Sandford (1867-72). On the other hand, the metapodials appear to belong to a smaller individual.

Until recent years nearly all fossil lion remains from British Middle and Upper Pleistocene sites were referred uncritically to *Felis spelaea* Goldfuss, but most workers do not now consider *F. spelaea* to be specifically distinct from the extant species, although the name is available for the large Upper Pleistocene race. (The Yorkshire Museum carnassial could reasonably be referred to *Panthera leo spelaea*.) Technically, the generic name *Panthera* Oken is invalid, since it was not published in binomial form (I.C.Z.N. opinion 417). However, it is so widely used for the large cats (other than the cheetah) that Morrison-Scott (1965) asked the International Commission on Zoological Nomenclature to validate *Panthera* by the use of the plenary powers. After an inconclusive ballot of the Commissioners, revised proposals for validating *Panthera* are currently under consideration (I.C.Z.N. *personal communication.*). If this application fails, the next available name is *Leo* Brehm.

Family HYAENIDAE

Genus *CROCUTA*

Crocuta crocuta spelaea (Goldfuss) **CAVE HYAENA**

1822 HYAENA, Young & Bird, p. 276, pl. 17, figs 5, 15, ?2
1823 HYAENA, Buckland, pp. 15-7; pl. 3, figs 3, 4, 5; pl. 4, figs 2, 3; pl. 5, figs 1, 2, 3, 4, 5, 9, 10, 11, 12; pl. ?, figs 2, 3, 4, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 30, 31; pl. 10, figs 6, 7, 8; pl. 13, figs 3, 4; pl. 23, fig. 10
1828 HYAENA, Young & Bird, p. 300; pl. 17, figs 3, 6, 17
1845 *Hyaena spelaea*, Owen, pp. 21-9
1846 *Hyaena spelaea*, Owen, pp. 138-60; fig. 55
1867 *Hyaena spelaea*, Dawkins
1885-7 *Hyaena crocuta* (Erxleben) Lydekker, pt. 1, pp. 70-9
1890 *Hyaena crocuta* Erxleben), Woodward & Sherborn, pp. 353-4
1902 *Hyaena crocuta*, Reynolds, p. 5; pl. 5, fig. 9
1907 *Hyaena crocuta spelaea*, Lydekker
1956 *Crocuta crocuta* (Erxleben), Rutter, p. 422

Material. Since most of the collections contain large numbers of specimens of this species, only a brief outline of the contents is given below.

AMS. 143/38, 144/38, 145/38, 146/38, 147/38 (teeth); *BMNH.* approximately 40 cranial and postcranial specimens, including maxillar and mandibular fragments, teeth, scapula, humerus, radius, ulna, pisiform, metacarpals, os innominatum, femur, tibia, calcaneum, astragalus, navicular and vertebrae; *GSM.* 18 cranial and postcranial specimens including teeth, astragalus, patella, metatarsals, phalanges and coprolites; *HMG.* V.5265, V.5383-9, V.5396, V.5397/1-2 (teeth); *OUM.* approximately 295 cranial and postcranial specimens including maxillar and mandibular fragments, teeth, humerus, ulna, femur, calcaneum, astragalus, sesamoids, metapodials, phalanges, os innominatum, vertebrae and coprolites; *RSM.* approximately 28 specimens, including cranial fragments, teeth and phalanges; *SMC.* approximately 42 specimens including maxillar and mandibular fragments, teeth and phalanges; *WES.* approximately 47 specimens, including teeth, radius, astragalus, navicular, metatarsals, phalanges and vertebrae; *WM.* approximately 17 specimens, including maxillar, and mandibular fragments, metapodials, phalange and vertebra; *YM.* approximately 90 specimens, including cranial and mandibular fragments, teeth ulnae, calcaneum, astragalus, sacrum fragment and vertebrae.

Remarks. The 600 specimens seen must represent only a small proportion of the total number of specimens found. Buckland (1823, p. 17), states that Gibson alone collected more than 300 hyaena canines and estimates that traces of at least 200 to 300 individuals must have been present in the cave deposit. In the material seen virtually all ages of individuals are represented from juveniles (many examples) through to very old animals in which the crowns of the teeth are almost completely worn away (e.g. *SMC.* D.20843). Almost every bone from the Cave shows characteristic hyaena damage or gnawings which can be paralleled exactly in specimens from Buckland's experiment with a live hyaena (Buckland 1823, especially pl. 23; Boylan 1968c, 1972) or in recent observations of African spotted hyaena populations (e.g. Sutcliffe 1970; Kruuk 1966, 1972, 1975).

The adult remains show that the Kirkdale animals were markedly larger than the present-day African spotted hyaena, *Crocuta crocuta crocuta* (Erxleben). For example, the mean length of the measured lower carnassials (M1.) from Kirkdale is 31.8 mm., compared with 27-29 mm. in the living African populations. Kurten (1957, p. 77, fig. 3) has effectively demonstrated the specific unity of the recent and late Pleistocene spotted hyaenas (despite a number of minor morphological differences), and has shown a definite character gradient. The smallest forms are found in the equatorial belt, and the size increases to the south and north, so that the northern European fossil populations are more than 18 per cent larger than those of the equatorial area, and can justifiably be regarded as a distinct race or subspecies, for which the species-rank name *spelaea* Goldfuss, is available.

It is important to note that, because of its large size, the Pleistocene cave hyaena would have been able to accommodate between the anterior premolars bones approximately 10 mm. thicker than the maximum bone which can be cracked by a present-day equatorial spotted hyaena, and would (theoretically, at least) have been able to exert approximately 80 per cent more force in the jaw than the equatorial animal. Any claim by supporters of the 'osteodontokeratic culture' hypothesis (e.g. Dart 1956) that hyaenas are incapable of certain types of damage to large bones should be considered in the light of this. This question is fully discussed elsewhere (Boylan 1972).

Order PROBOSCIDEA

Family ELEPHANTIDAE

Genus ELEPHAS Linnaeus

Elephas antiquus Falconer & Cautley

STRAIGHT TUSKED ELEPHANT

1822 ELEPHANT, Young & Bird, p. 274
1823 ELEPHANT, Buckland, pp. 15, 18; pl. 7; figs 1, 2
1828 ELEPHANT, Young & Bird, p. 299
1846 *Elephas primigenius*, Owen, pp. 218-23, 259
1867 *Elephas antiquus*, Dawkins
1877-81 *Elephas antiquus* Falconer, Adams, pp. 5, 6
1880 *Elephas antiquus* Falconer, Woodward & Sherborn, p. 341
1880 *Elephas primigenius* Blumenbach, Woodward & Sherborn, pp. 342-4
1885-7 *Elephas antiquus* Falconer, Lydekker, pt. 4, p. 131
1907 *Elephas antiquus*, Lydekker
1907 *Elephas primigenius*, Lydekker
1956 *Elephas antiquus* Falconer, Rutter, p. 428
1956 *Elephas primigenius* Blumenbach, Rutter, p. 428
1972 *Palaeoloxodon antiquus*, Boylan, p. 39

Material. AMS. ?158/38, (fragment of (?) M1.: '*Elephas*' sp.), *BMNH.* 74a (O.C.) (left lower (?3rd) milk molar), M.42329 (3rd milk molar); *GSM.* ?GS.349 (fragment of tusk, deeply eroded by stomach acid: '*Elephas*' sp.); *OUM.* (unreg.) (lower milk molar (?mm3), probably the specimen figured by Buckland, 1823, pl. 7, fig. 1): (unreg.), (fragment of a milk molar); *RSM.* ?(unreg.) (small fragment of tusk dentine: '*Elephas*' sp.), *YM.* (unreg.) (fragment of a large straight tusk), (unreg.) (upper milk molar, probably M2), (unreg.) (fragment of (?) *M1.*, sectioned and polished), (unreg.) distal end of humerus: '*Elephas*' sp.).

Remarks. The five milk molars noted above are all clearly this species, not *Mammuthus* spp.; the shape of the crowns, the number of 'plates', the thick, crimped enamel, the tendency towards a loxodont pattern on the crown, and the relative proportions of dentine and cement, are all indicative. Dawkins (1867) specifically excluded *Elephas primigenius* from the Kirkdale faunal list, and Adams (1877-81, p. 72), in the fossil elephant Palaeontographical Society monograph, did likewise. Owen (1846) and Rutter (1956) specifically refer to 'Reliquiae Diluvianae' (Buckland 1823, pl. 7, fig. 1), when including *E. primigenius* in their faunal lists, but the original of this figure is definitely *Elephas antiquus*.

In recent years most British workers have ascribed this widely occurring species to the genus *Palaeoloxodon* Matsumoto (type species: *Elephas namadicus naumanni* Makiyama from the Pleistocene of Japan), following Matsumoto (1924) and Osborn (1942) in grouping *El. antiquus* with other Pleistocene species which tend to display a loxodont pattern on the worn molar surface, and which were consequently thought to be related to the African elephant *Loxodonta africana*. However, the general cranial character of the *El. antiquus* group of species differs significantly from both *Loxodonta* and *Mammuthus* and is closest to that of the present-day Indian elephant *Elephas indicus*, and these species are probably best accommodated within the genus *Elephas* Linnaeus. This is discussed in some detail by Maglio (1973). More controversially, Maglio also argues persuasively (1973, pp. 40–43) that dentition of the European *El. antiquus* is not distinguishable either morphologically or statistically from a range of similar Upper Pleistocene Asiatic forms. If this interpretation is correct, then the name of *Elephas namadicus* Falconer and Cautley (type locality: Narbada, India) has priority over the name *E. antiquus* and should be adopted for the taxon.

Order ARTIODACTYLA
Family HIPPOPOTAMIDAE
Genus HIPPOPOTAMUS

Hippopotamus amphibius Linnaeus

HIPPOPOTAMUS

1822 UNKNOWN ANIMAL, ? HIPPOPOTAMUS, Young & Bird, pp. 275, 227; pl. 17, fig. 11
1823 HIPPOPOTAMUS, Buckland, pp. 15, 18; pl. 7, figs 8, 9, 10, 11; pl. 13, fig. 7
1828 HIPPOPOTAMUS, Young & Bird, p. 299; pl. 17; figs 2, 13
1845 *Hippopotamus major* Cuvier, Owen, p. 238
1846 *Hippopotamus major*, Owen, pp. 399–412
1867 *Hippopotamus major*, Dawkins
1885-7 *Hippopotamus amphibius* Linn., Lydekker, pt. 2, p. 286
1890 *Hippopotamus amphibius* Linnaeus, Woodward & Sherborn, pp. 351-2
1907 *Hippopotamus amphibius major*, Lydekker
1922 *Hippopotamus amphibius*, Reynolds, pp. 2, 6
1956 *Hippopotamus amphibius* L., Rutter, p. 425

Material. *BMNH*. 108 (O.C.) upper incisor fragment), M.42335 (last lower milk molar); *OUM* (unreg.) (part of crown of molar or premolar, and other fragments), (unreg.) (premolar), (unreg. (molar); *RSM*. (unreg.) (part of crown of a milk molar); *SMC*. 20812 imperfect adult molar); *YM*. (unreg.) (fragment of canine), (unreg.) (premolar, unreg.) (imperfect molar), (unreg.) (incisor fragment), (unreg.) (imperfect milk molar).

Remarks. At least one adult and one juvenile appear to be represented in the collections.

Family CERVIDAE

Genus CERVUS

Cervus elaphus Linnaeus **RED DEER**

1822 STAG, Young & Bird, p. 276; pl. 17, fig. 13
1823 STAG OR RED DEER, Buckland, p. 19; pl. 8, figs 11, 12; pl. 9, figs 3, 4
1826 RED DEER, Young & Bird, p. 300, pl. 17, fig. 15
1845 *Cervus elaphus*, Owen, pp. 264–5
1846 *Cervus (Strongyloceros) elaphus*, Owen, pp. 477–8
1867 *Cervus elaphus*, Dawkins
1885–6 *Cervus elaphus* Linn., Lydekker, pt. 2, p. 96
1890 *Cervus elaphus* Linnaeus, Woodward & Sherborn, pp. 330–2
1907 *Cervus elaphus*, Lydekker
1933 *Cervus elaphus*, Reynolds, p. 8
1956 *Cervus elaphus* L. Rutter, p. 426

Material. *BMNH*. 232 (O.C. (base of naturally-shed antler); *GSM*. GS.317 (base of naturally-shed antler); *OUM*. ?(unreg.) (8 adult and milk cheek teeth), (unreg.) (crown of third lower molar), (unreg.) (4 incisors), (unreg.) (upper molar); *SMC*. D.20806 (right upper M1.), ?0.20806 (milk molar); *WES*. 2038/39/1 and (lower true molars), ?2037/39 (a very large lower M3., but probably this species); *YM*. 630 (calcaneum), 761 (radius fragment), (unreg.) (two antler tine fragments), ?(unreg.) (phalange).

Remarks. Specimens of this species appear to be less common than those of *Megaloceros giganteus*. The Kirkdale area must have been occupied during the late spring when red deer stags shed their antlers, since all the antler bases seen and recorded have been naturally shed. This point was noticed by Young and Bird (1828, p. 300) who commented 'the rounded state of the base, in the horns found in the cave, shows that they have been shed from the head, not broken off by violence; a circumstance which may help to indicate the season of the year when these remains were deposited' (i.e. the date of Noah's Flood)

Cervus cf. *dama* Linnaeus **FALLOW DEER**

1823 A THIRD SPECIES OF DEER, OF THE SIZE OF A LARGE FALLOW DEER, Buckland, p. 263, pl. 8, figs 13, 14
1828 DEER (pars), Young & Bird, p. 300
1846 *Cervus dama*, Owen, pp. 483–4

Material. *OUM*. (unreg.) (lower cheek tooth); *WES*. ? (unreg.) (cervid astragalus, size of *C. dama*); ? unreg.) (cheek tooth); *YM*. ? (unreg.) (fragment of humerus, size of *C. dama*).

Remarks. Of all the species confirmed in this study, this is the least certain, since teeth are not particularly diagnostic in ruminants. However, the *OUM* specimen figured by Buckland (1823, pl. 8, figs 13, 14), corresponds very closely with specimens of recent fallow deer.

The fallow deer have, in recent times, been conventionally referred to a separate genus (*Dama*), but Corbet (1966, pp. 85 and 164) considers this to be unjustified.

Genus MEGALOCEROS

Megaloceros giganteus (Blumenbach) **GIANT DEER**

1823 VERY LARGE SPECIES OF DEER, Buckland, p. 263, pl. 8, figs 3, 9, 10; ? figs 5, 6; pl. 9, figs 1, 2
1867 *Megaceros hibernicus*, Dawkins
1869 *Cervus megaceros* Hart, Dawkins, p. 194
1885-7 *Cervus giganteus* (Blumenbach), Lydekker, pt. 2, pp. 85-8
1890 *Cervus giganteus* (Blumenbach), Woodward & Sherborn
1907 *Cervus giganteus*, Lydekker
1929 *Cervus giganteus*, Reynolds, p. 7
1956 *Megaceros hibernicus* Owen, Rutter, p. 426
1964 *Megaceros giganteus* (Blumenbach), Whitehead pp. 435–42
1972 *Megaceros giganteus*, Boylan, p. 39

Material. *BMNH*. 232 (O.C.) (right mandibular ramus fragment with M3.), 237 (O.C.) (maxillar fragment with 2 cheek teeth), 241 (O.V.) (right metacarpal); *GSM*. GS.318 (3rd lower molar); *OUM*. (unreg.) (6 upper and lower cheek teeth), (unreg.) (fused 2+3 cuneiform); *SMC*. D.20803, D.20861, D.20862 (upper cheek teeth); *WES*. (unreg.) (two upper premolars), ?(unreg.) (lower premolar), ? 2039/39 (lower P1.); *WM* KC27 (lower M3); *YM*. 601, 674, 680, 683, 684, 686 (14 unreg.) (upper and lower cheek teeth), (unreg.) (left mandibular ramus fragment with M2. & M3.), ? (unreg.), (calcaneum), ? (unreg.) juvenile mandibular ramus fragment with milk p3 (Buckland 1823, pl. 9, figs 5, 6).

Remarks. Giant deer remains are quite numerous in the collections. Although antlers have not been seen, it is usually quite easy to recognise the teeth and the metapodials, although in a minority of specimens (especially poorly-preserved specimens) it is difficult to distinguish between *Megaloceros* and bovids of a similar size.

Now that the International Commission on Zoological Nomenclature (Opinion 1080, 1977) has confirmed the availability of the Joshua Brookes *Catalogue* (Brookes 1828) for the purposes of nomenclature, the generic name *Megaloceros* Brookes has priority over *Megaceros* Owen, and Blumenbach's specific name has priority over *Cervus megaceros* Hart. The specific name *hibernicus* Owen was established under the Stricklandian Code of Nomenclature, to avoid the tautology in the name *Megaceros megaceros* Hart.

Family BOVIDAE

Genus BISON

Bison cf. *priscus* (Bojanus) **BISON**

1822 OX, Young & Bird, p. 276; pl. 17, fig. 4; ? figs 9, 14
1823 OX, Buckland, pp. 15, 18; pl. 8, figs 4, 7, 8; pl. 10, figs 2, 3, 4, 5; pl. 23, figs 2, 4, 8
1828 OX, Young & Bird, p. 299-300; pl. 17, fig. 5; ? figs 9, 11, 12, 16
1845 *Bos* or *Urus*, Owen, pp. 276-7
1867 *Bison priscus*, Dawkins
1885-7 *Bos taurus* var. *primigenius* (Bojanus), Lydekker, pt. 2, pp. 9-10

Material. Confirmed *Bison* cf. *priscus*, *BMNH*. 242 (O.C.), M.42336, M.26401 (metapodials); *GSM*. GS315 (fragment of metapodial); *OUM*. (unreg.) (2 metacarpals), 2 tibia fragments; 7 astragali, 6 calcanea, 5–3+4 fused carpals, 3 proximal

phalanges and one second phalange; *WES.* 2043/39 (metacarpal), 2067/40/1 (fragment of distal end of a metapodial); *W.M.* KC2 (metacarpal); *Y.M.* 78, 632 (5 unreg.), (astragali), (unreg. distal end of metatarsal).
'Bovid' sp., *A.MS.* (5 specimens); *B.M.N.H.* (16 specimens); *C.S.M.* (6 specimens); *H.M.G.* (4 specimens); *O.U.M.* (82 specimens); *S.M.C* (7 specimens); *WES.* (13 specimens); *Y.M.* (66 specimens).

Remarks. In the absence of horn-cores, the metapodials afford the most reliable distinction between *Bos* and *Bison*, and all the well-preserved metacarpals and metatarsals are clearly of *Bison*, and are considerably larger than those of the extant *Bison bonasus* (Linnaeus). They are therefore ascribed to the present species. Olsen (1960) considers that it is possible to distinguish between *Bos* and *Bison* in the detailed structure of many parts of the post-cranial skeleton, and his tests were applied to the large sample of bovid remains at Oxford, and to the astragali at York. Both recent and fossil specimens were examined, and the tests appear to be applicable to British fossil material: it was particularly instructive to compare the *Bison* remains from Kirkdale with the *Bos taurus* material (*O.U.M.*) used by Buckland in his experiments with a live spotted hyaena (Buckland 1823; Boylan 1967c). The two extant species of Bison are closely related to each other, as is the fossil *Bison priscus*, and all three may be geographical variants of a single species, in which case the valid name would be *Bison bison* (Linnaeus). The genus *Urus* Owen *non* H. Smith appears to be a synonym of *Bison* Linnaeus.

Order PERISSODACTYLA
Family RHINOCERATIDAE
Genus DICERORHINUS

Dicerorhinus hemitoechus (Falconer) **RHINOCEROS**

1822 RHINOCEROS, Young & Bird, p. 275; pl. 17, figs 7, 12
1822 *Palaeotherium magnum*, Young & Bird, p. 277, pl. 17, figs 6, 7, 8
1823 RHINOCEROS, Buckland, pp. 5, 18; pl. 7, figs 4, 5, 6
1828 RHINOCEROS, Young & Bird, p. 299; pl. 17, figs 7, 8, 14
1845 *Rhinoceros tichorhinus*, Owen, pp. 210–211
1846 *Rhinoceros tichorhinus*, Owen, p. 335; fig. 125
1867 *Rhinoceros leptorhinus* Owen, Dawkins
1885–7 *Rhinoceros leptorhinus* Owen, Lydekker, pt. 3, p. 104
1885–7 *Rhinoceros antiquitatis* Blumenbach, Lydekker, pt. 3, pp. 95–9
1890 *Rhinoceros antiquitatis* (Blumenbach), Woodward & Sherborn, pp. 379–80
1890 *Rhinoceros leptorhinus* Owen *non* Cuvier, Woodward & Sherborn, pp. 380–1
1907 *Rhinoceros leptorhinus*, Lydekker
1907 *Rhinoceros antiquitatis*, Lydekker
1956 *Rhinoceros hemitoechus* Falconer, Rutter, p. 424
1956 *Rhinoceros antiquitatis* Blumenbach, Rutter, p. 424
1972 '*Dicerorhinus hemitoechus*', Boylan, p. 39

Material. A.MS. 153/38 (upper premolar); *B.M.N.H.* 16 (O.C.) (upper milk molar figured as *R. tichorhinus* by Owen (1846, fig. 125), 124 (O.C.) (right upper M1.), 120

(O.C.) M.40366, & M.42332 (molars), M.42338 (milk molar), 28 (O.C.), 128 (O.C.), & (1 unreg.) (post-cranial specimens: '*Rhinoceros*' sp.); *GSM.* GS.343 (fragment of upper molar, '*Dicerorhinus*' sp.); *DUM.* (unreg.) (third left metatarsal; compares very closely with that of '*Dicerorhinus*' *sumatrensis* but is slightly larger, and has a less-prominent distal articulation); *RSM.* (unreg.) (fragment of tooth: '*Rhinoceros*' sp.); *SMC.* D.20857 (lower cheek tooth; probably right M1), D.20858 (crown of unworn upper cheek tooth, probably milk M1); *WES.* 2048/39/8, (very worn milk molar); *WM.* KC.23 (right lower molar), KC.24 (upper M3); *YM.* 599, 671, & (8 unreg.) (upper and lower cheek teeth), 787 & (unreg.) (astragali), 623 and 789 (fragments of tibia).

Remarks. All of the determinable teeth seen appear to be of this species, as do the teeth shown in Buckland's excellent illustrations. Records of woolly rhinoceros (*Coelodonta antiquitatis* or *R. tichorhinus*) appear to derive from Owen (1846) but the original of his figure 125 is clearly not *tichorhinus*. Falconer (1868, p. 253) noted that Owen incorrectly attributed the Oreston (Plymouth) rhinoceros remains to *tichorhinus* instead of *R. leptorhinus* Owen (=*hemitoechus*).

Although the generic name *Dicerorhinus* Gloger 1841, (type species: *Rhinoceros sumatrensis*, the present-day Sumatran rhinoceros) has been almost universally used in the present century for fossil forms, the name *Didermocerus* Brookes, 1828, appeared to be valid prior name, although it remained virtually unused until the publication of the Palaearctic and Indian *Checklist* of Ellerman and Morrison-Scott (1951), after which it was extensively used in the literature for the extant species. The problem was placed before the International Commission on Zoological Nomenclature (Boylan 1967a), and following written discussion by several specialists, a revised formal application for the supression of *Didermocerus* under the Commission's plenary powers, and for the validation of *Dicerorhinus*, was submitted to the I.C.Z.N. (Boylan and Green 1974). This application was granted by the Commission in Opinion 1080 (International Commission on Zoological Nomenclature 1977).

Order LAGOMORPHA

Family LEPORIDAE

Genus LEPUS

Lepus cf. *capensis* Linnaeus **BROWN HARE**

1823 HARE, RABBIT, Buckland, pp. 15, 19; pl. 10, figs 14, 15, 16, 17, 18; ? pl. 11, fig. 10; pl. 13, fig. 8
1828 RABBIT OR HARE, Young & Bird, p. 301
1846 *Lepus timidus*, Owen, pp. 210–1
1867 *Lepus timidus*, Dawkins
1867 *Lepus cuniculus*, Dawkins
1885–6 *Lepus timidus* Linn., Lydekker, pt. 1, p. 259
1890 *Lepus timidus* Linnaeus, Woodward & Sherborn, p. 358
1890 *Lepus cuniculus* Linnaeus, Woodward & Sherborn, p. 358

1907 *Lepus europaeus*, Lydekker
1907 *Lepus cuniculus*, Lydekker
1956 *Lepus europaeus*, Rutter, p. 423

Material. *B.M.N.H.* 57 O.C. (imperfect mandibular ramus); *O.U.M.* (unreg.) (tibia, calcaneum, metatarsals); *Y.M.* (unreg.) (part of innominate: *Lepus* sp.)

Remarks. The *B.M.N.H.* mandibular ramus (figured by Buckland, 1823, pl. 8, fig. 8) is very large: it is nearest in size to the present-day British brown hare (*Lepus capensis occidentalis*).

The detailed morphology of the mandible corresponds with that of *L. capensis*, except that the Kirkdale mandible is altogether more massive: the mandibular depth at the anterior cheek-tooth and the posterior cheek-tooth is 15.0 mm. and 17.8 mm. respectively, as compared with an average of 11.5 mm. and 16.0 mm. in *L. capensis*.

There is now convincing evidence to show that the European brown hare (*Lepus europaeus* Pallas) is conspecific with the South African species *Lepus capensis* Linnaeus (Petter 1961), and the name *L. capensis* is now being adopted (see for example Corbet 1964, pp. 6 and 11, and Corbet 1966, pp. 6 and 183).

Order RODENTIA
Family MURIDAE
Genus APODEMUS

Apodemus sp. MOUSE

? 1823 MOUSE (*pars*), Buckland, pp. 15, 19; pl. 9, figs 7, 8, 9
? 1846 *Mus musculus*, Owen, p. 209
1972 *Apodemus* sp. ? *flavicollis*, Boylan, p. 39
1976 *Apodemus sylvaticus* (Linnaeus), Sutcliffe & Kowalski, pp. 81–83

Material. O.U.M. Q.1413 (imperfect left mandibular ramus, with 1st and 2nd cheek teeth).

Remarks. This specimen is quite easily distinguished from the specimens of *Mus musculus* in the Buckland Collection (which are recent contaminants), and is clearly of this genus. The cheek teeth indicate that the specimen belongs to a large *Apodemus*: the 3rd cheek tooth is missing, so it is not possible to take accurate measurements, but the cheek teeth row length is in excess of 4.0 mm. and corresponds more closely with the size of the yellow-necked mouse (*Apodemus flavicollis*) rather than with the common wood mouse (*Apodemus sylvaticus*). It also lacks the anterior accessory cusp on the first lower cheek tooth which is normally developed in *Apodemus sylvaticus*. This, and other aspects of the detailed morphology of the cheek teeth and mandible, distinguish the specimen from a typical present-day *A. sylvaticus*, and suggest a possible affinity to *A. flavicollis*, but it is doubtful whether this species occurred in the British Pleistocene, and it seems more reasonable to follow Sutcliffe and Kowalski (1976, p. 81) in referring this solitary specimen to *Apodemus sylvaticus*.

Genus CLETHRIONOMYS

Clethrionomys glareolus (Schreber) **BANK VOLE**

1972 *Clethrionomys* cf. *glareolus*, Boylan, p. 39
1976 *Clethrionomys glareolus* (Schreber), Sutcliffe & Kowalski, pp. 92-94
Material. BMNH. M.264000 (one imperfect right mandibular ramus).

Remarks. Clethrionomys can be distinguished from *Microtus* spp. (field voles), by its rooted cheek teeth, in which the angles are rounded, not sharp. This single specimen was first recognised by the late M. A. C. Hinton (*M.S.* in *BMNH.*) who recorded it as *Evotomys* sp. The specimen is closely comparable in form and size to that of the present-day British bank vole.

Genus ARVICOLA

Arvicola cantiana-terrestris transition form group **WATER VOLE**

1823 WATER-RAT, Buckland, pp. 15, 18, 19; pl. 10, ? figs 11, 12; pl. 11, figs k, 2, 3, 4, 5, 6; ? figs 11, 12, 13, 14, 15, 16, 17, 18, 19
1828 WATER-RAT, Young & Bird, p. 301
1846 *Arvicola amphibius*, Owen, pp. 201-5
1867 *Arvicola amphibia*, Dawkins
1969 *Arvicola amphibius* Desm., Dawkins, p. 194
1885-7 *Arvicola amphibius* Linn., Lydekker, p. 231
1890 *Microtus amphibius* Linnaeus, Woodward & Sherborn, p. 367
1907 *Microtus amphibius*, Lydekker
1956 *Arvicola amphibius* (L.), Rutter, p. 423
1963 *Arvicola amphibius* (L.), Rutter, p. 333
1963 *Arvicola abbotti* Hinton, Rutter, p. 333
1972 *Arvicola terrestris* Boylan, p. 37
1976 *Arvicola cantiana/A. terrestris* complex Sutcliffe & Kowalski, pp. 104-5
Material, BMNH. M.432, M.10728, M.35682, M.40370, M.42357, M.44764, 540.c. (approx. 52 rami, loose teeth and post-cranial fragments); *HMG.* V.5398 (right mandibular ramus); *OUM.* (unreg.) (maxillar fragment with upper cheek teeth), (46 unreg.) (incisors), (12 unreg.) (cheek teeth), (8 unreg.) (mandibular rami), (2 unreg.) (ulnae), (11 unreg.) (femora) (5 unreg.) (tibiae), (unreg.) (numerous skeletal fragments); *RSM.* (unreg.) (4 ramus fragments, and loose teeth); *WM.* KC.35 (lower ramus fagment with cheek teeth); *YM.* 594. (imperfect skull, with upper teeth), 596. (two femora and one fragment of femur), (unreg.) (10 loose teeth, few skeletal fragments).

Remarks. According to Buckland, remains of the 'Water-Rat' outnumbered every other species, but only a small proportion of these seems to have been preserved, which is most unfortunate since a statistical study of a large sample of the Kirkdale finds would be very useful in determining the species position within the evolutionary sequence from *A. cantiana* (Hinton) to *A. terrestris* Linnaeus, now recognised by (among others) Koenigswald (1973) and Sutcliffe and Kowalski (1976). The majority of the Kirkdale specimens differ from the present-day British water vole, *A. terrestris amphibius* (Linnaeus) in that the cheek-tooth is relatively short compared with those of extant British forms: the average alveolar length in the maxilla was 8.8 mm., and in the mandible was only 6.4 mm., falling within the normal range of *A. cantiana*. Koenigswald (1973) distinguished stratigraphical and evolutionary stages within this genus on the basis of a detailed examination of the relative thickness of the enamel on the concave and convex sides of certain angles of the cheek teeth. Detailed examination of the relevant angles of the *BMNH.* specimens showed that the enamel was of equal thickness on each side, indicating the intermediate stage designated '*A. cantiana-terrestris* transition form' by Koenigswald.

Genus MICROTUS

Microtus agrestis (Linnaeus) **FIELD VOLE**

1846 *Arvicola agrestis*, Owen, p. 206
1867 *Arvicola agrestis*, Dawkins
1890 *Microtus agrestis* (Linnaeus), Woodward & Sherborn, p. 364
1907 *Microtus agrestis*, Lydekker
1956 ? *Microtus agrestis* (L.), Rutter, p. 423
1976 *Microtus agrestis* (Linnaeus), Sutcliffe & Kowalski, pp. 109-112

Material. BMNH. M.4025 (humerus and mandibular ramus), M.26400 ex M.432 (mandibular ramus); *OUM.* Q.1410 (fragment of palate and maxilla, with left and right 2nd and 3rd cheek teeth), Q.1411 (right mandibular ramus); *RSM.* (unreg.) (two mandibular rami); *YM.* (unreg.) (one cheek tooth).

Remarks. With one exception all of the material seen should properly be described as '*Microtus* sp., *arvalis-agrestis* group' since only the upper cheek teeth are really diagnostic. However, in *OUM.* Q.1410 the left upper second cheek tooth is damaged, but the right upper second cheek tooth clearly shows the anterior lingual cusp that appears to be diagnostic of *Microtus agrestis.*

(b) Doubtful or uncertain records

Order ARTIODACTYLA

Family SUIDAE

Genus SUS

Sus sp. **PIG**

1907 ? *Sus scrofa ferus*, Lydekker
1956 *Sus scrofa* L., Rutter, p. 424

Material. AMS. 154/38 (right lower second molar); *BMNH* M.44757 (premolar), M.44773 (imperfect canine); *WES.* 2050/39/2 (right lower first molar).

Remarks. The two *BMNH.* specimens are clearly not from Kirkdale, judging by their preservation, and both of the Scarborough specimens look rather fresh, so the record must be treated with considerable caution. It is also noteworthy that the first published reference to pig remains did not appear until 85 years after the discovery of the cave. Since the teeth of pigs are very distinctive (and were recorded by Buckland – from Hutton – in *Reliquiae Diluvianae,* 1823), such an omission would be very surprising. Young (1828) alleged that the teeth of 'hogs' were spurious, although he noted that they had found their way into collections of genuine Kirkdale bones.

Family CERVIDAE

Genus CERVUS

Cervus bucklandi Owen **BUCKLAND'S DEER**

1823 SMALLER SPECIES OF DEER, (pars) Buckland, p. 19, 264; pl. 9, fig. 5
1846 *Cervus bucklandi* (*n. sp.*), Owen, pp. 485–6, fig. 200
1890 *Rangifer tarandus* (Linnaeus), Woodward & Sherborn pp. 378–9
1956 *Rangifer tarandus* (L.), Rutter, p. 426
1964 *Cervus bucklandi* Owen, Whitehead, pp. 449–50
1964 ALMOST CERTAINLY ABNORMAL *Cervus elaphus* A. J. Sutcliffe, *in* Whitehead, 1964, p. 450

Material. None seen

Remarks. This species was based on a single antler fragment from Kirkdale Cave, figured by Buckland (1823, p. 9, fig. 5), in which no brow tine seems to be present. Owen (1846) created a new species to accommodate this specimen, which was markedly smaller than the *Cervus elaphus* antler-bases found at Kirkdale. Woodward and Sherborn (1890, p. 378) stated that the holotype was in the Oxford Museum, although there is no record of the specimen in an official annotated copy of *Reliquiae Diluvianae* in the University Museum. In the absence of the holotype it is impossible to interpret the species, although Dr Sutcliffe's suggestion that the specimen is of an abberent *Cervus elaphus* is a likely explanation. Alternatively, it might be a fragment of a juvenile *Megaloceros* antler. The illustrations of the specimen show little resemblance to *Rangifer,* the most common alternative suggestion, although 19th century attributions of material from South Wales to this species were almost certainly all reindeer antlers.

Order PERISSODACTYLA

Family EQUIDAE

Genus EQUUS

Equus caballus Linnaeus **HORSE**

1822 HORSE, Young & Bird, pp. 275–6
1823 HORSE, Buckland, pp. 15, 18; pl. 7, fig. 7; pl. 10, fig. 1
1828 HORSE, Young & Bird, p. 299
? 1845 *Equus* sp., Owen, p. 234
1846 *Equus fossilis*, Owen, p. 383
1867 *Equus fossilis*, Dawkins
1869 *Equus caballus* L., Dawkins, p. 194
1890 *Equus caballus* Linnaeus, Woodward & Sherborn, pp. 345–6
1907 *Equus caballus fossilis*, Lydekker
1956 *Equus caballus* L., Rutter, p. 424

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Material. *AMS*. 142/38 (lower M1); *BMNH*. 42336, 44765 & 242 (O.C.) 5 molars, 44020 (phalanx); *HMG*. V.5614/1-2 (molars); *WES*. (unreg.) 2048/39/1, -4, -5 (cheek-teeth) (unreg.) (cheek tooth fragment), 2048/39/3 (right upper M1. or M2.), 2075/40/1 (cheek-teeth fragment); *YM*. (unreg.) (three cheek-teeth).

Remarks. At the time of the original discoveries at Kirkdale there was considerable criticism of the records of horse teeth. Young and Bird (1822) refer to the activities of relic mongers, and Young (1828) specifically states that the specimens figured by Buckland were spurious, and alleges that all the remains of this animal extracted from the Cave, appear to have been thrown into it by some wags, or rogues, on purpose to increase the amount of relics. According to Owen (1845, p. 234), the Gibson collection (Royal College of Surgeons, London) included an *Equus* calcaneum coated with stalagmite but this specimen was lost in 1941. It is particularly interesting to note the total absence of horse teeth in Buckland's personal collection; this may indicate that Buckland agreed with Young and discarded the teeth in his collection. Of the specimens, four are preserved in a pink cave breccia, similar to that of Kent's Cavern, and are clearly not from Kirkdale (*HMG*. V.5614/1 – 2; *WES*. 2075/40/1 and one unreg.), All the other specimens appear to be quite modern except for *WES*. 2048/39/3 which might be genuine. The series of chemical analyses of the *BMNH*. horse teeth (see Appendix by K. P. Oakley, refs. FK, FL, FM) appear to confirm the view that they are spurious, although the evidence is not so certain in the case of the analysis of the phalangeal bone (ref. FJ), if this was in fact from Kirkdale Cave.

Order RODENTIA

Family CRICETIDAE

Genus DICROSTONYX

Dicrostonyx sp. **COLLARED LEMMING**

Material. *BMNH*. M.47096 ex M.432 (mandibular ramus) (Eniskillen Collection).

Remarks. This unlabelled specimen was first identified and listed by the late M. A. C. Hinton (M.S. note, *BMNH*.). Since this quite distinctive specimen does not seem to have been noticed prior to Hinton's determination (*c*. 1950) it seems likely that it is a fairly recent stray into the Kirkdale collections, in which it is completely out of place. It should also be noted that Kirkdale specimens are very rare in the Eniskillen Collection, which consists largely of material from the bone caves of Franconia (where lemming remains are common), although Lord Eniskillen is known to have exchanged a few specimens with Buckland, who was both his teacher and a close friend.

(c) Erroneous Records

Order PRIMATES

Family HOMINIDAE

Genus HOMO

Homo sapiens Linnaeus **MAN**

Material. BMNH. (M.432 fibular and metacarpal); *WES.* (imperfect left mandibular ramus).

Remarks. All three specimens appear to be relatively modern and are most likely to be from archaeological sites, judging by their state of preservation. The analyses of the *BMNH.* fibula clearly indicates that this has a relatively low fluorine content and relatively high nitrogen content, and is younger than the hippopotamus tooth as a control (see Appendix I). Dart (1956) argued that the fragmentation of the bones, etc. found in Kirkdale Cave was the result of human workmanship (an 'osteodontokeratic culture') not hyaena damage, but his view has been strongly refuted elsewhere (Boylan 1972).

Order CARNIVORA

Genus URSUS

Ursus spelaeus Rosenmuller **CAVE BEAR**

(for literature see *Ursus* cf. *arctos,* above)

Material. BMNH. M.4024 (5 molars, imperfect canine); *HMG.* V.5395/1 & 2 (molars).

Remarks. None of the eight specimens seen have the appearance of undoubted Kirkdale specimens – all have a rather powdery matrix, and more resemble those of the German bone-caves, such as Gailenreuth. In the case of the *BMNH.* specimens, it is of some significance that Lydekker (1885-7) does not list any bear remains from Kirkdale in his account of the national collection. Unfortunately, none of the specimens has an original label on it, but it is known that several of the original workers at Kirkdale received specimens from the German caves through exchanges with Egerton, Eniskillen and Buckland, and it is quite possible that such specimens could have been mixed with genuine Kirkdale material.

Order PINNIPEDIA

Family ODOBENIDAE

Genus ODOBENUS

Odobenus rosmarus Linnaeus **WALRUS**

Material. WM. KC. 33 (Fragment of canine).

Remarks. This specimen is clearly modern and has accidentally been mixed with the genuine Kirkdale material.

Order PROBOSCIDEA

Genus MAMMUTHUS

Mammuthus primigenius (Blumenbach) **MAMMOTH**

Material. BMNH. M.4017 (milk molar)

Remarks. The matrix and preservation of this specimen indicate that it is not from Kirkdale. Owen (1846, pp. 218–223) referred pl. 7, fig. 10 of Buckland (1823) to *Elephas primigenius,* but this figure is very clearly of a milk molar of *Elephas antiquus.* This mistake was quite understandable, since at that time *Elephas antiquus* was not recognised as a distinct species. However, the mammoth has tended to remain in the faunal lists despite the fact that Dawkins (1867) and Adams (1877–81) specifically excluded it from their lists.

Order ARTIODACTYLA

Family CERVIDAE

Genus RANGIFER

Rangifer tarandus (Linnaeus) **REINDEER**

1867 *Cervus tarandus,* Dawkins
1907 *Rangifer tarandus,* Lydekker
1933 *Rangifer tarandus* (L.), Reynolds, p. 27
1956 *Rangifer tarandus* (L.), Rutter

Material. BMNH. ? M.40365 (molar)

Remarks. The matrix and preservation of the *BMNH.* tooth is clearly that of one of the South Devon caves, not Kirkdale. The published references mostly hinge on pl. 9, fig. 5 of Buckland, 1823, i.e. '*Cervus bucklandi*' Owen (1846). The exact nature of the species is very much open to doubt, but the figures bear little resemblance, except in size to that of the reindeer, although an *OUM.* specimen of reindeer antler base, probably from Wookey Hole (*OUM.* Q.1464), is labelled *Cervus bucklandi* in what might possibly be Buckland's handwriting. (See also under *Cervus bucklandi* Owen page 270 above.)

Family BOVIDAE

Genus OVIBOS

Ovibos moschatus (Zimmerman) **MUSK OX**

Material. HMG. V.5360 (upper molar, determination confirmed by Dr. M. Kretzoi).

Remarks. Musk ox is represented by this single unlabelled cheek tooth which is noted in the catalogue as from Kirkdale. However, the preservation is quite unlike that of Kirkdale.

Ovis or *Capra* sp. **SHEEP OR GOAT**

Material. Y.M. (unreg.) (fragment of humerus and radius).

Remarks. These two bones are clearly quite modern. Young (1828) warned that spurious remains of sheep were thrown into the Cave by wags or rogues.

Order RODENTIA

Family MURIDAE

Genus MUS

Mus musculus Linnaeus **HOUSE MOUSE**

Material. OUM. Q.1412, Q.1414 (two mandibular rami).

Remarks. These two specimens are quite fresh in appearance, and are clearly contaminants. However, records of mice must be treated with caution since at least one specimen appears to be a genuine fossil, see *Apodemus* sp. (p. 267).

III. INTERPRETATION OF THE MAMMAL FAUNA

The conflicting views on the source of the bones in the cave-earth of Kirkdale Cave have recently been examined at length elsewhere (Boylan 1972) and in this paper only the identification and age of the bones are discussed.

There is little doubt that the principal reason for the errors found during the review of the Kirkdale fauna is that many specimens have been mis-identified in the past and all too often these errors have remained in the lists because subsequent authors had not seen the original material on which the identification was based. The collections of Kirkdale material are very difficult to work with because, in Buckland's words: 'Scarcely a single bone escaped fracture, with the exception of the astragalus, and other hard bones of the tarsus and carpus joints' (1823, p. 16). Some of the most indeterminable fragments have, in the past, been ascribed to species (or even subspecies) even though it is, in my view, difficult to make a certain attribution even at family level. Difficulties in nomenclature have also played a part in the confusion, as can be seen from the large number of synonyms listed, but it is to be hoped that a careful application of the International Code and of modern taxonomic principles will greatly improve the situation in time. Finally, it should be noted that at least 5% of the specimens seen are clearly not from Kirkdale: most of these have the appearance of material from some of the south Devon caves, such as Kent's Cavern, or of the Hartz bone-caves, such as Gailenreuth, and these have been a constant source of possible errors. These strays have not been specifically noted, except in critical species.

Recent interpretations have assumed that the Kirkdale mammals represent an Upper Pleistocene mixture of a warm fauna, which included *Elephas antiquus*, *Dicerorhinus hemitoechus*, *Hippopotamus*, *Bison* and *Megaloceros*, and a cold fauna which included *Mammuthus*, *Coelodonta* and *Rangifer* (e.g. Rutter 1963, pp. 5–6). However, the records of *Mammuthus* and *Coelodonta* are definitely erroneous, and those of *Rangifer* are almost certainly so. In the material traced, only the single mandibular ramus of *Dicrostonyx* sp. is certainly indicative of a cold fauna, and the origin of this particular specimen is open to question.

I therefore conclude that a single, interglacial, faunal assemblage is present, represented by the following species:–

Canis cf. *lupus* Linnaeus	? *Cervus bucklandi* Owen
Vulpes vulpes (Linnaeus)	*Megaloceros giganteus* (Blumenbach)
Ursus cf. *arctos* Linnaeus	*Bison* cf. *priscus* (Bojanus)
Mustela cf. *erminea* Linnaeus	*Dicerorhinus hemitoechus* (Falconer)
'*Panthera*' cf. leo (Linnaeus)	?? *Equus* sp.
Crocuta crocuta spelaea (Goldfuss)	*Lepus* cf. *capensis* Linnaeus
Elephas antiquus (Falconer & Cautley)	*Apodemus* sp.
Hippopotamus amphibius (Linnaeus)	*Clethrionomys* cf. *glareolus* (Schreber)
?? *Sus* sp.	*Arvicola cantiana-terrestris* transition form
Cervus elaphus Linnaeus	?? *Dicrostonyx* Sp.
Cervus cf. *dama* Linnaeus	*Microtus agrestis* (Linnaeus)

This faunal assemblage is similar in many respects to that of a considerable number of Upper Pleistocene interglacial sites in England. The associations of *Hippopotamus*, *Elephas antiquus*, *Bison* and *Dicerorhinus hemitoechus* is particularly characteristic and indicates very warm but relatively moist climatic conditions able to sustain a heavy herbivore population.

A substantial river system probably drained from the Pennines through the Vale of Pickering to the sea (Boylan 1977) giving suitable conditions for hippopotamus. It is perhaps significant that a *Hippopotamus amphibius* canine was collected from the river at Nunnington at the western end of the Vale in the 19th century (Boylan 1977). The limestone scarp to the north of the Vale would probably have been heavily wooded, whilst more open conditions might have been found on the sandstones of the Middle Jurassic of the North Yorkshire Moors to the north and on the chalk Wolds to the south, offering a variety of habitats for browsing and grazing species, such as the straight-tusked elephant and the bison respectively. As the herbivore population increased, the countryside would tend to become more open in character giving an open parkland habitat. Turner (1975) and Stuart (1976) have discussed in some detail the effects of such herbivore pressure on interglacial habitats occupied by similar populations to those of Kirkdale in eastern and southern England. The Hyaena population would have hunted across a wide area bringing back the remains of both its prey and of carrion to the Cave, which was clearly occupied by the Hyaenas for a period as a den complex in the manner graphically described by Buckland (1822; 1823).

Closely comparable English fossil mammal faunas include the following:–

Yorkshire. Sewerby Buried Cliff: *Ursus* sp., *Crocuta* crocuta, *Elephas antiquus, Hippopotamus amphibius,* ? *Megaloceros giganteus, Bison* cf. *priscus, Dicerorhinus hemitoechus, Arvicola cantiana-terrestris* (Boylan 1967b – nomenclature revised).

East Anglia. Barrington, Cambridge: *Canis lupus, Ursus arctos, Meles meles* (Linnaeus) (badger), *Crocuta crocuta, 'Panthera' leo, Elephas antiquus, Hippopotamus amphibius, Megaloceros giganteus, Cervus elaphus, Bos primigenius Bojanus* (giant ox), *Bison priscus, Dicerorhinus hemitoechus, Arvicola cantiana/terrestris* (List based on Gibbard and Stuart 1975; Sutcliffe and Kowalski 1976; and Stuart 1976). Swanton Morley, Norfolk (pollen zone Ip IIb horizon): *Hippopotamus amphibius, Bos primigenius, Clethrionomys glareolus* and *Arvicola cantiana/terrestris* (Sutcliffe and Kowalski 1976; Stuart 1976).

Thames Valley. Upper Floodplain Terrace of Trafalgar Square and other localities of Central London: *Ursus* sp., *'Panthera'* cf. *leo, Crocuta crocuta, Elephas antiquus, Hippopotamus amphibius, Sus* sp., *Cervus elaphus, Cervus dama, Bos primigenius, Bison* cf. *priscus, Dicerorhinus* sp. (Sutcliffe 1964, pp. 103–5; Stuart 1976).

Devon. Honiton By-Pass: *Elephas antiquus, Hippopotamus amphibius, Cervus elaphus, Bos primigenius* (Turner 1975). Joint Mitnor Cave: *Canis* cf. *lupus, Vulpes vulpes, Ursus* cf. *arctos, Meles meles* (badger), *Felis sylvestris* Linnaeus (wild cat), *'Panthera'* cf. *leo, Elephas antiquus, Hippopotamus amphibius, Sus* sp., *Cervus elaphus, Cervus dama, Megaloceros giganteus, Bison* cf. *priscus, Dicerorhinus hemitoechus, Lepus* sp. (Sutcliffe 1960). Tornewton Cave: Hyaena Stratum: *Canis* cf. *lupus, Vulpes vulpes, Ursus* sp., *'Panthera'* cf. *leo, Crocuta crocuta, Hippopotamus amphibius, Cervus elaphus, Cervus dama, Bos* or *Bison* sp., *Dicerorhinus hemitoechus, Lepus* sp., *Apodemus sylvaticus, Arvicola cantiana/terrestris* (Sutcliffe and Zeuner 1962; Kowalski 1967; Sutcliffe and Kowalski 1976).

Zeuner (1945) and King (1955) both discussed the characteristic faunas of the hippopotamus-bearing river terraces of East Anglia and the Thames Valley and suggested that all should be ascribed to the Last Interglacial. In his discussion of the age of the very rich mammal fauna of Joint Mitnor Cave, Devon, Sutcliffe (1960) gathered much evidence in support of this interpretation, and put forward further evidence in his reports on the Tornewton Cave excavation (Sutcliffe and Zeuner (1962) and on the mammal fauna of Swanscombe (Sutcliffe 1964).)

Clear palaeobotanical evidence in support of Ipswichian pollen zone Ip II dates for such faunas has been obtained from several sites, including Trafalgar Square (Franks 1960), Barrington (Gibbard and Stuart 1975) and Swanton Morley (Phillips 1976), although in the latter case, hippopotamus appears to have survived into the early part of zone Ip III (Stuart 1976, p. 239).

Stuart (1974; 1976) has discussed in detail the relationship between the various English Ipswichian mammal faunas and the palaeobotanical sequence, and both the Kirkdale Cave Fauna and that of the beach deposit of the nearby Sewerby Buried Cliff (Boylan 1967b) can be correlated with some confidence with Stuart's Zone Ip IIb faunas, which represent the climatic optimum of the Ipswichian Interglacial.

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IV. REFERENCES

ADAMS, A. L. 1877–1881. Monograph on the British Fossil Elephants. *Palaeont. Soc. Monogr.*

ANON. 1822. History of the Society (Continued). *Mem. Wernerian nat. Hist. Soc. Edinb.* **4,** 571-585.

BOYLAN, P. J. 1967a. *Didermocerus* Brookes, 1828, *v. Dicerorhinus* Gloger, 1841 (Mammalia: Rhinocerotidae), and the validity of A catalogue of the anatomical and zoological museum of Joshua Brookes, 1828. Z.N. (S.) 1779. *Bull. Zool. Nomencl.* **24,** 55-56.

——— 1967b. The Pleistocene mammalia of the Sewerby-Hessle Buried Cliff, East Yorkshire. *Proc. Yorks. geol. Soc.* **36,** 115-125.

——— 1967c. Dean William Buckland, 1784-1856: a pioneer in cave science. *Stud. Speleol.* **1,** 236-53.

——— 1972. The scientific significance of the Kirkdale Cave hyaenas. *Yorks. Phil. Soc. Ann. Rept for 1971.* 38-47.

——— 1977. *The Ice Age in Yorkshire and Humberside.* 32pp. Yorkshire Museum, York.

——— & GREEN, M. 1974. Request for the suppression of *Didermocerus* Brookes, 1828 (Mammalia). (Z.N.(S.) 1779). *Bull. Zool. Nomencl.* **31,** 135-9.

BROOKES, J. 1828. *A catalogue of the anatomical and zoological museum of Joshua Brookes.* 70 pp., London.

BUCKLAND, W. 1822. Account of an assemblage of fossil teeth and bones . . . discovered in a cave at Kirkdale . . . *Phil Trans. R. Soc. Lond.* **112,** 171-236.
——— 1823. *Reliquiae Diluvianae.* viii + 303 pp. Murray, London.
CORBET, G. 1964. *The identification of British mammals.* iii + 46 pp. London.
——— 1966. *The terrestrial mammals of Western Europe.* xi + 264 pp., London.
DART, R. 1956. The myth of the bone-accumulating hyaena. *Amer. Anthrop.* **58,** 40-62
DAWKINS, W. B. 1867. On the Pleistocene mammals of Yorkshire. (Abstract.) *Proc. Yorks. geol. Soc.* **4,** 502-510.
——— 1869. On the distribution of the British Postglacial mammals. *Q. Jl geol. Soc. Lond.* **25,** 192-217.
——— & SANDFORD, W. A. 1867-1872. The British Pleistocene Felidae. British Pleistocene Mammalia, vol. 1. *Palaeont. Soc. Monogr.*
EASTMEAD, W. 1824. *Historia Rievallensis.* xvi + 487 pp., London.
ELLERMAN, J. R. & MORRISON-SCOTT, T. C. S. 1951. *Checklist of Palaeoarctic and Indian mammals.* 810 pp., London.
ERDBRINK, D. P. 1953. *A review of fossil and recent bears of the old world.* xii + 597 pp., Deventer.
FALCONER, H. 1868. *Palaeontological Memoirs.* Vols 1 & 2, London.
FRANKS, J. W. 1960. Interglacial deposits at Trafalgar Square. *New Phytol.* **59,** 145-152.
GIBBARD, P. L. & STUART, A. J. 1975. Flora and vertebrate fauna of the Barrington Beds. *Geol. Mag.* **112,** 493-501.
GLOGER, C. W. L. 1841. *Gemeinnützige Hand- und Hilfsbuch der Naturgeschichte . . . Erster Band.* xxxi + 495 pp., Breslau.
INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE, 1977. Opinion 1080. *Didermocerus* Brookes, 1828 (Mammalia) suppressed under the plenary powers. *Bull. Zool. Nomencl.* **34,** 21-4.
KING, W. B. R. 1955. The Pleistocene Epoch in England. *Q. Jl geol. Soc. Lond.* **111,** 187-208.
KOENIGSWALD, W. VON. 1973. Veränderungen in der Kleinsaugerfauna von Mitteleuropa zwischen Cromer und Eem (Pleistocän). *Eiszeitalter Gegenw.*, Ohringen, **23-24,** 159-167.
KRUUK, H. 1972. *The Spotted Hyaena: A Study of Predation and Social Behaviour.* xci + 335 pp., Chicago.
——— 1975. *Hyaena.* 80 pp., Oxford.
KURTEN, B. 1957. The bears and hyaenas of the Interglacials. *Quarternaria* **4,** 69-81.
——— 1959. On the bears of the Holsteinian Interglacial. *Acta Univ. Stockholm: Stockholm Contrib. Geol.* **2,** 73-102.
LYDEKKER, R. 1885-1887. *Catalogue of Fossil Mammalia in the British Museum (Natural History).* (5 vols) London.
——— 1907. Palaeontology. pp. 99-110 *in Victoria History of Yorkshire.* **vol. 1.** xxiii + 523 pp., London.
MAGLIO, V. J. 1973. Origin and evolution of the Elephantidae. *Trans. amer. Phil. Soc. (New Series)* **63,** 1-149.
MATSUMOTO, H. 1924. Preliminary Note on Fossil Elephants in Japan. *Jl Geol. Soc. Tokyo* **31,** 255-272.
MORRISON-SCOTT, T. C. S. 1965. *Pan* Oken, 1816, and *Panthera* Oken, 1816 (Mammalia): proposed conservation under the plenary powers. Z.N. (S.) 482. *Bull. Zool. Nomencl.* **22,** 230-232.
NORTH, F. J. 1942. Paviland Cave, the 'Red Lady', the Deluge, and William Buckland. *Ann. of Sci.* **5,** 91-128.
OLSEN, S. J. 1960. Post-cranial characters of *Bison* and *Bos. Pap. Peabody Mus. Harvard* **35,** vii + 15 pp.
OSBORN, H. 1942. *Proboscidea.* Vol. II (pp. 805-1676). New York.
[OWEN, R.] 1845. *Catalogue of the fossil organic remains of Mammalia and Aves contained in the Museum of the Royal College of Surgeons of England.* vii + 391 pp., London.

[OWEN, R.] 1846. *A history of British fossil mammals and birds*. xlvi + 560 pp., London.
PETTER, F. 1961. Eléments d'une révision des lièvres européens et asiatiques du sous-genre *Lepus*. *Zeit. Saugetierk*. **26**, 30–40.
PHILLIPS, I. 1976. Pleistocene vegetational history and geology in Norfolk. *Phil. Trans. R. Soc. Lond*. **B275** (937), 215–86.
REYNOLDS, S. H. 1902. The Cave Hyaena. British Pleistocene Mammalia, vol. 2, pt. 1. *Palaeont. Soc. Monogr*.
——— 1906. The Bears. British Pleistocene Mammalia, vol. 2, pt. 2. *Palaeont. Soc. Monogr*.
——— 1909. The Canidae. British Pleistocene Mammalia, vol. 2, pt. 3. *Palaeont. Soc. Monogr*.
——— 1912. The Mustelidae. British Pleistocene Mammalia, vol. 2, pt. 4. *Palaeont. Soc. Monogr*.
——— 1922. Hippopotamus. British Pleistocene Mammalia, vol. 3, pt. 1. *Palaeont. Soc. Monogr*.
——— 1929. The Giant Deer. British Pleistocene Mammalia, vol. 3, pt. 3. *Palaeont. Soc. Monogr*.
——— 1933. The Red Deer, Reindeer and Roe. British Pleistocene Mammalia, vol. 3, pt. 4. *Palaeont. Soc. Monogr*.
RUTTER, J. G. 1956. The mammals of Pleistocene and Prehistoric times. pp. 419–430 in WALSH, G. B. & RIMMINGTON, F. C. (Eds), *The Natural History of the Scarborough District*. Vol. 2. xiv + 430 pp., Scarborough.
——— 1963. The animal remains from Kirkdale Cave. pp. 5–6 and 333–334 in MCDONNELL, J. (Ed.), *A history of Helmsley, Rievaulx and district*. xviii + 476 pp., York.
STUART, A. J. 1974. Pleistocene history of the British vertebrate fauna. *Biol. Rev*. **49**, 225–266.
——— 1976. The history of the mammal fauna during the Ipswichian/Last interglacial in England. *Phil. Trans. R. Soc. Lond*. **B276**, 221–250.
SUTCLIFFE, A. J. 1960. Joint Mitnor Cave, Buckfastleigh. *Trans. Torquay nat. Hist. Soc*. **13** (for 1958–1959), 1–26.
——— 1964. The mammalian fauna. Pp. 85–111 in OVEY, C.D. (Ed.), *The Swanscombe Skull*. xii + 216 pp. London.
——— 1970. Spotted Hyaena: crusher, gnawer, digester and collector of bones. *Nature, Lond*. **227**, 1110–1113.
——— & KOWALSKI, K. 1976. Pleistocene rodents of the British Isles. *Bull. Br. Mus. nat. Hist*. (Geol.) **27**, 33–147.
——— & ZEUNER, F. E. 1962. Excavations in the Torbryan Caves, Devonshire. I. Tornewton Cave. *Proc. Devon Archaeol. Expl. Soc*. **5** (5 + 6) (for 1957–58), 127–145.
TURNER, C. 1975. Der Einfluss grosser Mammalier auf die interglaziale Vegetation. *Quartärpaläontologie Berlin* **1**, 13–19.
WHITEHEAD, G. K. 1964. *The deer of Great Britain and Ireland*. xv + 597 pp., London.
WOODWARD, A. S. & SHERBORN, C. D. 1890. *A catalogue of British fossil vertebrata*. xxxv + 396 pp., London.
YOUNG, G. 1822. On the fossil remains of quadrupeds, etc., discovered in the cavern at Kirkdale. *Mem. Wernerian nat. Hist. Soc. Edinb*. **4**, 262–70.
——— 1828. On the fossil remains of quadrupeds, etc., discovered in the cavern at Kirkdale in Yorkshire. *Mem. Wernerian nat. Hist. Soc. Edinb*. **5**, 171–183.
——— & BIRD, J. 1822. *A geological survey of the Yorkshire Coast*. iv + 235 pp., Whitby.
——— & BIRD, J. 1828. *A geological survey of the Yorkshire Coast*. 2nd edition. iv + 360 pp., Whitby.
ZEUNER, F. E. 1945. *The Pleistocene Period*. 322 pp., London.

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APPENDIX I

ANALYSES OF BONE AND DENTINE FROM KIRKDALE CAVE

by KENNETH P. OAKLEY

At the time of writing, the available results of analyses of bones and dentine from Kirkdale Cave are as follows:–

BMNH Sample No.	Sample and Accession No.	F%	P_2O_5%	$\frac{100F}{P_2O_5}$	N%
ER	*Homo* fibula (*BMNH*: M. 432)	0.2	30.8 38.4	0.66 0.89	1.9
ES	Hippopotamus dentine (*BMNH*: 40367)	0.56 0.61	28.5 27.0	2.0 2.2	0.56
FJ	*Equus* phalanx (*BMNH*: 44020	—	—	—	1.16
FK	*Equus* dentine (*BMNH*: ?)	0.14	28.4	0.5	2.66
FL	*Equus* dentine (*BMNH*: 44765)	—	—	—	2.17
FM	*Equus* dentine	—	—	—	1.49
FP	*Crocuta* vertebra (*BMNH*: 42320)	0.25	24.60	1.0	1.26
FP1	(Second sample of FP)	—	—	—	1.34

APPENDIX 3

ENGLISH AND SCOTTISH GLACIAL LOCALITIES OF AGASSIZ, BUCKLAND AND LYELL, 1840

NOTE

The route followed in September and October 1840 by Louis Agassiz, accompanied for part of the time by Buckland, has been reconstructed in some detail by Gordon Davies (1968), and George White (1970) has added further details about the first week of October 1840.

Over the past five years (and over 8,500 miles of travelling), I have systematically visited and revisited the localities identified by Davies and White, and have broadened this work to try to find on the ground all of the many other localities referred to in the three reports given to the Geological Society in November and December 1840 by Agassiz (1841 B), Buckland (1841 A) and Lyell (1841), in order to provide an exact location and a summary description of each site.

Where specifically defined sites were described and referred to (eg the Bradford Kame at North Charlton, Northumberland, or what is now known as "Agassiz's Rock", in Edinburgh), the surviving field evidence of the actual site has been identified and reviewed; where exact sites are not referred to (eg "On many parts of the coast of Northumberland, especially near Newcastle", or "Loch Awe"), the whole area referred to has been looked at, and whenever possible typical or "voucher" localities, where the phenomena reported on in 1840 can be observed today, are identified, and a National Grid Reference and brief field description is given.

Altogether, the three 1840 papers referred to well over 100 named localities or areas (some of them very large indeed), and where practicable these names have been retained as the basis of the following list of sites and localities. However, in a considerable number of cases it seemed desirable to use more precise names, even though this might result in an increase in the number of localities in the list. (This has been particularly so in the case of the more general descriptions of large geographical areas: in such cases the "voucher" localities are usually recorded under the nearest significant place-name.)

In every case the locality name is followed by the quotation or quotations referring to it in one or more of the three 1840 papers, and then a brief field description etc is given. Where information is included from another source, the appropriate reference is given, and any interesting subsequent "classic" work or especially significant more recent interpretations, references to these are also included. However, it must be stressed that no attempt has been made to include a comprehensive list of references for each site, even though much of the scientific literature on the relevant areas of England and Scotland has been systematically reviewed in the work on identifying the sites.

Strangely enough, although most of the "classic" 1840 localities represent excellent teaching, demonstration and research material quite apart from their interest in terms of the history of science, surprisingly few have been re-examined in any detail during the past 140 years. The Crickhope Linn moraine in Dumfriesshire, which can reasonably be put forward as the first British locality at which glaciation was unequivocally recognised (Boylan, 1981: 3-4), attracted less than a dozen lines of print between Buckland's original note of 1841 and 1981.

The localities have been arranged alphabetically by name, grouped under counties in England, and regions followed by districts in Scotland.

ENGLAND

CUMBRIA

1. Ambleside

> " ... polished and striated surfaces ... but he found them on a recently exposed surface of greywacke in Dr Arnold's garden at Fox Howe near Ambleside;" (Buckland, 1841 A: 347).

The striated surfaces are no longer visible on the softish slates in the garden at NY 363051 (now known as Fox Ghyll House) but a yellowish-brown till with small erratics can be seen in the track by the side of the house. However, a striated, plucked and polished outcrop (almost a roche moutonée in shape) can be seen across the nearby stream at NY 366057 opposite Loughrigg Cottage, with the plucking and striations indicating a NW-SE ice direction (from the Rydal Water valley).

2. Barrow in Furness

> "The districts of Furness ... are extensively covered with deep deposits of glacier origin, derived from the upper ends of the Windermere and Coniston lakes ..." (Buckland, 1841 A: 347).

There are extensive, and well-known, areas of drumlins east and north-east of the town of Barrow in Furness, eg around Newton at SD 230716, and southwards to the coast at Newbiggin (SD 269693). Thick tills are exposed all along the coast to Ulverston (q.v.).

3. Brough in Stainmore

> " ... and a third great glacier, proceeding eastwards ... would cross transversely the upper part of the valley of the Eden, near Brough, and accumulate piles of ice against the opposite escarpment ..." (Buckland, 1841 A: 348).

Hummocky moraine topography is seen very well for a long distance along either side of the A66, and can be seen particularly well around the eastern end of the Brough by-pass at NY 810148, at North Stainmore (830151) and on Stainmore Summit (890126).

4. Burton

> "On the south of Kendal, the high roads from Burton and Milnethorpe [sic] to Lancaster, pass for the greater part over moraines or their detritus;" (Buckland, 1841 A: 347).
>
> "and smaller moraines, or their detritus, nearly fill the valley from Kendal to Morecombe [sic] Bay." (Buckland, 1841 A: 347). [Part]

The old high road from Lancaster to Kendal (now the A 6070) passes through an extensive area of very large drumlins, which are especially well developed around Dalton Hall SD 5375. Nearby well developed drumlins can be observed from the M6 motorway by the side of the Lancaster Canal just south of the Burton Services (eg SD 519751 and 523754 - individual large drumlins).

5. Chalk Beck

> "The remarkable assemblage of boulders of Criffle [sic] granite at Shalkbeck [sic] between Carlisle and Cockermouth, Dr Buckland conceives may have been transported across the Solway Firth on floating masses of ice." (Buckland, 1841 A: 348).

"Shalkbeck" was a common 19th Century usage, persisting into the present century (see Dixon, 1926), and till with Scottish erratics occurs over much of the Solway lowlands of N. Cumbria. Buckland certainly visited the well-known St Bees Sandstone quarries by the side of the Chalk Beck around NY 337460, and a locality near to this seems most likely. However, the area is now mostly intensively farmed arable land, and although there are some small surface erratics in some fields and along the roadsides, an extensive search of the area failed to discover the "remarkable assemblage" of Criffel granite erratics observed by Buckland.

6. Dalton in Furness

> "The districts of ... and Dalton are extensively covered with deep deposits of glacier origin ... and they contain a large admixture of clay, in consequence of the slaty nature of many of the mountains." (Buckland, 1841 A: 347).

Dalton in Furness (SD 2273) lies in an area of extensive thick tills, with many exposures, especially to the north and north-east, eg towards Marton (SD 240771).

7. Duddon Valley

> "Dr Buckland was prevented from personally examining, during his late tour, the south-west and west frontiers of the Cumberland mountains, but he conceives that many of the conical hillocks laid down on Fryer's large map of Cumberland, in the valley of the Duddon, at the south base of Harter Fell, are moraines;" (Buckland, 1841 A: 347).

Ascending the Duddon valley (Dunnerdale) from Ulpha (SD 198936) to Seathwaite (229961) south of Harter Fell, the valley has numerous fluvioglacial and hummocky moraine features. However, the most spectacular features of the Duddon valley are to the east and north-east of Harter Fell, from Hinning House (235996) to the foot of the Hard Knott Pass at NY 246017 and then eastwards along Wrynose Bottom, with prominent isolated and distinct kames and kame terraces, to the summit of the Wrynose Pass at the Three Shires Stone (NY 277028).

8. Dunmail Raise

> "... polished and striated surfaces ... on newly bared rocks by the side of the road ascending from Grassmere [sic] to the Pass of Wythburn;" (Buckland, 1841 A: 347).

The summit of the pass (NY 325127) is now better known as Dunmail Raise. Polished and striated outcrops are found by the stream and valley sides from Town Head (333100). There are good views of the heavy glacial erosion in the pass from the A591 road at 337085 just north of Grasmere, and the pass also has a large area of hummocky moraine near the summit at 325127.

9. Eamont Valley

> "... the detritus of moraines is stated to occupy the greater part of the valley of the Eamont from Ulleswater to its junction with the Eden." (Buckland, 1841 A: 346).

From Pooley Bridge (NY 470240 - q.v.) the A592 follows the valley of the Eamont down to Penrith by the M6 motorway junction no. 40 at 510290 and thence down to the River Eden at 587310. There are extensive glacial deposits all the way down the valley. From south-west to north-east, prominent glacial deposit features include: a substantial terminal moraine across the valley approx. 1 km. south of Dalemain (approx. 477264); extensive mounds, longitudinal ridges and hummocks around Stainton (490275); sand and gravel mounds and longitudinal ridges south of the river near Eamont Bridge around 520284; at Brougham Hall, which is built on a steep-sided kame terrace running from approx. 528278 to 532286; and there is a possible esker on the north side of the Eamont at its confluence with the R. Lowther at Brougham Castle (535291).

10. Edenhall

> "A remarkable group of these moraines is by the road side near Eden Hall [sic] four miles east of Penrith;" (Buckland, 1841 A: 346).

This classic area of large drumlins (subsequently studied by, among others, King and Hollingsworth, 1931) covers an area of more than 4 km. of the Eden valley close to the Eamont confluence at NY 587310. Some of the "best" topography is now difficult to see and interpret because of modern conifer afforestation, but a good impression can be gained from the B6412 road from Langwathby (572335) to Culgaith (605298), looking south-westwards across the R. Eden towards the Eamont and Edenhall Farm (566324).

11. Isel Hall

> "... moraines exist ... near Isle [sic], in the valley by which the Derwent descends from Bassenthwaite lake towards, Cockermouth ..." (Buckland, 1841 A: 347).

A substantial terminal moraine blocks the Derwent valley from approx. NY 161337 to 158335, with the ruins of the old Isel Hall on a prominent bluff at 159338, where the Derwent has cut a channel through the moraine.

12. Kendal

> "... longitudinal moraines ... in the valley of Kendal ..." (Agassiz, 1841 B: 330).
>
> "Thus, immediately below the gorge through which the Kent descends from the mountains of Kentmere and Long Sleddale, many hundreds of acres of the valley of Kendal are covered with large and lofty insulated piles of gravel;" (Buckland, 1841 A: 347).

Large drumlins composed mainly of sand and gravel, and with a general north-south orientation cover an area of over 12 sq. km. within the triangle formed by the northern outskirts of Kendal around SD 940510 in the south, and the main A591 and A6 roads towards Windermere and Shap respectively and bounded to the north by the minor road from Staveley (470987) to Garnett Bridge (525993). Perhaps the best impression of this ice margin complex is gained by travelling along the unclassified road that runs northwards from Kendal at 514933, via Ellergreen/Burneside (506956) to Staveley, following the line of the R. Kent valley. Particularly spectacular drumlin-form mounds can be seen at eg 509948 and 512957. The A6 road to Shap runs over these mounds from the R. Mint bridge at 522943 to near Thornybank (524983) and from the latter point a clear view of the north-eastern part of the drumlin field and of individual features around eg 523974 and 524966 can be obtained.

13. Kendal

> "and smaller moraines, or their detritus, nearly fill the valley from Kendal to Morecombe [sic] Bay." (Buckland, 1841 A: 347).

The main London-Glasgow railway line runs through another extensive NE-SW drumlin field around Oxenholme Junction (SD 531902).

14. Keswick

> "Near the centre of the lake district [sic] are extensive medial moraines on the shoulder of the hill called the Braw Top, and formed by glaciers at the junction of the valley of the Greta with that of Derwent Water." (Buckland, 1841 A: 347).

Although this is at first sight one of the most detailed descriptions of the location of a Lake District site, it is a puzzling one in that "Braw Top" does not seem to survive as a placename (at least in that form). From the description, Buckland must have been referring to the large mounds of till and gravel immediately to the north of the present town of Keswick at the foot of Latrigg - the southernmost extension of Skiddaw. These occur on the north side of the R. Greta and can now be viewed easily from above from the new A66 Keswick Bypass between NY 265244 and 280240. The old name of "Braw Top" may conceivably be the origin of "Briar Rigg" used for the area of modern housing built on the mounds of till and gravel around 268241.

15. Longsleddale

> "Five miles north-east of Kendal, on the high road from Shap, on the shoulder of the mountain in front of the valley of Long Sleddale [sic], and at an elevation of 500 feet, a group of moraines occupy about 200 acres, and is distinguished from the adjacent slate rocks by a superior fertility." (Buckland, 1841 A: 347).

The Longsleddale valley emerges from the fells at Thornybank (SD 522983), and the main A6 Shap road climbs up on to the large area of fertile till (exposed in small roadside cuttings and slips in a few places) from about the position of the surviving 1825 cast iron milepost ("Shap 12 miles") at 525981, presumably used by Buckland in pinpointing this location on the road. The undulating mounds of tills etc are mainly to the east of the main road around 527983 and extend to beyond Watchgate (529990). The deposits appear to be mainly of heavy till, which is visible in places in local roadside slips around SD 529998 and NY 535002 on the west side of the A6 road. The valley above the Garnett Bridge has extensive scatters of glacial erratics, particularly near Nether House Farm (NY 514003).

16. Lorton Vale

> "Dr Buckland is likewise convinced that moraines exist ... also between Crummoch [sic] Water and Lorton, in the valley of the Cocker;" (Buckland, 1841 A: 347).

Following the B5289 road parallel with the River Cocker from Crummock Water (NY 160200) towards Cockermouth (25305) numerous mounds, especially of sand and gravel occur on the valley floor. These include a moraine complex at the outfalls of Crummock Water and Loweswater around Scale Hill (135215), mounds at Low Lorton (152256), and a 2 km. long terminal moraine across the valley near Armaside (from approx. 130275 to 150275), now cut through by the present River Cocker valley at 135275, but also breached in the past at 144275, presumably by a meltwater channel.

17. Milnthorpe

> "On the south of Kendal the high roads from Burton and Milnethorpe [sic] to Lancaster, pass for the greater part over moraines or their detritus;" (Buckland, 1841 A: 347).

> "and smaller moraines, or their detritus, nearly fill the valley from Kendal to Morecombe Bay." (Buckland, 1841 A: 347). [Part]

A large area of drumlin-like gravel hummocks can be studied in the Kent Valley north of Levens Park, close to the A6 road, around SD 500870. Large till covered drumlins trending north-east - south-west cover the watershed between the Kent and Stainton Beck valleys from north of Sedgwick (around 518882) southwards to Milnthorpe (497815) and beyond. Some can be seen very clearly from the new South Lakeland bypass road (A591) from the M6 motorway junction no. 36 at Milton (533825) to Levens Park, eg around 512864, south of Sedgwick, and around Hincaster (509847). Others can be observed from the A6 road south of Levens, through Milnthorpe to Beetham (495826), and Milnthorpe itself. The various minor roads over the watershed, eg Leasgill and Heversham (497834) to Milton cross many drumlins and ridges at right angles.

18. Muncaster

> "... that some of the hillocks ... on the right of the Esk at the east and west extremities of Muncaster Fell, are also moraines formed by a glacier which descended the west side of Sca Fell;" [prediction] (Buckland, 1841 A: 347).

The Muncaster Fell (NX 120986) area is very complex because of a proglacial lake complex. Muncaster Fell itself appears to have been unglaciated, with prominent ice-margin drainage channels, and the depositional features include glacial outwash and proglacial lake terraces and fans, for example at Muncaster Castle itself, where the large outwash fan from the Branken Wall overflow channel diverts the River Esk at 107962.

19. Penrith

> "... longitudinal moraines ... as well as near Penrith ..." (Agassiz, 1841 B: 330).

> "Thus in the vicinity of Penrith, near the junction of the Eden with the Eament and the Lowther, are extensive moraines loaded with enormous blocks of porphyry and slate ..." (Buckland, 1841 A: 346).

See entries under Eamont Valley (no. 9) and Edenhall (no. 10).

20. Pooley Bridge

> "... the detritus of moraines is stated to occupy the greater part of the valley of the Eamont from Ulleswater ..." (Buckland, 1841 A: 346).

Although the Ullswater valley is a greatly over-deepened glacial trough (more than 60 m. deep in places, the present northern limit of the lake is partly controlled by a massive terminal moraine near Pooley Bridge, running at right angles to the valley from approx. NY 464245 to 473236, partly cut through by the River Eamont.

21. Rydal

> "... polished and striated surfaces ... near the slate quarry at Rydal;" (Buckland, 1841 A: 347).

The quarry is north of the A591 from Rydal Water to Grasmere at NY 348066. It is now abandoned and used as a National Park car park, but polished and striated surfaces can be found on the exposed rock surfaces just above the quarry face on the west side of the car park. There is also a heavily striated large rounded erratic of what appears to be St John's Vale microgranite (approx. 15 km. downstream from its outcrop), by the car park entrance.

22. St. John's Vale

> "Dr Buckland is likewise convinced that moraines exist near Church in the Valley;" (Buckland, 1841 A: 347).

Two very substantial retreat stage terminal moraines right across the St. John's Beck valley, the larger running from near Row End (Church in the Valley) at approx. NY 308227 to Wanthwaite (318229), and the second approx. 1 km. to the north around Shundraw, running from approx. 307235 to 316235.

23. Shap

> "... longitudinal moraines ... as well as near Penrith and Shap." (Agassiz, 1841 B: 330).

> "There are abundant proofs, Dr Buckland states, of the existence of this glacier in large mud and boulder moraines, in the ascent of the gorge between Shap Fell and Birbeck Fell, and in the furrows and striae, as well as the mammillated forms of the rocks at the portals of the gorge, particularly on the northern side." (Buckland, 1841 A: 348).

> "A glacier descending northwards from the Fell would ... carry with it, Dr Buckland says, blocks to the village of Shap, and strew them thickly over the space where they are now found;" (Buckland, 1841 A: 348).

Between 3 m. and 5 m. of variable till is well exposed on the top of the workings of the Amey Roadstone quarry in Shap village (NY 565106), and there are many exposures of till by the side of the A6 Shap Fell road through the Crookdale Beck valley from High Borrow Bridge (552040) to Wasdale Beck (561082). Buckland's reference to the "gorge" between Shap Fell and Birkbeck Fell is somewhat puzzling since there is little that would merit the term "gorge" on the Shap Fell road. Buckland's observations seem remarkably accurate throughout, but perhaps there is a mistake here, and the R. Lune gorge between Birkbeck Fell and Tebay Fell was intended (from Lowgill (SD 620970) and Tebay (NY 615047) - through which the London-Glasgow railway line and the M6 motorway now run).

There are many erratics of Shap granite east of the outcrop on Shap Fell, some up to approx. 115 m. above the highest point of the present granite outcrop, eg a large scatter on Carboniferous Limestone hillsides on the north side of the B6261 road from Shap village to the M6 junction 39, around NY 573127 on Hardendale Fell. Nearby is a single large (1 m.) boulder of Shap granite at NY 573125, on the south side of the B6261 road.

24. Stainton

> "and smaller moraines, or their detritus, nearly fill the valley from Kendal to Morecombe Bay." (Buckland, 1841 A: 347).

Leaving the M6 motorway at junction 36, the A65 road northwards to Kendal passes over several square kilometres of exceptionally large drumlins (up to 60-70 m. high and up to 1 km. long), aligned in a NE-SW direction. Individual drumlins near the road, eg at Crooklands (summits at SD 537836 and 540837), Endmoor (eg 533848 and 539850). North of Endmoor are a large number of smaller drumlins giving the characteristic "basket of eggs" topography to the east of the A65 road: viewpoints by the side of the road at SD 538855, 530873 and 532879).

25. Staveley

> "... polish on the rocks in situ ... . Similar phaenomena [sic] have been noticed ... in England in the neighbourhood of Kendal." (Agassiz, 1841 B: 330).

> "Thus in the neighbourhood of glaciers are found those rounded bosses which Saussure distinguishes by the name of roches moutonées ... he says they are very remarkable in the environs of Kendal." (Agassiz, 1841 B: 331).

General rounding and polishing and roches moutonées are very common phenomena in the fells to the west of Kendal separating the Kent and Windermere valleys, but there appears to be no precise information as to the particular features seen by Agassiz. Possibly these were in the outskirts of the town of Kendal itself (where there are many bare outcrops now largely büilt over) since Agassiz appears to have travelled by the main Kendal-Shap road (now the A6) rather than the route through the Lake District. Nevertheless, many good "voucher" localities can be found in the area, especially on the Staveley fells, eg over an area approx. 1 km. long parallel with the minor road through Borwick Fold, around SD 445971; a large group of roches moutonées north-east of Waingap Farm around 457965. In adjacent parishes rounded and polished outcrops and roches moutonées are also common, eg by the side of the A591 road 1 km. east of Windermere (around 418987) and near Crook (eg around 467955).

26. Ulverston

> "The districts of Furness, Ulverston and Dalton are extensively covered with deep deposits of glacier origin .... A capping of till and gravel, thirty to forty feel thick, overlies the great vein of haematite near Ulverston." (Buckland, 1841 A: 347).

Several haematite mines and quarries are identified by Rose and Dunham (1977: 111), in and around the town of Ulverston. However, the description and use of the term "near Ulverston" points to the haematite quarries at Plumpton Hall (SD 311786), which have been worked since the 13th century, and were the most productive in the area in the second quarter of the 19th century. The quarries are now being used by Cumbria County Council for waste disposal, but a section approx. 100 m. long can be examined in the estuary cliff nearby at 313785. This shows up to 6 m. of stiff grey gravelly till, with many erratics - mainly of local Carboniferous and Silurian material, but with some more distant Lake District erratics.

27. Walney Island

> "The numerous boulders upon the Isle of Walney also indicate the progress of the moraines from Windermere and Coniston to the north-east extremity of Morecombe [sic] Bay." (Buckland, 1841 A: 347).

Much of Walney Island has been built over since the late 19th century, but there are many reports of both large and small erratics indicating a westward movement of the ice out of the centre of the Lake District. Several large erratics excavated on Walney Island are displayed by the entrance to the small public park at SD 186687, opposite the main road bridge from Barrow-in-Furness. Many erratics can be found on the main Irish Sea foreshore, eg on the public beach by the golf course from SD 170700 southwards towards 183664.

28. Wasdale

> "... and that many of the hillocks near the village of Wasdale were formed by moraines descending westward." (Buckland, 1841 A: 347).

To the north and north-east of Nether Wasdale (NY 124040) is an extensive complex (approx. 4 sq. km.) of hummocky moraine and a clear retreat stage terminal moraine, around NY 1204 and 1304.

29. Windermere

> "... he is also of opinion that many of the rounded and mammillated rocks at the bottom of the valley leading from Helvellyn by the above localities [Rydal/Grasmere/Wythburn] to Windermere, owe their form to glacial action." (Buckland, 1841 A: 347-8).

Improvements of the A591 road appear to have obliterated most of the features observed by Buckland between Ambleside and Windermere, and lake-side developments have led to restricted access in most places. However, evidence of glacial scouring and rounding can still be seen between the main road and the lake in several places, eg around Low Wood Hotel at NY 386021, and in the grounds of the Brockholes National Park Information Centre at 390010.

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LANCASHIRE

30. Carnforth

> "On the south of Kendal, the high roads from Burton and Milnthorpe to Lancaster, pass for the greater part over moraines or their detritus." (Buckland, 1841 A: 347). [Part]

Prominent mounds of outwash gravels (currently being worked) can be seen on both sides of the M6 motorway just north of junction 35 at SD 515717 and 518714. South of Carnforth drumlin-like mounds of till with a north-east to south-west orientation can be seen from both the A6 and M6 roads, eg between Bolton-le-Sands and Nether Kellet, around 495682.

31. Halton

> "... the high roads from Burton and Milnthorpe to Lancaster, pass for the greater part over moraines or their detritus." (Buckland, 1841 A: 347). [Part]

Prominent drumlin-like mounds are seen just north of the R. Lune, again with a north-east to south-west orientation, on either side of the M6 motorway, around SD 499659.

32. Lancaster

> "... the high roads from Burton and Milnthorpe to Lancaster, pass for the greater part over moraines or their detritus; and Lancaster Castle, placed in front of the vomitory of the Lune, is stated to stand on a mixed mass of glacial debris, probably derived from the valley of the Lune." (Buckland, 1841 A: 347).

The summit of the hill is now completely built over, and only temporary exposures would give any information about the glacial deposits around the Castle and the Church around SD 474619. There is, however, a good view of the general form of the hill from the banks of the R. Lune by the A589 (Morecambe) road at SD 470625. To the north-east of the town centre, clear glacial deposition topography can be seen by the southern bank of the Lune, eg on the golf course by junction 34 of the M6 motorway at 495639.

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NORTHUMBERLAND

33. Berwick-upon-Tweed

> "... and on the left margin of the estuary of the Tweed, three miles north of Berwick, round tumuli and oblong mounds of gravel are lodged on the slope of a hill 300 or 400 feet above the level of the sea." (Buckland, 1841 A: 345-6).

Although the description seems quite clear, this proved to be one of the most difficult of all localities to identify on the ground. A point 3 miles north of the town would be under the sea, not on a hill 300 or 400 ft. high. Also, at Berwick, the R. Tweed valley is very narrow (well under one mile across), so the reference to the "left margin" was also puzzling. However, extensive fieldwork suggests that Buckland must have meant north<u>wards</u>, along the Great North Road towards Edinburgh (now the A1) which in fact leaves Berwick in a north-westerly direction. Passing East Hope Farm (NO 988550), the road passes considerable areas of hummocky ground with small, predominantly gravel, mounds which can be seen very well around 987557 between the road and the cliff top at Needle's Eye, and the main London to Edinburgh railway line cuts through such a mound at 990557. Larger-scale features can be seen to the west of the road at Folly Farm around 980560. This area is at the foot of Halidon Hill, 163 m. high, which may be the hill referred to in Buckland's description. There are larger-scale glacial mounds along the road from Folly Farm to the Scottish border at 973550.

34. <u>Kirknewton</u>

> "On the left bank of the College Burn, immediately above the bridge at Kirknewton, Dr Buckland discovered last autumn a moraine thirty feet high, stratified near the top to a depth of a few feet, but composed chiefly of unstratified gravel, inclosing fragmentary portions of a bed of laminated sand about three feet thick. Some of these fragments were in a vertical position, others were inclined, and the laminae of which they were composed, were, for the greater part, variously contorted. He is of the opinion that these detached portions were severed from their original position, moved forward, and contorted by the pressure of a glacier, which descended the deep trough of the College Burn from the northern summit of the Cheviots." (Buckland, 1841 A: 346).

This important feature (NO 906299) is readily accessible by means of a footpath along the west bank of the College Burn from the bridge 1 km. west of Kirknewton village which takes the B6351 road over the Burn. 143 years later, there is really very little that can be added either to Buckland's excellent field description or to his interpretation. The sand horizon serves as an excellent marker for examining the marked contortions in the internal structure. The moraine is asymmetrical, with a downstream dip of about 60° and an upstream dip of about 25°, and appears to have been about 150-200 m. across originally, although much has now been eroded away by the stream.

35. North Charlton

> "At the village of North Charlton, between Belford and Alnwick, Mr C. Trevelyan pointed out to Dr Buckland in 1821, a tortuous ridge of gravel which was supposed to be an inexplicable work of art; but which he became convinced, after an examination in 1838 of the upper glacier of Grindelwald and that of Rosenlaui, is a lateral moraine." (Buckland, 1841 A: 346).

This locality is part of the well-known "Bradford Kame" complex (see eg Gregory, 1922; Carruthers et al, 1927: 135-45; Carruthers et al, 1930: 94-98). At North Charlton Buckland's locality can be very easily recognised about 100 m. east of the Great North Road (A1). A prominent ridge, mainly of gravel and sand, runs approximately north-south in a sinuous manner. Generally, it is approx. 6 m. high and perhaps an average of 15-20 m. across in the North Charlton area. At Buckland's locality the coarser gravel and till core is capped with a series of six overlapping conical-shaped mounds of finer sand running from NU 171228 to 171225, by the farm track running eastwards from the A1 towards

Charlton Hall and Doxford Farm. The till core can be seen in small exposures at 170233 by the minor road leading eastwards to Tyneley Farm. The whole "Bradford Kame" complex continues both northwards and southwards from this locality, for a total distance of more than 20 km. There has been, and still is, much controversy about the nature and origin of this feature, but the form around North Charlton suggests that it is basically an esker, at least in that part of the complex.

36. Wooler district

> "Dr Buckland was prevented from examining the gorges through which the Burns descend from the eastern extremity of the Cheviots, but he directs attention to them as points where striae and other proofs of glacial action may be found. Immediately below the vomitories of the eastern valleys of the Cheviots, enormous moraines are stated to cover a tract four miles from north to south, and two from west to east; and the high road to wind among cultivated mounds of them from near Wooler, through North and South Middleton, and by West and East Lillburn [sic] to Rosedean [sic] and Wooperton." (Buckland, 1841 A: 346).

This area (approx. 20 sq. km. in extent) is traversed by the A697 main road running north-south, and has some of the most spectacular (and largest-scale) kame and kettle topography in England, even though it must have been greatly "tamed" by centuries of arable cultivation and drainage.

Wooler itself lies on a substantial till ridge approx. 15 m. high running from NT 991286 to 995278, which can be viewed from the A697 town centre bypass. Travelling southwards it is worth taking the minor road up the west side of Wooler Water towards North Middleton, which has spectacular views down onto the fluvioglacial kame and kettle topography south of Wooler at various points, eg from Happy Valley at NT 998248. Nearby are dissected kame terraces and similar glacial deposition features in Happy Valley itself at 999253 and just north of North Middleton village at NT 999249 and NU 000243. At South Middleton till is exposed in a slip in the hillside at NT 998234, and many small Cheviot erratics occur in the till and on the fields around NU 004237.

The kettles, kames eskers and other features can similarly be examined around Lilburn (eg at Lilburn Hall, NU 014255, and East Lilburn, 044236), and along the A697 road between Roseden (NU 037217) and Wooperton (044205).

Perhaps the best general viewpoint of the whole area is the side of the B6346 road at NU 049203, just before it begins its final descent to the A697 by the site of the former Wooperton station. The area was examined in some detail at the beginning of this century by Bullerwell (1910), who recognised the fluvioglacial origin of the kames etc. In recent years the area has been studied and geomorphologically mapped in some detail by Clapperton (eg 1971).

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TYNE AND WEAR

37. Tynemouth

> "On many parts of the coast of Northumberland, especially near Newcastle, deposits of till rest upon carboniferous rocks." (Buckland, 1841 A: 346).

The Northumberland and Tyne and Wear coasts north of the Tyne have till capping the cliffs in along most of their length. A good "voucher" locality that is readily accessible from Newcastle upon Tyne is the coast at Tynemouth. For example, on the north side of Sharpness Point at NZ 372699, approx. ½ km. north of Tynemouth Priory (which is itself on a till-covered cliff top), up to 4 m. of brown till lies directly on the succession of sandstones, clays and a coal. Just to the north, in the middle of the Long Sands bay that separates Tynemouth from Cullercoats (366706), the till becomes a greyish boulder clay with sand partings and lenses, and increases to approx. 12 m. in thickness.

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SCOTLAND

BORDERS REGION, BERWICKSHIRE DISTRICT

38. Ayton

> "... between Cockburn's Path and Ayton, moraines dispersed in terraces are also visible at various heights on both sides of the river;" (Buckland, 1841 A: 345). [Part]

Clearly Buckland observed these features from the Great North Road (now the A1) from Cockburnspath southwards towards Berwick-upon-Tweed, eg a large mound of till about ½ km. long can be seen under the wood at Aytonlaw from NT 913614 to 916611; also on south side of road above Eye Water approx. 1 km. long from NT 899620 to 906618.

39. Houndwood

> "... between Cockburn's Path and Ayton, moraines dispersed in terraces are also visible at various heights on both sides of the river;" (Buckland, 1841 A: 345). [Part]

At Houndwood there is a substantial dissected till feature on the south side of the river between the A1 and the Berwick-Edinburgh railway line with a further morainic feature parallel to the valley side behind, from NT 840638 to 845635, with a good exposure of coarse, bouldery till in landslips and worn patches above the river; also a large till mound is cut by the railway line around NT 828641.

40. Cockburnspath

> "... between Cockburn's Path and Ayton moraines dispersed in terraces are also visible at various heights on both sides of the river;" (Buckland, 1841 A: 345). [Part]

An extensive area (approx. 5 sq. km.) of moundy terrace gravel deposits extending along the south-east side of the Dunglas Burn is centred on the village of Cockburnspath, and extends northwards to the sea. The dissected mounds are up to 10-12 m. high and consist of both coarse gravels and finer cross-bedded sands, and are best seen in the Kinegar gravel pit, approx. ½ km. south-west of the village at NT 772705.

41. Reston

> "... between Cockburn's Path and Ayton, moraines dispersed in terraces are also visible at various heights on both sides of the river;" (Buckland, 1841 A: 345). [Part]

A further good example of the features noted by Buckland is seen at Reston, where the village is built on a prominent elongated mound almost 1 km. long above the Eye Water from NT 876621 to 885621: good view looking southwards from A1 road near Heaugh Head at NT 880624.

CENTRAL REGION, STIRLING DISTRICT

42. Brig o' Turk

> "Moraines are stated to cover more or less the valley of the Teith from Loch Katherine to Callender ..." (Buckland, 1841 A: 336).

There is a large terminal moraine complex at the head of Loch Achray around NN 503066, and around Brig o' Turk itself, centred on approx. NN 530065, but largely masked by modern afforestation: both can be viewed from the A821 Trossachs tourist route.

43. Callander

> "... the lofty terraces flanking the valley from Callender to Doune are considered to be the detritus of moraines, modified by the great floods which accompanied the melting of the ice. One of them, near Callender [sic], has been mapped as the vallum of a Roman camp." (Buckland, 1841 A: 336).

In the town of Callander there is the well-known sinuous "Roman Camp" esker on the north bank of the R. Teith running from approx. NN 630076 to 635073. The "Roman Camp" name still survives in the town, with a fairly modern hotel of that name, even though the natural origin of the feature was established as long ago as 1794 (Robertson, 1794).

There are also large morainic or fluvioglacial mounds on the south side of the R. Teith in Callander around NN 633070, and can be viewed from the A81 around 630070.

44. Daldorn

> "The little lakes on the right bank of the Teith, four miles east of Callender, Dr Buckland considers due to moraines obstructing the drainage of the country;" (Buckland, 1841 A: 336).

There is an extensive area of kame and kettle topography south-east of Callander, with the Wester Loch of Dalorn at NN 671035 as the largest kettle still holding water. Other prominent kettles in hummocky glacial deposits are the unnamed small lochs at NN 675034 and 674026.

45. Doune

> "... the lofty terraces flanking the valley from Callender [sic] to Doune ..." (Buckland, 1841 A: 336).

The Callander and Teith Valley features (q.v.) continue with hummocky ground south and east of Doune, eg around Doune Castle (NN 730010) and Blair Drummond (NS 730989).

46. Loch Venachar

> "Moraines are stated to cover more or less the valley of the Teith from Loch Katherine to Callender," (Buckland, 1841 A: 336).

Most of the valley floor between Brig o' Turk and Callander is now masked by the flooding to create the Loch Venachar hydro-electric scheme. However, good examples of valley side morainic debris can be seen around Coilantogle (NN 595073), and there is a splendid large perched erratic block, known as the Sampson Stone, high on the north side of the valley at NN 604077, which can be seen from the A821/A892 junction at NN 603074.

47. Stirling

> "Proofs of Glacial Action at Stirling and Edinburgh. - Having thus shown that glaciers once existed in the glens and mountainous districts of Scotland, Dr Buckland proceeds to point out the evidence of glacial action at points but little raised above the level of the sea, and distant from any lofty group of mountains. In 1824 he had noticed that the trap-rock then recently exposed on the summit of the hill, between

> the castle and the church, was polished and striated, but at his last visit in 1840 these evidences had become obliterated by weathering." (Buckland, 1841 A: 336).

> "The cave is not three hundred feet above the level of the sea, and the proving of glacial action at this point justifies, the author states, the belief that glaciers may also at that period have covered Calton Hill and the Castle Hills of Edinburgh and Stirling." (Buckland, 1841 A: 337).

> "In the lowland districts he notices also the occurrence of rounded, polished and striated surfaces upon the top of the basaltic rocks of Stirling Castle, ..." (Buckland, 1841 B: 551).

Although the first quotation does not explicitly identify the 1824 observation as Stirling rather than Edinburgh, it is quite clear from the context, and in particular the way in which the first Edinburgh locality is introduced in the next sentence, that Stirling is definitely intended. The Anniversary Address summary (Buckland, 1841 B: 511) is explicit. The centre of Stirling is on a classic crag-and-tail, with the Castle on the crest of the glacially eroded west-north-west face of the quartz-dolerite sill of the Castle Crag, with the Castle at NS 789942 and the parish church referred to by Buckland at 782937. The crag-and-tail is orientated approximately west-north-west to south-south-east, and the face is at present about 70 m. high. However, there are very thick drift deposits at the foot of the hill (55 m. below O.D. to the rockhead 1½ km. away in the I.G.S. Stirling No 1 Borehole near Kaimes at 772945) (Francis et al., 1970: 265), so the actual height of the face of the crag must be of the order of 130 m. above the rockhead. The "tail" is over 2 km. long. The whole feature can be seen very well from the sliproads of junction 10 (with the A84) of the M9 motorway at NS 776953 or from the A9 road about 1½ km. south of junction 9 of the M9, near Bridge of Allan (eg NS 780980).

48. Teith Valley

> "and lofty terraces flanking the valley from Callander to Doune are considered to be the detritus of moraines, modified by the great floods which accompanied the melting of the ice ... and the greater part of the first table-land on the right bank of the Teith, between Callender [sic] and Doune, including the portion on which stands Mr Smith's farm, to be composed of re-arranged glacial detritus." (Buckland, 1841 A: 336).

A belt of eskers and kames almost fills the Teith Valley south-east of Callander. These features are best seen by following the B8032 on the south side of the R. Teith from NN 636052 near Callander to Doune Bridge (NN 722012). There are massive mounds of gravel, sand and till up to 50 m. high on the south side of the river, eg around Torrie (summits of mounds at NN 645058, 655057, 677042 and 659045); Dalorn Lochs (see separate entry no. 44), Lanrick Castle grounds, from NN 683030 to 702024. The alternative route down the Teith Valley from Callander, via the A84 main road, shows similar large mounds between Dalvorich (650066) and Burn of Cambus (707030). A typical example of these mounds is being worked for sand and gravel by the Callander Sand and Gravel on the north side of the A84 at Cambusbeg (NN 667047) where there is a face approx. 5 m. high in a 15 m. high mound.

The glacial deposits of the Teith Valley have been examined in some detail recently by the I.G.S. (Francis et al. 1970: 256-74; Merrit and Laxton, 1982: 19-22).

DUMFRIES AND GALLOWAY REGION, NITHSDALE DISTRICT

49. Crichope Linn

> "Moraine near Dumfries. - The picturesque ravine of Crickhope [sic] Linn, about two miles north of Closeburn, and one mile east of Thornhill, intersects nearly horizontal strata of new

> red sandstone, and is traversed by the Dolland rivulet. On emerging from the upper end of the ravine a long terminal moraine is visible, stretching nearly across the mountain valley, from which the Dolland Burn descends to fall into Crickhope Linn; and it resembles, when viewed from a distance, a vallum of an ancient camp, being covered with turf. It is formed principally of an unstratified mass of rolled pebbles, derived from the slates of the adjacent Lowder Hills, with a few rounded fragments of granite, the nearest rock of which in situ is that of Loch Doon, in Galloway, thirty miles to the north-west. Its height varies from twenty to thirty feet; its breadth at the base is about one hundred feet, and its length is four hundred yards. At the southern extremity it is traversed by the Dolland rivulet, and at the northern by the Crickhope Water; and in the centre it is intersected by a road." (Buckland, 1841 A: 333).

This is the locality at which evidence of glaciation was first unequivocally recognised in the British Isles (Boylan, 1981: 3-4), and is still immediately identifiable from Buckland's clear description. The small gravelly moraine crosses the Crichope Linn valley from NX 923948 to 920955, and is approx. 900 m. long and a maximum of 5 m. high.

The locality is best approached from the main A76 Dumfries to Cumnock road by the unclassified road to the east 1½ km. north of Closeburn (junction at NX 891932) and thence via Closeburnmill (904945) and the farm road towards Dollard (922949). This farm road is clearly the road referred to in Buckland's description. It crosses the moraine at right angles approx. 100 m. before the farm (at about 921951), where there are two small roadside exposures showing the stony till core of the moraine, which is approx. 12 m. high and 20-3- m. across at this point. Most of the erratics appear to be derived from the nearby Lowther Hills, but small stones of the characteristic Loch Doon granite can also be identified, as noted by Buckland.

Considering the historic significance of the locality, there has been remarkably little interest in it since Buckland's original publication of the site. The area was mapped on the 6" scale by H M Skae of the Geological Survey of Scotland in 1868, and the original Field Slip is deposited in the I.G.S. Library, Murchison House, Edinburgh (Dumfries 31 NE). Skae mapped the moraine as a kame over a patch of gravel, and a similar explanation was given by J Horne in the Sheet Memoir (Skae, 1877). Only Charlesworth (1926) appears to have recognised the historical significance of the locality and provided an acceptable 20th century interpretation - that the feature is, indeed, a moraine associated with a lobe of a major Nithsdale Valley glacier.

GRAMPIAN REGION, CITY OF ABERDEEN DISTRICT

50. Aberdeen

> "Moraines in Aberdeenshire. - Dr Buckland considers the gravel and sand which cover the greater part of the granite table-land from Aberdeen to Stonehaven to be the detritus of moraines;" (Buckland, 1841 A: 333).

> "... the 6th and last locality visited conjointly was the site and neighbourhood of the town of New Aberdeen, where the polished surface of the granite had been noticed by Dr Fleming, and where remodified detritus of morains forms the hillocks of gravel between the town and the sea on the north side of the estuary of the Dee, and cliffs of gravel and till or boulder clay occur on the south of the same estuary." (Buckland, 1841 B: 511).

The old main road southwards from the centre of Aberdeen has been by-passed and is now the A956. Immediately after climbing out of the Dee Valley, at Nigg the road passes through a large area of prominent gravel hummocks, approx. 1 km. x 4 km. in extent, eg to the east of the road at NJ 943017 looking towards mounds at North Loirston, 946019. In this area the gravel mounds are markedly elongated approx. north-south and are up to 100 m. long. A small natural section in one of these, showing a coarse boulder gravel, can be examined adjacent to the road at the 943017 viewpoint referred to above. Simpson (1948) investigated these gravels in some detail and considered them to be morainic, and of the "Perthshire" (ie Loch Lomond) readvance. Murdoch (1975) in his review of the glacial deposits of this area found that these meltwater deposits are often covered by an impersistent layer of till.

North of the rivers, modern building has obscured the localities likely to have been referred to in the town centre, but hummocky ground can be seen from the A947 road near Dyce Airport (eg around NJ 895110) and along the coast from 956098 northwards.

GRAMPIAN REGION, KINCARDINE AND DEESIDE DISTRICT

51. Auchenblae

> "... the large insulated tumuli and tortuous ridges of gravel, occupying one hundred acres, near Forden [sic], a mile east of Achinbald [sic], to be terminal moraines;" (Buckland, 1841 A: 333).

South of Stonehaven the old main road southwards went via Brechin, along the line of the present A94. In this area are many square kilometres of gravel and till hummocks. Examples close to the road can be seen cose to the A94 road around Candy Farm, where there is an area of hummocks, mostly of red gravelly till, approx. ½ sq. km. in area, centred on NO 789802. Similar features are also visible on both sides of the road to Fordoun Inn at NO 750758.

At Auchenblae are two massive sand and gravel ridges one on each side of the Luther Water parallel with the river. The feature on the west side of the stream from NO 726779 southwards to 727772 where it terminates in a steep south-facing slope approx. 20 metres high. A section approx. 3 metres high shows coarse gravel in a partly overgrown abandoned pit at NO 726779, and sandier deposits are visible in slips near to top of the west side around NO 728775. The ridge on the east side of the Luther Water is even higher - approx. 30 metres high above the stream at its maximum. This runs southwards from the centre of the village at NO 727786 to approx. 722774, with a large working sand pit quarrying the eastern slope of the ridge at 732776. There are also prominent isolated mounds of sand and gravel in the area, eg by Fordoun House at NO 732770.

52. Fettercairn

> "... also the blocks, large pebbles, and small gravel spread over *the first level portions of the valley of the North Esk*, after emerging from the Sub-Grampians, to be the residue of moraines re-arranged by water." (Buckland, 1841 A: 333).

Between Fettercairn and Edzell there are large sandy mounds on both sides of the B966, eg at Cairnton which has a prehistoric fort recorded on the top of Green Cairn at NO 633723, and another prominent mound at NO 630721. There are also prominent ridges and kames in the parkland of The Burn, around NO 590725 although these are largely obscured by the extensive woodlands.

This outwash etc complex straddles the Region boundary, which runs down the middle of the North Esk: see also Edzell, Tayside Region, Angus District, no. 83.

53. Findon

> "Dr Buckland considers the gravel and sand which cover the greater part of the granite table-land from Aberdeen to Stonehaven to be the detritus of moraines;" (Buckland, 1841 A: 333)

A fluvioglacial terrace, centred around NO 940985, has an exposure of approx. 3 m. of bouldery gravel in a pit at 938987.

54. Muchalls

> "Dr Buckland considers the gravel and sand which cover the greater part of the granite table-land from Aberdeen to Stonehaven to be the detritus of moraines;" (Buckland, 1841 A: 333).

South of Nigg Bay the old road from Aberdeen to Stonehaven followed the line of the present A92. Good examples of the features observed by Buckland can be seen in many places, and are particularly well seen on the west side of the road around Muchalls Castle (NO 896916), where there are a prominent series of till and gravel hummocks. Nearby are a row of three prominent hummocks in a row, running north-south with Westport Farm on the most southerly of these at NO 885894, and these mounds continue to the west of the road for approx. 2 km. around Logie (NO 887887) to Megray (884879) and on the east of the A92 road a prominent mound is cut through by the main railway line on the cliff top above Red Man at NO 890887.

55. Stonehaven

> "Dr Buckland considers the gravel and sand which cover the greater part of the granite table-land from Aberdeen to Stonehaven to be the detritus of moraines;" (Buckland, 1841 A: 333).

There are extensive areas of sand and gravel mounds and ridges, traversed by the main A92 road to the north of the town from

NO 885874 to 880871, and these continue westwards on both sides of the river for approx. 2½ km., with extensive areas north and south of the river, respectively centred on approx. NO 855890, and approx. 860870.

HIGHLAND REGION, LOCHABER DISTRICT

56. Ben Nevis

> "... he informed M. Agassiz that he had noticed in Scotland and England phaenomena [sic] similar to those he had just examined, but which he had attributed to diluvial action; ... and, in 1824, in the company of Mr Lyell, grooves and striae on the granite rocks near the east base of Ben Nevis." (Buckland, 1841 A: 332).
>
> "We have found abundant Traces of Glaciers round Ben Nevis ..." (Buckland to Fleming, 4 October 1840, quoted by White, 1970).

These are, of course, very vague descriptions, and it is impossible in the absence of other evidence to suggest an exact location. However, it is clear that Buckland took Agassiz to Loch Treig (q.v.), so the small rounded outcrops with south-north striations on each side of the minor road leading to Loch Treig at eg NN 342796, and three small possible roches moutonées just south of this road at NN 341796 and facing directly into Coire Laire, may be suggested as easily accessible "voucher" examples. There is, of course, abundant evidence of glacial striation, grooving and down-valley movement of erratics all around the Ben Nevis range, and readily accessible examples are perhaps best seen in Glen Nevis, just above Fort William, eg the well-known and much-photographed large roche moutonée alongside the road above Polldubh (143685) and the rounded and heavily striated outcrops by the side of the Glen Nevis road at NN 160687, and the huge erratic boulder known as the Dun Dige above Glen Nevis House at 127717.

The statement that "morains [sic] ... on the sides and bottom of a mountain valley, occurs near Sir George Mackenzie's residence at Coul, at the south-west base of Ben Nevis" (F. Buckland, 1858: lv-lvi) seems to be an attempt to correct the misprint "Ben Wevis" in the Anniversary Address (Buckland, 1841 B: 511), but "Ben Wyvis" was evidently intended.

57. Glen Roy

"Another class of phaenomena [sic] connected with glaciers, is the formation of lakes by the extension of glaciers from lateral valleys into the main valley; and M. Agassiz is of opinion, that the parallel roads of Glen Roy were formed by a lake which was produced in consequence of a lateral glacier projecting across the glen near Bridge Roy, and another across the valley of Glen Speane [sic]. Lakes thus formed naturally give rise to stratified deposits and parallel roads, or beds of detritus at different levels." (Agassiz, 1841 B: 331-2).

"After these general remarks, Dr Buckland proceeds to describe the evidence of glaciers observed by him in Scotland last autumn, ... but he forbears to dwell on the phaenomena [sic] of parallel terraces, though he is convinced that they are the effects of lakes produced by glaciers." (Buckland, 1841 A: 333).

"... 4thly, the rounded, polished and striated surfaces, accompanied by morains, in Glen Roy and the valley of the Spean; from the position of which they infer that the lake, to which many writers have referred the origin of the parallel roads of Glen Roy, was caused by two glaciers descending from Ben Nevis across the valley of the Spean, in the same manner as in 1818 a temporary lake was formed by a barrier of ice in the Val de Bagnes above Martigny; and as at this time, a barrier formed by the glacier of Miage protruding across the Allée Blanche is the sole cause of the Lake Combal, which would immediately be left dry like Glen Roy, should any case remove the protruding barrier of the glacier of Miage. (See Captain Basil Hall's Patchwork, vol. i.p.114)." (Buckland, 1841 B: 511).

See also Agassiz, 1842: 236-40.

This famous location (now a National Nature Reserve because of its scientific importance) had been the subject of much speculation, comment and controversy for the greater part of a century at the time of the visit of Agassiz and Buckland in the Autumn of 1840, including a strongly argued paper in support of the marine submergence hypothesis by Charles Darwin (1839), which he subsequently deeply regretted. The interpretation of Agassiz, supported by Buckland, was fully vindicated by the classic study of Jamieson (1863), and by all subsequent work.

There is an excellent guide to the National Nature Reserve by Sissons (1977), who has also published over the past few years a number of important review papers on various aspects of Glen Roy and the related phenomena in adjacent glens, and the history of the investigation of the area (eg Sissons, 1979a, 1981; Sissons and Cornish, 1983).

The best general visual introduction to the complex history of Glen Roy is obtained from the Nature Conservancy Council's car park and viewpoint at NN 298853, which is on the west side of the valley just above a fine retreat stage moraine, now cut through by the River Roy, together with prominent kames downstream around 298858 and with a good kame terrace on the east side of the valley just above the river at 298847. Looking northwards from the viewpoint, the "parallel roads" - proglacial lake shorelines - can be seen high on the sides of the valley, with the 260 m., 315 m. and 330 m. levels being particularly prominent. A short climb from the viewpoint brings you onto the 260 m. "parallel road" at approx.

NN 296853, where the form of the fossil shoreline can be studied, and from where there is an even better view of the whole Glen and the cols/overflow channels that controlled the levels of the higher "parallel roads".

Laminated sediments of the proglacial lake can be studied in several places, particularly in a roadside section at NN 296859, where fine dropstones of igneous and metamorphic erratics are seen from time to time, distorting the lake bottom laminated clays.

58. Loch Leven (including Ballachulish)

> "... blocks and masses of gravel everywhere diverge from the central chains of the country, following the course of the valleys. Thus in the valleys of ... Loch Leven from east to west ..." (Agassiz, 1841 B: 328).
>
> "... polish on the rocks in situ ... Similar phenomena have been noticed by M. Agassiz in Scotland ... near Ballachalish" [sic]. (Agassiz, 1841 B: 330).
>
> "Thus in the neighbourhood of glaciers are found those rounded bosses which Saussure distinguishes by the name of "roches moutonées". These phenomena M. Agassiz ... has observed ... also in Scotland, on the banks of ... Loch Leven ..." (Agassiz, 1841 B: 331).
>
> "... striated rocks ... and the best examples M. Agassiz has seen in Scotland, are those of Ballahulish" [sic]. (Agassiz, 1841 B: 331).
>
> "The granitic and porphyritic rocks of many valleys in Scotland exhibit polishings equally brilliant with those at present observed on the slaty serpentines of the flanks of the glaciers of Monte Rosa. The most remarkable of these polishings that I have seen in Scotland are those of the banks of Loch Leven near Ballahulish [sic], ..." (Agassiz, 1842: 225).

On the north side of the Loch are many large glacially moulded and striated outcrops, for example around a car park in an abandoned quarry at NN 125611. Nearby, along the shore at 125610 are spectacular examples of grooving and striation parallel with the line of the valley, with at least 7 longitudinal grooves at approx. 1 m. intervals and up to 20 cm. deep. There are several possible roches moutonées in a wooded area by the shore around the Mausoleum at 071598, and clear roches moutonées in the small harbour at 062601 and two further examples parallel to the side of the Loch at 085597. In all of these areas are scatters of granite erratics indicating an east-west ice movement. There are also glacially rounded rock outcrops on the south side of the Loch at Ballachulish village between the A828 and the loch-side at NN 080584.

59. Loch Treig

> "... longitudinal moraines ... disposed in ridges with a double talus, one flank of which is presented to the glacier, and the other to the side of the valley ... at the outlet of Loch Traig" [sic]. (Agassiz, 1841 B: 330).

> "When we study the arrangement of erratic blocks of certain valleys in Scotland, we feel inclined to imagine ourselves in a valley of the Swiss Alps. I shall never forget the impression I experienced at the sight of the terraced mounds of blocks which occur at the mouth of the valley of Loch Treig, where it joins Glen Spean; it seemed to me as if I were looking at the numerous moraines of the neighbourhood of Tines, in the valley of Chamounix. These mounds or ramparts abut against the walls of the valleys, frequently forming at the mouths of the valleys a series of concentric belts, which occur precisely at those places where, supposing that the valley had at one period been occupied by a glacier, it ought to have terminated by the terminal moraines pushing against one another." (Agassiz, 1842: 221-2).

A very large moraine complex (mapped by Sissons, 1977) blocks the outlet of Glen Treig at the junction with Glen Spean, and although recent afforestation masks much of it, the terminal moraine can be observed from the A86 approx. 1 km. west of Laggan Dam, by the road to Tulloch station, at NN 360807, looking southwards to the moraine much of National Grid square NN 3679 (and extending far beyond this). Above the terminal phase of the moraine, other features of the complex can be studied from the minor road that leaves the A86 at NN 341809 and leads southwards to Loch Treig. The minor road crosses a further moraine across the valley approx. 1 km. north of Fersit at NN 349789, which dams back the small loch of An Dubh Lochan. Further south still, the moraine complex includes fresh kame and kettle topography around the head of the public road near Fersit (NN 349784). Other notable features of this area include fine kame terraces down the side of the Treig and Allt Laire valleys from approx. NN 348782 to 347791, a good section in the boulder moraine deposits at Allt Laire bridge at 346795, a remarkably deep kettle on the west side of the road at 338803, with a good natural section approx. 4 m. high in a sandy kame on the east side of the road at the same point.

HIGHLAND REGION, ROSS AND CROMARTY DISTRICT

60. Beauly Firth

> "... longitudinal moraines ... disposed in ridges with a double talus, one flank of which is presented to the glacier, and the other to the side of the valley ... on the borders of the bay of Beauley" [sic]. (Agassiz, 1841 B: 330).

Following the north shore of the Firth along the minor coastal road from Muir of Ord to the new road bridge to Inverness at North Kessock, lateral till and gravel mounds and ridges, some partly re-worked by the raised beaches, can be seen almost continuously, usually approx. 100 m. inland parallel to the shore, with a low raised beach in front. Particularly clear examples can be seen for almost 2 km. from Recastle (NH 585495) round the bay to near Coulmore

(600486), and then around Corgrain Point to a series of spectacular steep-sided longitudinal ridges near the Coulmore Water Sports Centre at 614484. Other particularly marked features occur north of the coastal road at NH 630484, by Charlestown (641484), and the series of lateral ridges and mounds end with several large elongated but rounded mounds of till and gravel around North Kessock, with the village itself standing on the seaward end of the series at NH 650480.

61. Ben Wyvis

> "... he informed M. Agassiz that he had noticed in Scotland and England phaenomena [sic] similar to those he had just examined, but which he had attributed to diluvial action... . About the same time [ie 1824] Sir George Mackenzie pointed out to the author in a valley near the base of Ben Wyvis, a high ridge of gravel, laid obliquely across, in a manner inexplicable by any action of water, but in which, after his examination of the effects of glaciers in Switzerland, he recognises the form and condition of a moraine." (Buckland, 1841 A: 332-3).

Although the location appears to be imprecise, this description matches exactly the massive gravelly ridge that appears to be a terminal moraine that completely closes Glen Glass, north-east of the main Ben Wyvis summit, and clearly visible for a considerable distance from the road up the glen. This runs at right angles to the valley side from NH 556688 to approx. 558681, although the River Glass and Allt nan Caorach streams now cut through it. The highest point stands more than 60 m. almost vertically above the main river on the down-valley side at Cadha Dubh, 558682. Natural sections showing coarse mixed gravels with finer laminated sands above can be seen adjacent to the road at 554687 and 555688. Downstream of the main rampart the northern end appears to merge into a high lateral terrace, approx. 40 m. above the river, along which the road runs for approx. 1 km. below the main terminal moraine, and from which there are excellent views of the main feature, eg from NH 566677.

LOTHIAN REGION, CITY OF EDINBURGH DISTRICT

62. Edinburgh: Arthur's Seat

> "In October 1840, Mr McLaren found a surface on a portion of rock near the south-west base of Arthur's Seat." (Buckland, 1841 A: 336).

There is extensive evidence of rounding and plucking on the lower outcrops of Arthur's Seat above the Holyrood Park road around NT 275726.

63. Edinburgh: Bangholm Bower

> "... and in 1840, in a railway section at Bangholm Bower, one mile north-east of Edinburgh, he found in stratified till and sand many striated and fluted boulders." (Buckland, 1841 A: 336).

The cutting is still identifiable on the main east coast Edinburgh to London railway line at NT 290743, but is completely grassed over. (I am much indebted to Graeme Cruickshank, Local History Officer, Edinburgh City Museums, for his historical research for me on this locality.)

64. Edinburgh: Blackford Hill

> "Some of these effects may be imagined to have been produced by stones projecting from the sides or bottom of floating masses of ice; but it is impossible, Dr Buckland observes, to account by such agency for the polish and striae on rocks at Blackford Hill, two miles south of Edinburgh, pointed out to him by Lord Greenock in 1834. On the south face of this hill, at the base of a nearly vertical cliff of trap, is a natural vault, partly filled with gravel and sand, cemented by a recent infiltration of

carbonate of lime. The sides and roof of the vault are highly polished, and covered with striae, irregularly arranged with respect to the whole surface, but in parallel groups over limited extents. These striae, Dr Buckland says, cannot be referred to the action of pebbles moved by water; 1st, because fragments of stone set in motion by a fluid cannot produce such continuous parallel lines; and 2ndly, because if they could produce them, the lines would be parallel to the direction of the current: it is impossible, he adds, to refer them to the effects of stones fixed in floating ice, as no such masses could have come in contact with the roof of a low vault. On the contrary, it is easy, he says, to explain the phaenomena of the polish by the long-continued action of fragments of ice forced into the cave laterally from the bottom of a glacier descending the valley, on the margin of which the vault is placed; and the irregular grouping of the parallel striae to the unequal motion of different fragments of ice, charged with particles of stone firmly fixed in them, like the teeth of a file. The cave is not three hundred feet above the level of the sea, and the proving of glacial action at this point justifies, the author states, the belief that glaciers may also at that period have covered Calton Hill and the Castle Hills of Edinburgh and Stirling." (Buckland, 1841 A: 336-7).

"That is the work of ice." (Agassiz, 27 October 1840, quoted by Maclaren, 1841).

"AGASSIZ ROCK
IN 1840
LOUIS AGASSIZ SWISS GEOLOGIST
STATED THAT THIS ROCK WAS
POLISHED AND GROOVED BY
ICE DURING THE GREAT ICE AGE"
(Bronze plaque fixed to rock)

"Of these ice-worn surfaces in the central area perhaps the most interesting is that on the southern declivity of Blackford Hill, which has become one of the classic spots connected with the early history of Glacial Geology in Scotland. In 1840 it was shown by Charles Maclaren to Agassiz, who at once recognised in the moulded and grooved surface the work of land ice. Here the cliff of andesite has been under cut and has been worn into a cave which is grooved and striated like the overhanging cliff. The converging striae at the western entrance of the cave and the diverging markings at the exit plainly show that the ice must have behaved like a plastic substance under enormous pressure due to the thickness of the mer de glace." (Peach et al., 1910: 327).

The summit of Blackford Hill is at NT 255706, and the form of the hill, while not a clear crag-and-tail, strongly suggests a west to east ice movement, with a steep west to west-north-west face.

Agassiz's Rock with Buckland's cave, in which the glacial striations covered by a thin calcite deposit can still be clearly seen, is on the south side of the Blackford Hill parkland area, south-east of the summit, at NT 259703. The face is approx. 5 m. high, with heavy glacial polishing, and three deep striations approx. 60-80 cm. apart running up the face about 3 m. below the memorial plaque. Further striations can be seen underneath the overhang.

The locality can be reached on foot from the summit or from the Royal Observatory nearby, or by a track that leaves the A701 road in an easterly direction from a five-way junction at NT 271702 (Libberton Dams), alongside the Braid Burn.

65. Edinburgh: Calton Hill

> "The grooves and scratches described by Sir James Hall on the Costorphine hills near Edinburgh, and on the surface of Calton Hill, Prof. Agassiz is of opinion cannot be explained by the action of water; but they resemble, he says, the effects produced by the under-surface of modern glaciers ..." (Buckland, 1841 A: 336).
>
> "Dr Buckland has in his possession lithographs copied from drawings made by Mr James Hall, of distinct west and east furrows which extend over a portion of the north side of the summit of Calton Hill, ..." (Buckland, 1841 A: 336).
>
> Agassiz was "... much gratified by the display which he considered as very characteristic of the former existence of glaciers there." (Robert Jameson's diary, 27 October 1840, quoted by Davies, 1970: 282).
>
> "The most remarkable of these polishings that I have seen in Scotland are ... and those of the neighbourhood of Edinburgh, where the late Sir James Hall was the first to observe them." (Agassiz, 1842: 225).

Calton Hill is second only to the Castle Rock in terms of its prominence in the centre of Edinburgh approx. 300 m. north-east of Waverley Station at the end of Princes Street, and has on it various monuments (including that to John Playfair) and the old Observatory.

The summit area around NT 263743 still has the weathered surface of the Carboniferous volcanics exposed in places, but none of the glacial striations figured by Sir James Hall in about 1824 appear to be visible at the present time. However, a little way below the summit, beneath the Playfair Monument and the Observatory, a small rounded, polished and striated outcrop can be seen at 263742. From this same point there is also an excellent view of the crag-and-tail of the Castle Rock and the Royal Mile, 1 km. to the south-west.

66. <u>Edinburgh: Castle Rock</u>

> "In his recent examination, in company with Mr McLaren, of the Castle Rock at Edinburgh, Dr Buckland found further proofs of the correctness of the glacial theory, by discovering at points where he anticipated they would occur, namely, on the north-west angle of the rock, distinct striae upon a vertical polished surface; and at its base a nearly horizontal portion of rock, covered with deep striae; also on the south-west angle obscure traces of striae and polished surfaces." (Buckland, 1841 A: 336).

Castle Rock is a well-known crag-and-tail feature facing west from the vertical crag above the Princes Street Gardens (NT 249736), with the tail stretching almost 2 km. eastwards to Holyrood (269739) down the line of the Royal Mile. Clear glacial polishing and deep striations can be seen on the face of Castle Rock at 252736, near St Margaret's Well just south of the railway line, and on the north-west face at 249736, glacially rounded outcrops are seen at the base of the cliff with plucked overhanging rocks above.

67. Edinburgh: Corstophine Hills

> "Dr Buckland saw similar dressings [ie striations] in 1824 in a sandstone quarry near the house of Lord Jeffrey, two miles west of Edinburgh;" (Buckland, 1841 A: 336).

> "In the lowland districts he notices [sic] also the occurrence of rounded, polished and striated surfaces upon the tops of the basaltic rocks of ... the Corstophin hills [sic], and other hard trap rocks near Edinburgh, ..." (Buckland, 1841 B: 511).

Francis Jeffrey (1773-1850), writer, critic and lawyer, and Editor of the Edinburgh Review, became Lord Jeffrey on his appointment as a Judge of the Court of Sessions in 1834. In 1815 he took Craigcrook Castle on the eastern slopes of Corstophine Hill (NT 210744) and after restoring it used it as his summer residence for the rest of his life. (Dictionary of National Biography). In October 1824, Buckland and Lyell dined at Craigcrook during their geological tour of Scotland, and Lyell mentioned the event in a letter to his mother, dated 18 October 1824 (Wilson, 1972: 131).

The Corstophine Hills run approx. north-south and are produced by intrusive sills and sandstones within the Lower Oil Shale Group of the Calciferous Sandstone Series. At their northern limit they are crossed by the A90 road from Edinburgh to Queensferry, at NT 201751, and the southern face is now the Edinburgh Zoo. No striated surfaces of sandstone have been found, but good westward-facing striations can be seen on the volcanics, eg around 206742 and 207738.

68. Craigleith

> "Dr Buckland has in his possession lithographs copied from drawings made by Mr James Hall, of distinct west and east furrows which extend over a portion of the north side of the summit of Calton Hill, and on the surface of the carboniferous sandstone at Craig Leith [sic] Quarry." (Buckland, 1841 A: 336).

This locality appears to have been lost by 1840, in that Buckland does not seem to have found evidence of striations there himself. The quarry itself has long since been filled, and the exact locality has not been traced. The most likely site is beside the abandoned railway just north of the A9 (Queensferry/Forth Bridge) road around NT 226745 in the present district of Craigleith.

LOTHIAN REGION, EAST LOTHIAN DISTRICT

69. Dunbar area

> "... and for three miles to the south-east of Dunbar extends a series of terraces or modified lateral moraines." (Buckland, 1841 A: 345).

In Dunbar itself the south-east part of the built-up area is on an area of large gravelly mounds, eg on the cliff top just by the town centre at NT 685785, and indeed the old town centre itself is probably on a similar feature at 670787.

The old Great North Road (A1) from Edinburgh to Newcastle runs over similar large mounds and ridges and passed similar areas filling the ground between the road and the cliff top all the way to Cockburnspath and then beyond (see under Borders Region for details of the localities beyond the Lothian Region border at the Dunglass Burn, NT 772722). Along the East Lothian section of the route, particularly good examples can be seen at East Barns (716764), Thorntonloch (751742) and at 756745 near Bilsdean, where both the road and the railway cross at right angles a large ridge almost 1 km. long running from 752729 to the cliff top at 757736.

70. East Linton

> "Four miles west of Dunbar another long and lofty ridge of gravel stretches along the right bank of the river [North Tyne];" (Buckland, 1841 A: 345).

There can be little doubt that this description refers to the prominent esker-like ridge of gravel up to 6-8 m. high near Knowes to the north of the A1 road running from NT 609780 to 612779, with further moundy gravels continuing to beyond Kirklandhill at about 621781. There is a good view of these from the A1 at 608774.

71. Haddington

> "A large portion of the low lands between Edinburgh and Haddington is composed of till or unstratified glacier-mud containing pebbles. In the valley of the North Tyne, about one mile east of Haddington, is a longitudinal moraine mid-way between, and parallel to, the river and the high road;" (Buckland, 1841 A: 345).

From Musselburgh (NT 341736) all the way to Haddington (511739), and beyond there is a thick covering of heavy, dark red or brown, stony till, with occasional gravel particles. There are few exposures, but the general character of the area can be seen when crossing from west to east (or vice-versa) by the Great North Road (A1), which was clearly the route used by Buckland, judging by the choice of examples, in this area, all of which follow the main road.

The "longitudinal moraine" between the road and the R. North Tyne appears to be either an esker or a kame terrace remnant, approx. 4-5 m. high and perhaps 20-30 m. across originally, although it is now heavily ploughed and degraded. It runs from approx. NT 525746 to 556755, a distance of 3 km. The ploughed surface suggests that at least in part the ridge is composed of (or covered with) a reddish stony till, but no sections appear to be available at present. There is a good general view looking southwards from the A1 at 548754.

STRATHCLYDE REGION, ARGYLL AND BUTE DISTRICT

72. Bonawe

> "The phaenomena in Scotland, wherein M. Agassiz and Dr Buckland recognized the evidences of glacial action, consist in the union of rounded, polished, striated and furrowed surfaces with morains and transported blocks, analogous to the similarly associated phaenomena upon the Jura and in the Alps. They are described in the six following localities. 1st, the morains on the summit level of the road between Inverary and Loch Awe: 2ndly, the rounded, polished and striated surfaces of granite near the water's edge at the ferry of Bunawe [sic] ..." (Buckland, 1841 B: 511).

> "The granitic and porphyritic rocks of many valleys in Scotland exhibit polishings equally brilliant with those at present observed on the slaty serpentines of the flanks of the glaciers of Monte Rosa. The most remarkable of these polishings that I have seen in Scotland are those ... of Bunaw [sic] Ferry ..." (Agassiz, 1842: 225).

The old ferry crossing of Loch Etive was from Taynuit pier (NN 010326)to Eilean Duirinnis (010330) near the Bonawe granite quarries. It is almost certain that Agassiz and Buckland would have used this ferry travelling northwards towards Fort William, and would have seen the very clear glacial rounding and polishing, with down-valley striations, close to the northern landing of the ferry, eg around 009331 and 010332.

73. Glen Aray, including Inveraray

> "... longitudinal moraines ... near Inverary [sic]," (Agassiz, 1841 A: 330).

> "I have already said that the mounds of blocks, and the polished rocks, are every where found to be intimately connected

> together; but I do not mean to say that polished rocks are not met with where there are no mounds, and that mounds are not met with where there are no polished rocks; for it may happen that the rocks on which the ancient glaciers moved were, in certain localities, very little calculated to retain the polish, and that they may have lost their original lustre, while the moraines composed of rocks of the elevated portions of the valleys still exist on their flanks. It is thus that we see very beautiful examples of mounds and ancient moraines in Glenary [sic], above Inverary Castle, although there are no polished rocks in the immediate vicinity;" (Agassiz, 1842: 226).

Inveraray Castle lies on a large moraine complex with many Grampian erratics, running from approx. NN 094087 to 101097.

The A819 road northwards from Inveraray runs continuously over spectacular kames, kame terraces and hummocky moraine up to the summit of Glen Aray at NN 094183.

74. Loch Awe

> "... the distribution of blocks and gravel, as well as the polished and striated surfaces in situ ... diverge from the central chains of the country, following the course of the valleys. Thus in the valleys of ... Loch Awe from north-west to south-east ..." (Agassiz, 1841 B: 328).

> "Thus in the neighbourhood of glaciers are found those rounded bosses which Saussure distinguishes by the name of "roches moutonées" ... also in Scotland on the banks of Loch Awe ..." (Agassiz, 1841 B: 331).

Water level changes and road diversions because of the hydro-electric scheme appear to have masked much of the evidence seen by Agassiz, but there are many very large erratics, eg on the south side of the A819 road at NN 133270, just inside the entrance to a forestry plantation, and there are extensive scatters of erratics on the valley side around 123259, and some large kames with erratics below the same road around 116244.

On the sides of the Loch, evidence of glacial erosion includes probable roches moutonées at 083222 (Eilean an t-Sagairt) and 008169, striations on lochside outcrops above the B840 road at 009178, rounding, grooving and striation along the side of the loch at NM 997153 and 994146.

However, the most spectacular evidence of down-valley glacial erosion is the scouring across the hills on the north side of the Loch, between Kilchrenan (NN 036229) and the Pass of Brander (047287). An area of over 40 sq. km. rising to summits of about 270 m. has been deeply scoured, leaving many dozens of clear roches moutonées, eg on the hill above the Kilchrenan village at 042229, and all around Loch Tromlee (052260).

75. Loch Etive

> "... the distribution of blocks and gravel, as well as the polished and striated surfaces of rocks in situ ... diverge from the central chains of the country, following the course of the valleys. Thus in the valleys of ... Loch Etine [sic] ... from east to west;" (Agassiz, 1841 B: 328).

> "On the other hand, we frequently see beautifully polished rocks without moraines; and this is especially the case with the very abrupt walls of narrow valleys, where the blocks have fallen down at the period of the retreat of the ice, and have reached the bottom of the valleys without resting on their flanks. In such instances, instead of presenting the form of moraines, the blocks are scattered irregularly over the surface. We have an example of this on the northern walls of Loch Etive." (Agassiz, 1842: 226).

There are abundant rounded erratics of the various granites in particular, always down-stream of their outcrops. On the south side of the Loch are very extensive surface scatters of rounded erratics of all sizes, for example around Taynuilt (NN 004312). These include the well-known "Rob Roy's Putting Stone" - a huge block of Ben Cruachan granite, amongst a scatter of erratics just north of the main A85 road at NN 013331, approx. 2 km. east of Taynuilt, and the even larger erratic of Glen Etive granite on the shore of Airds Bay north-west of the village at NN 001319 (identifications by Kynaston and Hill, 1908: 164). On the north shore of the loch are extensive scatters of erratics also indicating an east-west ice movement, for example between the B845 and the loch-side near Inverestagen at NM 987351.

Clear striations on rounded and grooved outcrops can be seen at many places on both sides of the Loch, right down to the sea: for example on the foreshore both west (NM 905341) and east (913344) of the Falls of Connel, at the threshold of Loch Etive.

(See also Bonawe (no. 72) - striations etc, and Muckairn (no. 78) - moraine complex, for other Loch Etive localities).

76. Loch Fyne

> "... the distribution of blocks and gravel, as well as the polished and striated surfaces of rocks *in situ* ... diverge from the central chains of the country, following the course of the valleys. Thus in the valleys of ... Loch Fine [sic] ... from north-west to south-east ..." (Agassiz, 1841 B: 328).

A fine, large, striated and grooved roche moutonée forms Dundarave Point (NN 143096), and from this point there is also a good view of the large moraine at the lower end of Glen Kinglas around Ard Kinglas (NN 175102).

(See also Glen Aray, including Inveraray (no. 73) and Strachur (no. 79) for other Loch Fyne localities.)

77. Loch Long

> "... the distribution of blocks and gravel, as well as the polished and striated surfaces of rocks in situ ... diverge from the central chains of the country, following the course of the valleys. Thus in the valleys of ... Loch Long, they range from north to south;" (Agassiz, 1841 B: 328).

The former lochside evidence on the accessible south-east side of the Loch (in the Dumbarton District) is apparently totally lost because of the widening of the A814 road. However, from the east side, clear signs of characteristic glacial scouring and rounding are visible on the (inaccessible) north-east side of the Loch. For example, the glaciated outcrops at NS 244972 can be observed from the A814 at 251972, and another good example at 255996 can be observed from the upper hairpin bend at 257998 on the minor road from Craggan through Glen Douglas to Loch Lomond. (The 1" Geological Survey map (Scotland: Sheet 38) records north-south striations at both of the above locations).

78. Muckairn Castle

> "... longitudinal moraines ... disposed in ridges with a double talus, one flank of which is presented to the glacier, and the other to the side of the valley ... at Muc Airn [sic]" (Agassiz, 1841 B: 330).

This large morainic complex is now heavily forested and difficult to see and interpret in detail, but appears to occupy a substantial area along the south bank around Muckairn Castle from at least NM 976333 to 996328, and could well prove to be even more extensive in detailed mapping. The general hummocky form of the feature can be seen from the main A85 road along the southern side of Loch Etive, but the general form of the moraine is now best seen across the Loch from the north bank, eg near Ardchattan Priory (NM 975347) and Kennacraig (NM 999344).

79. Strachur

> "... longitudinal moraines ... on the flanks of all glaciers ... likewise ... at Strankaer [sic]". (Agassiz, 1841 B: 330).

The spelling in the published text, from the secretary's dictation notes rather than an original manuscript for publication, is rather odd, but Strachur, on the south side of Loch Fyne opposite Inveraray matches Agassiz's note. The village of Strachur is on a very large moraine complex about 1 km. long, blocking the side valley from NN 085011 to 095019.

STRATHCLYDE REGION, CITY OF GLASGOW DISTRICT

80. Glasgow

> "[I] had scarcely arrived in Glasgow, when I found remote traces of the action of glaciers," (Agassiz, quoted by Charles Maclaren, 1840).

> "It is not to be understood that there are no large angular blocks in England and in Scotland; but there is this distinction to be made, that these blocks are generally not far distant from their natural position in situ, or that they are in small number compared with those which have evidently been acted on by a prolonged mechanical operation. But this is not all; far from being found lying at the surface of the ground, the large blocks are for the most part heaped up in a confused manner along with the smaller ones of all degrees of size, from the dimension of the smallest pebbles to the colossal volume of the largest erratic blocks, in a deposit of clay unequally distributed over all the low portions of the country. This deposit of clay, which is of very unequal thickness, and exhibits no trace of stratification, is what is termed till in Scotland. There is no locality in which I have been able to study the till more completely than at Glasgow, where the numerous works carried on in 1840 for the embellishment of the town had exposed it at many points; but everywhere it presents the same characters; the rounded, polished, and scratched blocks of very various dimensions, are every where indiscriminately mixed together in a marly or clayey paste. It is evident that it was with this mass, and in this mass, that the rounded and polished blocks have been transported during the whole journey which they have performed together, while the angular blocks have certainly not been rubbed in this manner. Mr T Edington has, to the advantage of geologists, brought together,

> in his park at Glasgow, a magnificent collection of these polished and scratched blocks from the neighbourhood of the town." (Agassiz, 1842: 228).

It is decidedly odd that not a single reference to Glasgow appears in either of the November-December 1840 communications to the Geological Society of Agassiz (1841 B) or Buckland (1841 A). Agassiz clearly recognised the glacial origin of the Glasgow till immediately on his arrival at the British Association meeting on or before 21 September 1840 (Davies, 1968), and must have discussed this evidence with Buckland (who had arrived eager to tell Agassiz about his Crichope Linn observations, and to finalise details of their planned joint expedition to the Highlands to see the many features that Buckland now suspected were of glacial origin). Davies (1968) identified the area of the "numerous works" of 1840 as in the area then known as Bell's Park, the area immediately to the west of the St Mungo's Cathedral and the Royal Infirmary (NS 601656). The area is today bounded to the east by Castle Street in front of the Infirmary, to the south by Cathedral Street, to the west by Buchanan Street, and to the north by the M8 motorway - an area about 1 km. x ½ km. in extent. Much of the area was re-developed for a second time in the late 1970s to create the St Mungo Avenue development (597658), and the Cathedral Street part of the former Bell's Park was partly re-developed for extensions to the Strathclyde University campus. A thick, dark, stony till was, for example, exposed briefly in 1981 in the foundations for a Strathclyde University building just south of Cathedral Street, on the corner of Montrose Street and Rotten Row (596655).

In fact, apart from the crag-and-tail on which is the Necropolis (605655), most of the City area has an extensive and thick till covering, that has been ice-moulded to form a very extensive drumlin field, with a pronounced east-west trend, and frequently underlain by megadrumlins often more than 1 km. long (Rose and Letzer, 1977). West and north of the City the till can be seen in natural sections (eg where the Endrick Water cuts through the Loch Lomond Readvance moraine and the Clyde Beds near Gartness (NS 498864), where it is a stiff reddish-brown stony clay , but within the City the till is nowadays only seen in temporary exposures.

STRATHCLYDE REGION, DUMBARTON DISTRICT

81. Loch Lomond

> "... the distribution of blocks and gravel, as well as the polished and striated surfaces of rocks in situ ... diverge from the central chains of the country, following the course of the valleys. Thus in the valleys of Loch Lomond ... they range from north to south;" (Agassiz, 1841 B: 328).

Although modern road improvements and widening have greatly modified the lochside features, many areas of smoothed and striated rocks can still be examined along the main A82 road on the west side of Loch Lomond. For example, by Rubha Mor at NN 36001, there is polishing and grooving of the foreshore and the rounded outcrops on the promontory, and nearby there are clear north-south striations on the rounded rock outcrops immediately above the A82 road at NN 345000 and 345001. Continuing northwards, there is also clear smoothing, grooving and striation of the foreshore on both sides of Rubha Dubh at NN 335015 and at Stuc an-t-Robiart (336013). The promontory just north of Inveruglas at NN 323098 is also rounded, grooved and striated and has a public picnic area and viewpoint on it. From this there is a clear view of the very prominent roche moutonée of Inveruglas Castle Isle (NN 323095). Further north still, the headland of Rudha Ben (NN 330130) is another grooved and striated roche moutonée.

TAYSIDE REGION, ANGUS DISTRICT

82. Cortachy

"Moraines in Forfarshire. - The cones and ridges of gravel at Cortachy ... and at the confluence of the Carity valley with that of the Proson, are considered by Dr Buckland to have been produced by glaciers, and modified in part subsequently by water. The polish and striae on a porphyritic rock near the summit of the hill, on the left side of the main valley, and immediately above the moraines, he is of opinion must also be assigned to glacier action." (Buckland, 1841 A: 333).

"At Cortachíe [sic], about four miles below the barrier of Glenairn, the South Esk enters the country of old red sandstone, and a mile and a half lower it is joined by the Proson, and a mile yet lower by the Carity. In the district in which these streams unite there is a considerable thickness of unstratified matter full of Grampian boulders, and covered for the greater part with stratified gravel and sand. In some cases the latter exhibit the diagonal laminae common in subaqueous formations; and in others the strata are so contorted, that a perpendicular shaft might intersect the same beds three times. In the latter instances the surface of the subjacent red boulder clay has not partaken of the movement by which the stratified deposit was contorted; and in consequence Mr Lyell ascribed the effect, when he first beheld it in 1839, to the lateral pressure of large masses of drifted ice repeatedly stranding upon a shoal of soft materials. In the middle of the tract between the South Esk and the Proson is a dry valley, and to the south of this valley, near the Proson, an excavation was made ten years ago, which exposed extremely contorted beds overtopped by others perfectly horizontal, having been formed by tranquil deposition after the disturbance of strata previously deposited. The phaenomena exhibited by the till in this district, Mr Lyell conceives, might be well accounted for by supposing the union of three or four large glaciers; but he considers it difficult to explain the accumulation of the overlying stratified materials, the top of which must be 600 feet above the level of the sea, and facing the Strath." (Lyell, 1841: 34D - 1).

From the driveway to Cortachy Castle (NO 394597) south-eastwards to the confluence of the R. South Esk and the Prosen Water

(408584), an area of almost 1 sq. km. is covered with thick outwash sands and gravels, with many mounds and other irregularities. The area is best viewed from the B955 Kirnemuir to Glen Clova road at 401581 (just above Prosen Bridge). An isolated kame approx. 100 m. long by 30 m. across and 8-10 m. high can be examined in detail nearby at 386605, in the junction between the Glen Clova and Glen Prosen roads by the Post Office in Dykehead. This has a section in the west side showing a core of gravel and boulders (many with heavy striations), with some sandier bands, the whole feature being covered by a thin brown till.

(See also Pearsie, no. 92).

83. Edzell

> "... also the blocks, large pebbles, and small gravel spread over the first level portions of the valley of the North Esk, after emerging from the Sub-Grampians, to be the residue of moraines, re-arranged by water." (Buckland, 1841 A: 333).

Above Edzell there is a substantial morainic ridge, approx. 20 m. high, almost blocking the valley below Auchmull, and running from NO 580741 to 585745, with large kamiform mounds continuing down the North Esk valley to approx. NO 592726.

This outwash etc complex straddles the boundary between the Grampian and Tayside Regions, which runs down the middle of the R. North Esk in this area (see also Fettercairn, Grampian Region, Kincardine and Deeside District, no. 52).

84. Forfar

> "The glacier theory, the author states, appears to offer a happy solution of the problem of the marl-loch gravels, the longitudinal banks being regarded as lateral and medial moraines, and the transverse ridges as terminal. The chief objections are the stratification of the upper part of the banks, and the necessity of assuming a glacier thirty-four miles in length, with a fall of only 300 or 400 feet of country.
>
> It has always appeared to Mr Lyell and Mr Blackadder remarkable, that the marl-loch gravels at Forfar are nearly 100 feet above the tract of till which separates them from the valley of South Esk, in Strathmore. In the present configuration of the country, water could not deposit the Forfar gravels without extending to the South Esk, the detritus of which is distinct, and separated by a low district of till without gravel. The only explanations of these phaenomena Mr Lyell considers to be either that the till is the moraine of a glacier, or that there has been a local change of relative levels of lands, by which the gravel of Forfar was uplifted, or the till to the northward depressed." (Lyell, 1841: 343).

Lyell's first major geological study had been on the Holocene freshwater shell-marks of the small lochs of the Forfar area, submitted to the Geological Society in 1824 but not published for a further 2 years (Lyell, 1826), so his re-attribution of the hollows containing these lochs to a glacial origin was particularly significant.

The "perched" water level of these lochs occupying hollows in the till and gravel mounds can be seen in many places. At the Loch of Forfar itself (NO 445505), the surrounding mounds can be seen on both the south side (around Orchardbank, 440501) and downstream, between Nether Drumley (421501) and Lochmill (428497).

East of Forfar, the A932 road passes a succession of large kettles, some still containing lochs, as at Loch Fithie (490513), Rescobie Loch (515517) and Balgavies Loch (534509).

85. Glenarn

> "The great transverse barrier at Glenairn [sic], where the valley of the South Esk contracts from a mile to half a mile in breadth, and is flanked by steep mountains, Mr Lyell formerly regarded as very difficult of explanation. Seen from below, this barrier resembles an artificial dam 200 feet high, with numerous hillocks on its summit. On the eastern side it appears to have been denuded to the extent of about 300 yards by the Esk. Its breadth from north to south is about half a mile. The lower part, 30 feet in depth, laid open in the river cliff, consists of impervious, unstratified mud, full of boulders; but the total vertical thickness of this deposit is stated to be from 50 to 80 feet; and the upper part of the barrier is composed of from 50 to 100 feet of very fine stratified materials. It is not possible, Mr Lyell observes, to account for the accumulation of this barrier by the agency of water, particularly as no tributary joins the Esk at this point; but if the barrier be supposed to be the large terminal moraine of a receding glacier, then its form and position, he says, are easily to be understood. M. Agassiz, in his work on glaciers, shows, that when these masses of ice enter a narrow defile from a broader valley, the lateral moraines are forced towards the centre, and the mass of transported matter is spread more uniformly over the whole. Such a terminal moraine left by a receding glacier in a defile, Mr Lyell states, would dam back the waters of the glacier, and produce a lake; and the phaenomena presented by the barrier of Glenairn, and the plain which extends in its rear, are fully explicable on the assumption of their having been produced by a glacier. The stratification of the upper portion of the barrier is also shown to be partly in accordance with the effects produced by the formation of ponds of water on the surface of moraines; but Mr Lyell states, that the accumulation of so great a capping of stratified materials is still the most obscure character of the deposits under consideration." (Lyell, 1841: 340).

This massive retreat stage (or perhaps Loch Lomond Readvance stage) terminal moraine has blocked Glen Clova completely, although the R. South Esk now cuts through the main rampart at NO 378643.

The downstream face can be seen from the B955 road to Glen Clova from the entrance to Crossbog Farm (381625) northwards, and although the southern face of the moraine is now afforested, the form can be seen clearly - running from approx. 376643 on the west side of the valley to approx. 379644 above the river gorge.

There is little to add to Lyell's clear and detailed field description. Above the 60 m. high crest of the moraine, the road runs northwards over characteristic dead ice hummocky moraine as far as the river bridge at 373653, with many kettle holes - mostly now just boggy hollows, but with a very good example about 80 m. diameter still holding water just by the side of the road at 370653.

Above the river bridge are three large lake flats, stretching northwards towards Rottal (370697), the largest around Braeminzion (365669), indicating a prolonged moraine-dammed lake phase before the river finally cut back to the valley floor through the Glenarm moraine.

86. Glen Clova

> "The terraces or lateral mounds very generally increase in width and depth as they descend from the higher to the lower glens, attaining in the latter sometimes a thickness of 100 feet, and occasionally so great a breadth as to leave only sufficient room for the river to pass. The inferior part is always unstratified, consisting of mud and sand, in which large angular and rounded fragments of rocks are imbedded. These boulders are more and more rounded as their distance increases from the hills whence they could have been detached; but they are more frequently flat-sided than pebbles which have been rounded by water; and they become more diversified in character by the junction of every tributary glen. In the upper part the mounds often consist of 40 to 80 feet of the same materials as the lower, but regularly stratified. Mr Lyell then proceeds to illustrate his subject by describing in detail the phaenomena presented by the valley of the South Esk and those of its tributaries.
>
> The South Esk springs from a shallow lake nearly 3000 feet above the level of the sea, and twenty miles from Strathmore. For six miles the river flows through a district composed partly of gneiss, traversed by veins of granite or eurite, and partly of granite. The fragments derived from this high region may be traced downwards continuously for twelve miles to Cortachie; and as a proof that the detritus forming the lateral mounds has followed the same downward course, Mr Lyell states that it preserves throughout, as well in the main as in the

> lateral glens, an uniformly grey colour; while the detritus of the lower zone of mica-slate is invariably tinged red, this colour being also imparted to the debris of the still lower portions of the glens, notwithstanding the intermixture of pale brown materials obtained from the clay-slate of that district. Another proof of the detritus not having been drifted upwards, is the absence in the higher portions of the glens of the blocks of pure white quartz which abound in the region of mica-schist, and have been derived from the numerous veins and beds of quartz belonging to that formation. ... The phaenomena exhibited by the lateral mounds, Mr Lyell states, agree well with the hypothesis of their being the lateral moraines of glaciers; and he adds, that he had never been able to reconcile these phaenomena, particularly the want of stratification, with the theory of the accumulations of the detritus during submergence, and the removal by denudation of the central portions of a deposit which had by that means filled the glens. (Lyell, 1841: 339).

Glen Clova, with its north-westerly upper arm - Glen Doll, is an outstandingly clear example of a glaciated valley.

Four important localities were noticed individually by Lyell, and have therefore been dealt with separately, the corries of Loch Brandy (no. 89) and Loch Wharral (no. 90), the terminal moraine of Glenarm (no. 85), and the southern limit of the Glen around Cortachy (no. 82).

Other examples of glacial features seen ascending the valley from south to north include:

1. Large-scale kame terraces on the east side of the South Esk below Brocklas, around 380637, which divert the river at that point, viewpoint on the B9555 road near Middlehill Farm entrance, 377638.
2. The Glenarm moraine (see no. 85).
3. Large marginal kames at at Braeminzion (364667) and Tarabuckle (361675), and a large kame complex in the

centre of the former alluvial lake flat ½ km. north-east of Tarabuckle, centred around 363680.

4. Further large area of large-scale valley floor kames and hummocky moraine covering an area of approx. 2 sq. km. from east of The Drums (359691) and west of Rottal (370697) to the south, to Newbigging (344714) and Wheen (361710) in the north (see also Loch Wharral, no. 90).
5. On the south-west side of the river, from Newbigging (344714) to the river crossing south-west of Clova village (325727) the road runs continuously over longitudinal ridges of gravel and till, probably kame terrace remnants, with some isolated conical hummocks around Caddam (330724).
6. On the north-east side of the river the road from Wheen (361710) runs over smaller marginal hummocky kames through to Clova village (317731), with a number of kettles (eg just north of the road at 335726).
7. Above Clova (317731), the single-track road (on the north-eastern side of the river) runs continuously over large kames and kame terraces all the way to the car park at the Glendoll picnic area (284761). However, the south-west side of the valley is deeply scoured and is bare apart from scree accumulations and a small area of kames below the small (apparently un-named) quarry around 293745.

87. Kinnordy

"Lyell has adopted your theory in toto!!! On my showing him a beautiful cluster of moraines within two miles of his father's

> house, he instantly accepted it, as solving a host of difficulties that have all his life embarrassed him. And not these only, but similar moraines and detritus of moraines that cover half of the adjoining counties are explicable on your theory, and he has consented to my proposal that he should immediately lay them all down on a map of the county and describe them in a paper to be read the day after yours at the Geological Society." (Buckland to Agassiz, 15 October 1840, quoted in E.C. Agassiz, 1885: 309-10).

It is decidedly odd that Kinnordy as such does not appear as a locality in any of the Geological Society papers of November-December 1840: perhaps this was a "tactical" decision (see main text and Boylan, 1981: 7-8). Kinnordy Loch (NO 360543) was discussed at length in Lyell's paper on the shell-marl lochs of Forfarshire (Lyell, 1826) and there is no doubt that the glacial origin of this must have been recognised by Lyell and Buckland.

The natural direction of drainage to the south-west of the Loch is completely blocked by a succession of till ridges up to 40 m. high around 343537 and 352528, forcing the Loch to drain eastwards through the town of Kirriemuir (although there is now a small artificial channel partly draining the Loch south-westwards from 358539), from which point on the B951 road there is a good view of both the Loch, and the till basin in which it lies.

Kinnordy House, the Lyells' family home, stands on a ridge of till at 368553. Immediately to the north, the minor road to Prosen crosses till mounds between East Inch (370557) and Mearns (369566), and then an extensive field of sandy kames covering large areas of the northern flank of the hill on either side of the road, down to the Carity Burn (363580), eg around Newmill Farm (368578).

(See also Pearsie, no. 92, and Cortachy, no. 82).

88. Kirriemuir

> "The till constitutes invariably the oldest part of the detritus. The boulders which it contains sometimes exceed three feet in diameter: on the north muir of Korriemuir [sic] is a block of trap-rocks, six feet by five feet, and near it is a mass of mica-schist, nine feet long by four feet wide and three high." (Lyell, 1841: 341).

Since 1840, the old "North Muir" has been partly enclosed and has the modern suburb of Northmuir built on it (NO 387554). One part survives at the golf course (388559), but the remainder is now arable land, in which there are many scatters of smaller erratics, but few large blocks survive.

The large "Standing Stone" recorded as an antiquity by the Ordnance Survey at 384563, is of mica-schist and bears clear signs of the drilling of holes for explosives. There are many fragments of mica-schist scattered around and in the adjacent field wall, and although the stone is now barely half the size described by Lyell, this may well be the one described by him, but now much reduced by blasting.

There seems to be no sign of the large block of "trap", and this too may have been blown up to clear the fields or for use as building material. However, there is a large scatter of erratics, including many Grampian types, by the corner of the drive from the B955 road to Auchlishie Farm at 393568.

89. Loch Brandy

"The distribution of an enormous mass of boulders on the

> southern side of Loch Brandy, and clearly derived from the precipices which overhang the Loch on the three other sides, is advanced as another proof in favour of the glacial theory. It is impossible to conjecture, Mr Lyell says, how these blocks could have been transported half a mile over a deep lake; but let it be imagined that the Loch was once occupied by a glacier, and the difficulty is removed." (Lyell, 1841: 339-40).

Loch Brandy (NO 339755) lies in a spectacular "text-book" corrie at an altitude of about 650 m., on the north side of Glen Clova, and is approached by footpaths on either side of the corrie outfall from Clova village (317731).

There is a prominent corrie moraine rampart at 338750, with many large blocks, which continue down the hillside towards Clova.

90. Loch Wharral

> "Loch Whorral [sic] about a mile to the east of Loch Brandy, is also surrounded on its north, east and western sides by precipices of gneiss, and presents on its southern an immense accumulation of boulders with other detritus, strewed over with angular blocks of gneiss, in some instances twenty feet in diameter. This moraine is several hundred yards wide, and exceeds twenty feet in depth, terminating at the borders of the plain of Clova in a multitude of hillocks and ridges much resembling in shape some terminal moraines examined by Mr Lyell in Switzerland." (Lyell, 1841 A: 340).

Loch Wharral (NO 358744) lies in another classic corrie, approached by footpaths from Wheen (361710) or the side of Adielinn Plantation (354715).

There is a small rampart at 359740, but much morainic material, including large blocks and till all the way down to the valley floor below Wheen, where it forms the large mass of hummocky moraine between Wheen and Rottal, and reaching as far south as 367704.

91. Lunan Bay

> "One of the most remarkable peculiarities of the transported materials of Forfarshire and Perthshire is a continuous stream, from three to three and a half miles wide, of boulders and pebbles, traceable from near Dunkeld, by Coupar, to the south of Blairgowrie, then through the lowest part of Strathmore, and afterwards in a straight line through the lowest depression of the Sidlaw Hills from Forfar to Lunan Bay, a distance of thirty-four miles. ... Though the country occupied by these marl-loch lakes is not traversed longitudinally by any river, yet it is so low, that if the transported matter were removed, a very slight depression would cause the sea to flow from Lunan Bay by Forfar to Blairgowrie and Dunkeld." (Lyell, 1841: 342).

East of the Forfar lochs (q.v. no. 84), the Lunan Water follows the ancient valley over hummocky sand and gravel deposits, with kames and other mounds up to 12-15 m. high between Balgavies Loch (NO 53850) and Guthrie (567505). East of Guthrie, massive outwash terraces flank both sides of the valley all the way to Lunan Bay (690510). Near Friokheim (NO 595496), the B965 road towards Inverkeilor (666494), passes sand and gravel pits with faces up to 5 m. high at Kinnell (606501) near Boysack Mills (623496), and near The Grange (656494 and 662494) just west of Inverkeilor.

Although over the greater part of Lunan Bay itself the glacial deposits are buried under Postglacial alluvium and sand dunes, the outwash terraces can be traced on the north side of the village of Lunan, east of Braehead (NO 690527).

92. Pearsie

> "Moraines in Forfarshire. - The cones and ridges of gravel at Cortachy and Piersie [sic] near Kirriemuir, and at the confluence of the Carity valley with that of the Proson, are considered by Dr Buckland to have been produced by glaciers, and modified in part subsequently by water. The polish and striae on a porphyritic rock near the summit of the hill, on the left side of the main valley, and immediatealy above the moraines, he is

> of opinion must also be asigned to glacier action." (Buckland, 1841 A: 333).
>
> "In following out the narrow ridge which intervenes between the Proson and the Carity, during last October, in company with Dr Buckland, the latter drew the author's attention to a spot half a mile south-west of the House of Pearsie, where the surface of a porphyry rock was polished, furrowed, and scratched." (Lyell, 1841: 341).

About 50 m. south of Prosen Bridge on the B955 to Glen Clova (NO 396585), a minor road climbs westwards towards Pearsie onto the top of a remarkable terrace of coarse outwash gravels, cut into by the Prosen Water from the north and the Carity Burn from the south. The stream erosion has reduced the terrace to a ridge over 2½ km. long from approx. 368588 to 397582, which is only 15 m. across at the narrowest point above East Kinwhirrie Farm at 385586, where the ridge stands over 40 m. high above the adjacent river valleys. The material becomes finer towards the top, and there are small mounds of fine sand in places by the side of the road along the top of the ridge (eg at 379588, where there is a small roadside section).

Thick tills and gravels appear to cover all of the area around Pearsie (366595), including the point "half a mile south-west" (presumably somewhere around the crossroads at 360589) where the striated porphyry was recognised and pointed out by Buckland in October 1840. Despite extensive searching, no rock outcrop of any kind has been found in the area, let alone a striated one, and it therefore seems likely that "a ... rock" in the two accounts refers to a "polished, furrowed, and scratched" striated boulder, which are abundant in the local glacial deposits.

Buckland's "cones" are presumably the large kames in the Carity Burn valley around 364577 already mentioned under Kinnordy (no. 87, above).

93. Pitscandly Hill

> "The third district, or that of the Sidlaw Hills, claimed Mr Lyell's attention more particularly on account of the Grampian boulders with which it abounds. This range, whose greatest height is 1500 feet above the sea, is composed of anticlinal strata of grey sandstone, belonging to the old red sandstone, with associated trap. It is covered, as well as the whole of the country between Strathmore and the Tay, with the impervious till, containing Grampian boulders and fragments of the subjacent grey sandstone. The finest instances of erratics observed by Mr Lyell occur on Pitscanly [sic] Hill, 700 feet ... . About forty feet below the summit, on the southern side ... is a block of mica-slate thirteen feet long, seven broad, and seven in height above the ground. Four smaller and equally angular masses, from three to six feet in diameter, lie close to its north end, as if severed from it. One of the nearest points at which this gneiss occurs in situ, is the Craig of Balloch, fifteen miles distant, on the northern extremity of the Creigh Hill, and between these points intervenes the great valley of Strathmore and the hills of Finhaven." (Lyell, 1841: 344).

Pitscandly Hill lies 4 km. north-east of Forfar between the B9134 road to Brechin and the B9113 road to Montrose, with the summit at about 200 m. at NO 500533.

The huge block of mica-schist appears to have totally disappeared: certainly very extensive searching of the whole of the summit area on all sides failed to find it. Whether it has weathered away, or been broken up by passing geologists is a mystery.

There are, however, numerous smaller mica-schist erratics, especially approx. 100 m. south-east of the Rob's Reed Dun, around 491523, where there are also clear west-north-west to east-south-east striations on exposed surfaces of Old Red Sandstone. A wide range of other Grampian erratic types are also found across the summit of the hill, eg around 494528, and accompanied by east-north-east to west-south-west striations on a very fine-grained sandstone at 497529.

94. Ruthven

> "No great river follows this course, but it is marked everywhere by lakes or ponds, which afford shell-marl, swamps, and peat-mosses, commonly surrounded by ridges of detritus from fifty to seventy feet high, consisting in the lower part of till and boulders, and in the upper of stratified gravel, sand, loam and clay, in some instances curved or contorted. The form of the included spaces is sometimes oval, sometimes quadrangular. The finest examples are in the lower tract, which has the Dean for its southern boundary, and the road from the bridge of Ruthven to the south of the grounds of Lindertis for its northern. The Grampian boulders are throughout the same; but there are associated with them masses of actinolite schist, which Mr Blackadder has ascertained could be derived only from the valley of the Tay. The fragments of secondary rocks belong to the formations of the districts in which they occur." (Lyell, 1841: 342)

Eastwards from Bridge of Ruthven (NO 290489) the area of massive mounds of outwash gravels, up to 1 km. in extent and up to 20 m. high, covers an area of at least 12 sq. km. between the Dean Water and the A926 Blairgowrie to Kirriemuir road, from which there are good views looking southwards between Bridge of Ruthven and Craigton (329505) in particular. Various minor roads also cross the area. For example, the minor road from the A926 at 299492 southwards to Meigle passes one of the largest mounds at 300489, and smaller features by Ruthven House and Castle (303480). The minor road southwards from 314501 near Baitland runs through an area of eleven large mounds between 316496 and 328489, including exposures of fine laminated sands in a timber yard at 320494 and in a rabbit warren in the small wood at 323488. There are further small mounds west of Cookston around 332482, and Leys of Lindertis (338498).

The group of mounds around Westhill (311495) are being progressively worked for sand and gravel by the Westhill Sand Co Ltd (access from the A926 at 310500). The current quarry, at 315495, is being worked with a 15 m. high face, which shows 1-2 m. of coarse gravels overlying laminated sands with a few thin clay partings, the whole section being heavily faulted and sheered. There are many erratics, mainly of local Old Red Sandstone, but with some Highland material from the Grampians.

95. Turin Hill

> "The finest instances of erratics observed by Mr Lyell occur on Pitscanly [sic] Hill, 700 feet, and the adjacent hill of Turin, 800 feet above the level of the sea." (Lyell, 1841: 344).

The summit of Turin Hill (NO 515536) is approx 2 km. east of Pitscandly Hill (q.v. no. 93) on the same outcrop of Old Red Sandstone. The whole of the hill has a thick scattering of both local and Highland erratics across the unenclosed moorland areas, eg around the summit, and by the footpath from the B9134 at Whinnydrum (514549), around 512539.

TAYSIDE REGION, CITY OF DUNDEE DISTRICT

96. Dighty Water

> "Another line of stratified detritus ranges at a higher level from the Loch of Lundie, along the Dichty [sic] Water, to the sea at Moray [sic] Firth, a distance of thirteen miles; and it is stated that many others might be enumerated." (Lyell, 1841: 343).

Lundie Loch (NO 288372) is a large kettle still approx. half full of open water, with the remainder being a reclaimed bog, that is currently being afforested. On the east and north sides are very large mounds of reddish till, and large mounds of till or gravel to the east, around 295371, cut off the Loch from the head stream of the Dighty Water, the Dronley Burn, which emerges from a spring in the farmyard at Clushmill (300371), as well as from field drainage ditches from another small kettle loch at 300382 by Thriepley.

Following the Dronley Burn downstream, there are large lateral mounds of gravel plus solid bluffs of till downstream of the A927 (Alyth to Dundee) road bridge over the Burn ½ km. south of the village of North Dronley, around 338362.

Near Auchray (365354), the stream becomes the Dighty Water, and from this point there are large longitudinal mounds of gravel along the south side of the river to Kirkton (377354), where the village stands on gravel hummocks. About 1 km. to the east the glacial deposits are over 8 m. high on the south side of the river immediately below the farm at 386347, and can be viewed from the eastern entrance to the Strathmartine Hospital.

Continuing downstream, the river has been considerably modified as it flows through the built-up area of north Dundee, but lateral mounds parallel to the stream, and hummocky ground, can be seen in places, eg near Balmuir (400340) and at the Caird Park Golf Course around 405335, north of the A972 Dundee Ring Road.

The Dighty Water finally reaches the Firth of Tay at 485317 near Monifieth ("Moray Firth" being a printing mistake).

97. Sidlaw Hills

> "The third district, or that of the Sidlaw Hills, claimed Mr Lyell's attention more particularly on account of the Grampian boulders with which it abounds. This range, whose greatest height is 1500 feet above the sea, is composed of anticlinal strata of grey sandstone, belonging to the old red standstone, with associated trap. It is covered, as well as the whole of the country between Strathmore and the Tay, with the impervious till, containing Grampian boulders and fragments of the subjacent grey sandstone ... . Other Grampian boulders, from three to six feet in diameter, occur on the hills between Lumley Den and Lundie, at the height of 1000 feet; and Mr Blackadder has found fragments of mica-schist one foot in diameter on the summit of Craigowl, the highest point of the Sidlaw Hills, and exceeding 1500 feet above the level of the sea." (Lyell, 1841: 344).

There are extensive scatters of both local and Grampian erratics in most parts of the Sidlaws that have not been converted to arable land or improved pasture.

Lumley Den (NO 403416) is a well-known beauty spot on the main A928 road across the Sidlaws from Dundee to Glamis and Kirriemuir. In addition to many erratics in the stream bed, there are extensive scatters of erratics of many sizes on both sides of the pass. For example, just by the west side of the road at the end of the layby approx. 600 m. below the Lumley Den summit at 399418 is a large rounded boulder approx. 1 m. in diameter of a quartz biotite schist. (This locality is technically in the Angus District).

Most of the other hills have spreads of erratics, eg Craigowl (summit at 378399), around the Cairns on Balluderon Hill at

361394, around Long Loch 295390, and around Lundie Loch, where although there are no surface erratics because of the clearance of the fields, many can be seen in the walls and alongside the trackway towards Wester Keith and Long Loch, eg around 392373.

TAYSIDE REGION, PERTH AND KINROSS DISTRICT

98. Amulree (Glen Quaich)

> "The village of Amulrie [sic] is considered by the author to stand on a group of low moraines; and the road for two or three miles from it, towards Glen Almond, to traverse small moraines or surfaces of mica slate, rounded by glaciers." (Buckland, 1841 A: 335).

The village of Amulree (NN 900368) stands on an area of very hummocky ground constricting Glen Quaich, opposite the Girron Burn valley. This appears to be morainic, and there is a substantial alluvial flat west of the moraine, in which Loch Freuchie (865377) probably represents the last remnant of a substantial moraine - dammed loch. There is a good view from the hill on the A822 road just west of the village at approx. 904367.

Continuing southwards, the modern A822 road towards Glen Almond and Crieff crosses areas of substantial kame terraces and hummocky moraine continuously from 900364 (where there is a small disused quarry in which a coarse gravel of local schists and quartz pebbles can be seen) to 889327, near the summit above Sma' Glen.

The old road, that would have been followed by Buckland, is a section of General Wade's Military Road, which runs in a direct line from the edge of the valley side south of Amulree (899364) over the col to the old milestone at 892337, and this crosses a number of bare and rounded outcrops, around 895355 in particular.

99. Blair Atholl

> "... likewise [moraines] ... the detritus ... on the left flank of the Garrie [sic] from Killicrankie [sic] to Blair Athol [sic]." (Buckland, 1841 A: 334).

The north-east side of the valley has a thick covering of till, with prominent mounds in places, eg 1 km. east of Bridge of Tilt around NN 885653 and 888650, near Ballentoul (seen very clearly from the new Blair Atholl By-Pass on the A9, and accessible from the old A9 road. Thick outwash gravels fill the valley floor, and a small section can be seen near the Club House of the Golf Club (876651).

100. Blairgowrie

> "The vast longitudinal and insulated ridges of gravel, extending for two or three miles up the valley east of Blair Gowrie [sic], and the transverse barriers forming a succession of small lakes in the valley of the Lunanburn, to the west of that town, he considers to be moraines;" (Buckland, 1841 A: 333-4).

East of Blairgowrie, the A926 road runs over massive mounds of fluvioglacial sand and gravel from Rattray (NO 183465) to Ruthven (NO 290489). The deposits are especially sandy and hummocky between Rattray and East Rattray (210458), and are largely covered with commercial raspberry fields, and with prominent mounds to the south, eg at NO 210455 and 219455.

West and south of Blairgowrie the Lunan Burn valley contains a succession of small, connected, lakes, each separated by hummocky drift, continuing the line of lochs that start near Dunkeld (q.v.)

(115443). The Loch of Clunie (115443) is separated from the Loch of Drumellie (142444) by a large hummocky ridge around 120445, and there are smaller lochs south of Muirton (183435): in all there are eleven prominent kettles in the hummocky deposits of the area, although not all of them are now water-filled.

In the area between Blairgowrie (178453) and Meikleour (157395), the hummocky deposits are overlain with deposits of outwash, seen in small exposures on Blairgowrie Golf Course, around 186425.

101. Bohally

> "Similar mammillated masses of mica slate retaining striae and flutings are visible at Bohaly [sic], one and a half miles east of Tumel [sic] Bridge." (Buckland, 1841 A: 334).

The raising of the level of Loch Tummel as part of the hydro-electric scheme has flooded all the outcrops near Bohally (NN 785591). However, for comparison, there is a clearly striated roche moutonée on the south side of the B846 road from Tummel Bridge to Kinloch Rannoch near Drumchastle at 680586. Two directions of striation can be seen, with the heavier striation and grooving running south-south-west to north-north-east intersecting finer west-east striations.

102. Comrie

> "Proofs of Glaciers in and near Strath Earn. - This part of the valley of the Earn is flanked irregularly with ridges and terraces of gravel, the detritus of moraines; and on its north side, in the woods adjacent to Lawers House, near Comrie, hard slaty rocks of the Devonian or old red standstone system have been rounded and striated. At the west end of Comrie, near the bridge, blue slate rocks have been also rounded and guttered." (Buckland, 1841 A: 335).

The northern side of the valley of Strath Earn is flanked with remnants of a series of large kame terraces standing up to 20 m. above the valley floor of the River Earn from Comrie (NN 775223) eastwards. These fragments of sand and gravel terraces can be seen from the A85 road from Comrie eastwards to Crieff, eg around Comrie Golf Course (777225), Clathick (813226) and south-west of Loch Monzievaird (around 835228).

The glacially-rounded outcrops near Lawers House, referred to by Buckland, are also just north of the A85 road at NN 785224, and other examples can be seen nearby at Miltons (NN 782225) and near the Club House of Comrie Golf Club at 778223.

The "rounded and guttered" blue slate rocks referred to are by the River Earn at the old bridge about 600 m. west of the town centre at NN 768220.

103. Dunkeld

> "On his return to Neuchatel from the glaciers of Rosenlaui and Grindelwald, he informed M. Agassiz that he had noticed in Scotland and England phaenomena similar to those he had just examined, but which he had attributed to diluvial action: thus in 1811 he had observed on the head rocks on the left side of the gorge of the Tay, near Dunkeld, rounded and polished surfaces;" (Buckland, 1841 A: 332).
>
> "... he considers to be moraines; likewise the lofty mounds comprising the ornamental grounds adjacent to Dunkeld Castle; the detritus covering the left flank of the valley of the Tay, along a great part of the road from Dunkeld to Logierait;" (Buckland, 1841 A: 334).

The 1811 location has not been positively identified in extensive searching, but two possibilities are some of the exposed rocks either above the river around the well-known beauty spot of

King's Seat (NO 008427) or perhaps along the line of the Perth to Inverness road (now widened considerably and re-aligned) around 008433.

There are very large areas covered by a fluvioglacial complex on either side of the river, with kames, kame terraces and hummocky gravel and sand deposits almost 2 km. wide from Dunkeld Cathedral (025426) to Birnam (035416).

North-eastward, massive mounds of glacial deposits east of Fungarth (035433) help to enclose the Loch of Lowes and Loch of Craiglush at the head of the succession of lakes in the Lunan Burn valley (q.v.).

Northwards from the gorge by King's Seat, the Tay valley has further large areas of massive kame and outwash terraces, standing up to 20 m. above the wide alluvial plain of the river, with hummocky gravel and sand above these, eg, above the A9 road at NO 005483, near Dowally, at NN 996503 and 998496, near Kindallachan, and NN 986517 and 990510 near Cuil-an-duin.

(For Logierait northwards, see Pitlochry - Killiecrankie, no. 111).

104. Fortingall

> "Dr Buckland considers to be moraines, or the detritus of moraines; also the deeply-scored and fluted boulders of hornblende rock, with other debris near Fortingal [sic], at the junction of Glen Moulin [sic] with Glen Lyon." (Buckland, 1841 A: 334).

Glen Lyon has thick deposits of outwash sands and gravels along the valley floor, but at Fortingall (NN 732466) there is a prominent gravel terrace area in the outwash, standing up to approx. 20 m. above the river.

The Allt Odhar descends from Gleann Muilinn through the centre of the village, and glacial outwash from Gleann Muilinn has presumably contributed to the size of the lateral terrace at this point, which diverts the River Lyon almost 3/4 km. southwards past Bridge of Lyon (728466).

105. Glen Almond

> "A few conical moraines appear also on the high lands between Glen Almond and Crieff." (Buckland, 1841 A: 335).

Buckland clearly followed the old Military Road southwards from the bank of the River Almond (NN 907294) in the Sma' Glen gorge of Glen Almond, whence the Military Road crossed the spur of Gualann na Faing (906284) to Foulford Inn (899268). From there, it followed the line of the present A822 to Gilmorton and thence to Crieff (along the line of the present A85 Perth to Crieff road).

The whole of the valleys from Sma' Glen to just above Monzie (around 888258) are covered with hummocky moraine with conical kames in a number of places, which can be seen very well from the modern road, particularly along the summit area from the Fendoch Burn (906271) to the junction with the minor road to Monzie (888258).

106. Glen Cochill

> "Moraines in Glen Cofield [sic] - A remarkable group of moraines occurs on the high lands which divide the valleys of the Tay and the Bran; and between the sixteenth and fourteenth milestones thirty or forty round-topped moraines, from thirty to sixty feet high, are crowded together like sepulchral tumuli. These mounds, composed of unstratified gravel and boulders, Dr Buckland says cannot be referred to the action of water, as they are placed precisely where a current descending from the adjacent high lands would have acted with the greatest velocity; and they exactly resemble some of the moraines in the valley of the Rhone, between Martigny and Lőek." (Buckland, 1841 A: 334-5).

There can be little doubt that Buckland's "Glen Cofield" is the present "Glen Cochill" from the location and description.

The A826 road southwards from Aberfeldy (NN 855490) towards Amulree (NN 900368) and thence to Crieff follows the line of General Wade's Military Road for the greater part of the distance. From the summit of the road at about NN 885450 by the side of Loch na Craige southwards the road crosses spectacular kame and hummocky moraine topography, and from about the bridge over the Cochill Burn at 908419 the valley is filled with mounds up to 20 m. high for a distance of about 2 km., and smaller hummocks and terraces continue on the west side of the valley down to the River Braan at NN 918381.

107. Glen Lednock

> "Evidence of Glaciers near Comrie. - In this district Dr Buckland tested the value of the glacial theory by marking in anticipation on a map the localities where there ought to be evidences of glaciers having existed, if the theory were founded on correct principles. The results coincided with the anticipations. On a hill above the gorge, called the Devil's Cauldron, near Fentallich, are rounded surfaces of greenstone, partially covered by moraines; and at Kenagart, also immediately above the Devil's Cauldron, is a small cluster of moraines, easily separable into lateral and terminal. Two miles up the

valley a medial moraine forms a ridge on the level ground, in front of the confluence of Glen Lednoch and Glen Garron. The farmhouse of Invergeldy is stated to stand on the detritus of a moraine, and the glen descending to it from Ben-na-cho-ny to be partially obstructed with moraines. The surface of the granite at Invergeldy, which supplied the stone for Lord Melville's monument at Crieff, is rounded and mammillated, but too much weathered to present a polish or striae. On a hill of trap, however, half a mile south of the farm of Lurg, there is a distinct polish, striated in the direction which a glacier descending the subjacent valley would assume." (Buckland, 1841 A: 335).

Buckland described the localities in Glen Lednock seen on ascending the valley by the minor road from the A85 road in the centre of Comrie at NN 770221 to Glenmaik (725283): throughout Buckland's observations can be closely identified.

The "Deil's Caldran" (present-day spelling) is at 767236. Around Kingarth Farm (764245) an area of prominent kames and kame terraces cover the valley floor between 767238 and 765245. At Funtullich (749221), is a well-rounded and heavily striated roche moutonée facing directly up the valley.

"Glen Garron" appears to be a transcription or printing error: probably "Glen Girron" was intended, since the Allt Mathaig valley lies below the prominent crag known as "The Girron" (700257). If this identification is correct, then the clear "medial moraine" (probably an eroded kame terrace remnant) at the junction of the Allt Mathaig and River Lednock near Glenmaik at approx. 729281 was intended.

Around Invergeldie (741277) are rounded outcrops of granite, and the farmhouse itself stands on the prominent terminal moraine of the Invergeldie Burn valley, which descends from Ben Chonzie (774308) - Buckland's "Ben-na-cho-ny".

Presumably the polished and striated surface south of Lurg (766257) seen by Buckland was one of the numerous outcrops on the east side of the River Lednock below Creag Bhalg, around 767253.

108. Glen Turrett (Crieff)

> "In Glen Turret [sic], on the shoulder of the mountain immediately above the south-west extremity of Loch Turret, a very deep ravine intersects a vast lateral moraine, which Dr Buckland shows must have been lodged there whilst the Loch was a mass of ice, and the valley above it filled with a glacier more than five hundred feet above the present level of the lake. At the falls of the Turret, at the lower extremity of the gorge, is an extensive lodgement of moraines; and at the upper end, on the left bank of the Turret, near a gate which crosses the road, the slate-rocks are polished and furrowed; and at both these localities Dr Buckland had anticipated that glacial action ought to be found." (Buckland, 1841 A: 335).

The upper part of Glen Turrett has been greatly altered in recent years because of the building of a large dam at NN 820266, creating the large Loch Turrett Reservoir. However, the "vast lateral moraine" of Buckland can be clearly identified on the south-west side of the valley below the dam, around 827255, and continuing up the valley towards the line of the dam.

At the head of the gorge of the Falls of Turrett, around 838245, there are rounded glaciated bare rock surfaces. Below the gorge the Turrett Burn runs through large-scale hummocky moraine down to the bridge at Hosh (856236). Coarse outwash gravels and finer outwash sands fill most of the valley down to the A85 Comrie to Crieff road, near Dalvreck (856228), where 6-8 m. of gravel is being worked over sand.

109. Linn of Tummel

> "Dr Buckland mentions the mammillated, polished and striated slate rocks, about one mile above the falls of the Tumel [sic], on the left portal of the gorge of the valley, as the effects of a glacier which descended the gorge: he notices also the rounded outline and polish on veins of quartz, which project eight or ten inches above the weathered surfaces of masses of mica slate near the same locality." (Buckland, 1841 A: 334).

The Linn of Tummel is a series of waterfalls around NN 906600, just above the Garry valley. The River Tummel runs over mammilated and polished rocks, but no striations as such have been found on the surfaces exposed at present.

However, there is an excellent "voucher" locality approx. 4 km. upstream at the "Queen's View", above Loch Tummel at NN 865597. There is now a Forestry Commission Visitor Centre and Viewpoint here, around which there is excellent evidence of glacial plucking and striation along the side of the valley above the Loch. Striations running west-east are also visible on a bare patch of rock in the new concreted footpath from the car park to the Viewpoint.

110. Loch Earn

> "Evidence of Glaciers near Loch Earn. - On the north bank of the Loch rounded and furrowed surfaces and portions of lateral moraines are exposed by the roadside; and at Loch Earn Head [sic] is a group of conical moraines at the junction of Glen Ogle with Loch Earn, and at the very point where, had they been brought by a rapid current, they would have been propelled into the Loch. It is nevertheless the exact position where the terminal moraine of a glacier would be deposited." (Buckland, 1841 A: 335-6).

The striated and furrowed outcrops by the loch-side have mostly been masked by the raising of the water level, because of the hydro-electric scheme, and the widening and improvement of the main A85 road along the north bank of the loch.

However, a high ridge of till can be seen near the picnic site west of Wester Glentarken (NN 662246), just north of the main road.

The A85 descending from Glen Ogle in to Lochearnhead (NN 590257) runs over an area of hummocky moraine, kames and kame terraces more than 1 sq. km. in extent, and the features are well seen from the road between 577260 and 586245. Southwards from Lochearnhead, the A84 towards Callander similarly cuts through an area of large mounds of till around NN 578216.

(Note: the boundary between Tayside Region (Perth and Kinross District) and Central Region (Stirling District) runs around the shore of Loch Earn, and the Lochearnhead localities are technically in Central Region, although most of Loch Earn and its valley are in Tayside Region.)

111. Pitlochry - Killiecrankie

> "... he considers to be moraines ... the detritus ... on the left flank of the Tumel [sic] valley from Logierait to Killicrankie [sic]; and on the left flank of the Garrie [sic], from Killicrankie to Blair athol [sic].
>
> The vast congeries of gravel and boulders on the shoulder of the mountain, exactly opposite the gorge of the Tumel, Dr Buckland is of opinion was lodged there by glaciers which descended the lateral valley of the Tumel from the north side

> of Schiehallion and the adjacent mountains, and were forced across the valley of the Garry, in the same manner as modern glaciers of the Alps (that of the Val de Bagne, for example,) descend from the transverse, and extend across the longitudinal valleys." (Buckland, 1841 A: 334).

Logierait (NN 972519) and Ballinluig on the east side of the Tummel lie on prominent terraces of glacial outwash gravels, standing on both sides of the Tummel at heights of up to 25-30 m. above the river up to the hydro-electric dam at Pitlochry (940576), and these terraces also flank the Tay westwards to Aberfeldy (855491).

Above the level of the fluvioglacial terraces, the Tummel valley has thick kame terraces and deposits of hummocky moraine, composed mainly of outwash sands and gravels, along which the A9 Perth to Inverness road runs from Ballinluig (978524) to Pitlochry (942580), where the town is built on an area of sandy hummocks.

North of Pitlochry, there is a large area of hummocky gravel and outwash opposite the Tummel Gorge around Faskally (922595), 1 km. south of the new high-level Garry Bridge - the area "exactly opposite the gorge of the Tumel" of Buckland.

North of the Bridge is the Pass of Killiecrankie, through which the A9 road passes high on the east side of the gorge, on a thick valley-side coating of brownish stony till, well exposed in, for example, an exposure about 50 m. long and up to 7 m. high on the east side of the road at NN 916614.

North of the Pass, prominent hummocky kames and kame terraces are seen behind the village of Killiecrankie, around 917630, and are continuous on the north-eastern side of the valley from the Allt Girnaig (913630) to Adelane (900639), and thence to Blair Atholl (q.v.).

112. Schiehallion

> "Evidences of Glaciers on Schiehallion. - The north and north-east shoulders of the mountain present rounded, polished, and striated surfaces, many of which have been recently exposed by the construction of new roads. On the left flank of the valley called the Braes of Foss, and near the thirteenth milestone, a newly-exposed porphyry dyke, forty feet wide, exhibited a polished surface and striated, parallel to the line of descent which a glacier from Schiehallion would take; and on the right flank, one hundred yards north of the eleventh milestone, another and smaller dyke of porphyry presented similar phaenomena. In the intermediate space the recently uncovered slate rocks and quartzite are rounded, polished, grooved, and striated, parallel to the direction which a glacier would assume where each surface is situated." (Buckland, 1841 A: 334).

Buckland evidently travelled from Loch Rannoch to Taymouth Castle by the Military Road from Kinloch Rannoch bridge (NN 661586) along the northern flank of Schiehallion (1083 m. high) via the Braes of Foss (750559) to join the present B846 road at 776543.

Buckland's first locality is easily identifiable on the side of the road at NN 725567, where evidence of glacial plucking and rounding is visible on the surface of the metamorphic rocks by the side of the dyke. No striations appear to survive at this precise point, but good striations trending east-south-east can be examined near the road at 730564. The second locality is almost exactly 3 km. east of this, again by the side of the road at 745560, about 500 m.

west of Braes of Foss Farm. Here good striations in an east-north-easterly direction still survive.

Extensive areas of hummocky moraine and small kames can also be seen from the Military Road, eg at NN 751559, and between 774539 and 776520.

113. Taymouth

> "Moraines at Taymouth. - Two lofty ridges of gravel, which cross the park at right angles to the sides of the valley between the village of Kenmore and Taymouth Castle, the hill, on which stands an ornamental dairy-house, and the gravel, on which are situated the woods overhanging the left bank of the lower end of Loch Tay ...". (Buckland, 1841: 334).

The parkland of Taymouth Castle (NN 784465) is now mainly used as a golf course. The area of hummocky outwash gravel and sand forms a prominent terrace more than 30 m. high on the south side of the River Tay from Kenmore (772455) at the eastern end of Loch Tay to beyond the Castle itself, and covers an area of approx. 1 sq. km. The feature can be examined at ground level from the golf course roads and paths, and it is clear that the deposit is very variable, from coarse rounded gravel to mounds of very fine sands. The general character of the area can be seen very well from the A827 road from Kenmore towards Aberfeldy, which overlooks the Taymouth Castle area for the first 2 km. from Kenmore itself. The "ornamental dairy-house" referred to by Buckland is a parkland folly, still surviving at 781456.

Coarse gravels and hummocky moraine can also be seen on the north bank of Loch Tay just north of Kenmore, around Mains (771459).

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REFERENCES

NOTE: (1) Appendix 2 is photographically reproduced from the printed paper, and is separately referenced: only where works have also been cited in other Sections have they been included in this bibliography as well;

(2) A small number of minor papers by William Buckland have not been cited in the final revision and shortening of the text, hence the gaps in this part of the list of references.

ADAMS, HC 1878 Wykehamica. A History of Winchester College and Commoners. (Oxford).

AGASSIZ, E C 1885 Louis Agassiz. His Life and Correspondence. Vol. 1. (London).

AGASSIZ, L 1837A Discours prononcé à l'ouverture des séances de la Société Helvétique des Sciences Naturelles à Neuchatel le 24 juillet 1837. Actes Soc. Helv. des Sci. Nat. 22: v-xxxii.

——— 1837B Des glaciers, des moraines, et des blocs erratiques. Biblio. Univ. Sci. Genève. 12: 369-394.

——— 1838A On the Erratic Blocks of the Jura. Edinb. N. Phil. J. 24: 176-179.

——— 1838B Upon Glaciers, Moraines and Erratic Blocks; being the Address delivered at the opening of the Helvetic Natural History Society at Neuchatel, on the 24th of July 1837, by its President, M. L. Agassiz. Edinb. N. Phil. J. 24: 364-383.

——— 1840 Etudes sur les Glaciers (2 vols.). (Neuchatel).

——— 1841A On the polished and striated surfaces of the rocks which form the beds of glaciers in the Alps. Proc. Geol. Soc. Lond. 3(71): 321-322.

——— 1841B On glaciers, and the evidence of their once having existed in Scotland, Ireland and England. Proc. Geol. Soc. Lond. 3(72): 327-332.

——— 1841C On glaciers and boulders in Switzerland. Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1840): 113-114.

——— 1842 The Glacial Theory and its recent Progress. Edinb. N. Phil. J. 33 (66): 217-283.

ALEXANDER, E M M 1964 Father John MacEnery: Scientist or Charlatan? Rept. Trans. Devon. Assoc. Advmt. Sci. 96: 113-146.

ANDREWS, S M 1982 The Discovery of Fossil Fishes in Scotland up to 1845 with Checklists of Agassiz's Figured Specimens. (Edinburgh).

ANON. 1823 History of the Society (continued). Mem. Wernerian Nat. Hist. Soc. Edinb. 4(2): 571-585.

——— 1839 Royal Academy of Sciences of Paris. Lond. Edinb. Phil. Mag. (3rd Ser.) 15: 158-159.

ANON. 1840 Substance of a Notice, by Professor Agassiz, to the Geological Section of the British Association, on Glaciers and Boulders in Switzerland. (Glasgow).
——— 1856 Obituary - Rev. Dr. Buckland. Amer. J. Sci. 22: 449-452.
ARKELL, W J 1947 The Geology of the Country around Weymouth, Swanage, Corfe & Lulworth. Sheets 341, 342, 343. Mem. Geol. Surv. G.B.
AUSTEN, R A C 1840 On the bone caves of Devonshire. Proc. Geol. Soc. Lond. 3: 286-287.
——— 1842 On the Geology of the South-east of Devonshire. Trans. Geol. Soc. Lond. Ser. 2. 6: 433-489.

BABBAGE, C 1830 Reflections on the Decline of Science in England and on some of its causes. (London).
BALMER, H 1970 Ignaz Venetz. Gesnerus 27(3/4): 138-168.
BEAUMONT, E D E 1831 Researches on some of the Revolutions which have Taken Place on the Surface of the Globe. Phil. Mag. 10: 241-264.
BEHRENSMEYER, A K 1975 The taphonomy and paleoecology of Plio-Pleistecene vertebrate assemblages east of Lake Rudolph, Kenya. Bull. Mus. Comp. Zool. Harv. 146: 473-578.
BEHRENSMEYER, A K & HILL, A (editors) 1980 Fossils in the Making. Vertebrate Taphonomy and Paleoecology. (Chicago & London).
BENSON, A C & ESHER Visc. 1907 The Letters of Queen Victoria. Vol. II. 1844-1853. (London).
BERMAN, M 1978 Social Change and Scientific Organisation: the Royal Institution, 1799-1844. (London).
BIGOT, A 1943 A Propos d'un portrait de William Buckland. Bull. Soc. Linn. Normandie (1943): 130-1.
BLEWITT, O 1832 The Panorama of Torquay (2nd Edition). (London & Torquay).
BOMPAS, G C 1891 The Life of Frank Buckland: A new edition. (London).
BOWLER, P J 1976 Fossils and Progress. Palaeontology and the Idea of Progressive Evolution in the Nineteenth Century. (New York).
BOYLAN, P J 1967 Dean William Buckland, 1784-1856: a pioneer in cave science. Stud. Speleol. 1 (5): 236-253.
——— 1970 An Unpublished Portrait of Dean William Buckland, 1784-1856. J. Soc. Biblphy. Nat. Hist. 5(5): 350-354.
——— 1972 The Scientific Significance of the Kirkdale Cave Hyaenas. Ann. Rept. Yorks. Philos. Soc. (for 1971). (150th Anniversary Volume): 38-47.
——— 1978 The Role of William Buckland (1784-1856) in the Recognition of Glaciation in the British Isles. Zusamm. VIII Symposium INHIGEO Munster 12-24 Sept. 1978: 33
——— 1979 The controversy of the Moulin-Quignon jaw: the role of Hugh Falconer. pp. 171-199 in Jordanova & Porter, 1979 (q.v.).
——— 1981A A new revision of the Pleistocene mammalian fauna of Kirkdale Cave, Yorkshire. Proc. Yorks. Geol. Soc. 43(3): 253-280.
——— 1981B The Role of William Buckland (1784-1856) in the Recognition of Glaciation in Great Britain. pp. 1-8 in NEALE, J & FLENLEY, J (editors). The Quaternary in Britain. (Oxford).
BRAIN, C K 1981 The Hunters or the Hunted?. An Introduction to African Cave Taphonomy. (Chicago & London).
BREWSTER, D 1830. Charles Babbage, Reflections on the Decline of Science in England. Quart. Rev. 43: 305-342.
——— 1831 Great Scientific Meeting to be held at York. Edinb. J. Sci. 4: 374.

BRITISH ARCHAEOLOGICAL ASSOCIATION 1844 First Annual Meeting of the British Archaeological Association, Canterbury, September 1844. Archaeol. J. 1: 267-282

BROCK, W H 1966 The selection of the authors of the Bridgewater Treatises. Notes & Records Roy. Soc. Lond. 21(2): 162-179.

——————— 1981 Advancing Science: The British Association and the Professional Practice of Science. pp. 89-117 in MacLeod, R & Collins, P 1981 (q.v.).

BRODERIP, W J 1828 Observations on the Jaw of a Fossil Mammiferous animal, found in the Stonesfield slate. Zool. J. 3: 408-411.

BROGNIART, J 1819 Concerning the method of collecting, labelling, and transmitting specimens of fossil organised bodies, and of the accompanying rocks, solicited by M. Brogniart. Amer. J. Sci. 1: 71-74.

BROUGHTON, Lord 1910 Recollections of a Long Life. Vol. V. 1834-1840.

BUCKLAND, F T 1858 Memoir of the Very Rev. William Buckland, D.D., F.R.S., Dean of Westminster. pp. xix-lxx in Buckland, W. 1858. Geology and Mineralogy considered with reference to Natural Theology. (3rd edition), edited by F T Buckland. (London).

BUCKLAND, W 1817A Description of an Insulated Group of Rocks of Slate and Greenstone in Cumberland and Westmoreland, on the east side of Appleby, between Melmerby and Murton. Trans. Geol. Soc. (Ser. 1), 4: 105-116.

——————— 1817B Description of a series of Specimens from the Plastic Clay near Reading, Berks: with Observations on the Formation to which these Beds belong. Trans. Geol. Soc. (Ser. 1), 4: 277-304.

——————— 1817C Description of the Paramoudra, a singular fossil body that is found in the chalk of the North of Ireland; with some general Observations upon Flints in Chalk, tending to illustrate the History of their formation. Trans. Geol. Soc. Lond. (Ser. 1), 4: 413-423.

——————— 1818 (? date) Order of Superposition of Strata in the British Islands. (broadsheet - no publication details).

——————— 1819 On the Geological Structure of the South Western Coal District. Ann. Philos. 13: 221-222.

——————— 1820 Vindiciae Geologicae; or the Connection of Geology with Religion explained. (Oxford).

——————— 1821A Notice on the Geological Structure of a part of the Island of Madagascar, founded on a Collection transmitted to the Right Honourable the Earl Bathurst, by Governor Farquhar, in the year 1819; with Observations on some Specimens from the Interior of New South Wales, collected during Mr. Oxley's Expedition to the River Macquarie, in the year 1818, and transmitted to Earl Bathurst. Trans. Geol. Soc. Lond., (Ser. 1), 5: 476-481.

——————— 1821B Sur la structure géognostique des Alpes et des parties adjacentes du continent, et sur leurs rapports avec les Roches secondaires et de transition de l'Angleterre. J. Physique 93: 20-46.

——————— 1821C Notice of a Paper laid before the Geological Society on the Structure of the Alps and adjoining Parts of the Continent, and their Relation to the Secondary and Transition Rocks of England. Ann. Philos. (N.S.), 1: 450-468.

BUCKLAND, W 1821D Description of the Quartz Rock of the Lickey Hill in Worcestershire, and of the Strata immediately surrounding it; with considerations on the evidences of a Recent Deluge afforded by the gravel beds of Warwickshire and Oxfordshire, and the valley of the Thames from Oxford downwards to London; and an Appendix, containing analogous proofs of diluvian action. Collected from various authorities. Trans. Geol. Soc. (Ser. 1), 5: 506-544.

——————— 1821E Instructions for conducting Geological Investigations, and collecting Specimens. Amer. J. Sci., 3: 249-251.

——————— 1822A Account of an Assemblage of Fossil Teeth and Bones belonging to extinct Species of Elephant, Rhinoceros, Hippopotamus, and Hyaena, and some other Animals discovered in a Cave at Kirkdale, near Kirby Moorside, Yorkshire. Ann. Philos. 19: 227-230.

——————— 1822B Account of an Assemblage of Fossil Teeth and Bones ... discovered in a Cave at Kirkdale, near Kirby Moorside, Yorkshire. Phil. Trans. Roy. Soc. 122: 171-236.

——————— 1822C Account of an Assemblage of Fossil Teeth and Bones ... discovered in a Cave at Kirkdale, near Kirby Moorside, Yorkshire. Ann. Philos. 20: 133-145 & 173-194; Froriep. Notizen, 2: 164-168; J. de Physique 96: 220-245 & 308-330; Ann. de Chimie 22 (1823): 305-315; Edinb. Phil. J. 8 (1823): 56-62 & 9 (1823): 221-228; Phil. Mag. 62 (1823): 112-114. [various titles]

——————— 1822D On the Formation of Vallies by Diluvial Excavation, as illustrated by the Vallies which intersect the Coast of Devon and Dorset. Ann. Philos. 20: 66-68.

——————— 1823A Reliquiae Diluvianae; or, Observations on the Organic Remains contained in Caves, Fissures, and Diluvial Gravel, and on other Geological Phenomena, attesting the Action of An Universal Deluge. (London).

——————— 1823B Account of Bones discovered in Caves and Fissures in various Parts of the Continent. Ann. Philos. 21: 467.

——————— 1824A On the Excavation of Valleys by diluvian Action, as illustrated by a succession of Valleys which intersect the South Coast of Dorset and Devon. Trans. Geol. Soc. Lond. (Ser. 2) 1 (1): 95-102.

——————— 1824B Reliquiae *Diluvianae ... (2nd edition). London.*

——————— 1824C Notice on the Megalosaurus or great Fossil Lizard of Stonesfield. Trans. Geol. Soc. Lond. (Ser. 2) 1 (2): 390-396.

——————— 1825A Reply to some observations in Dr. Fleming's Remarks on the Distribution of British Animals. Edinb. Phil. J. 12: 304-319.

——————— 1825B On the Discovery of the Anoplotherium Commune in the Isle of Wight. Ann. Philos. 26: 360-361.

——————— 1825C On the valley of Kingsclere near Newbury, and the evidence it affords of disturbances affecting the green sand, chalk and plastic clay formations. Ann. Philos. 25: 465-467.

——————— 1825D Organic Remains in Kent's Hole and Chudleigh Cave. Monthly Mag. Brit. Register 59: 190-191.

——————— 1826 Notice of the Hyaena's Den near Torquay. Edinb. New Phil. J. 14: 363-364.

——————— 1827A On the Interior Dens of Living Hyaenas. Edinb. New Phil. J. 2: 377-380.

——————— 1827B Observations on the bones of hyaenas and other animals in the Cavern of Lunel. Proc. Geol. Soc. Lond. 1 (1): 3-6.

BUCKLAND, W 1827C The discovery of a number of fossil bones of bears in the Grotto d'Osselles. Proc. Geol. Soc. 1,(3): 21-22. (Abstracts and translations: Ann. Sci. Nat. 10: 306-320; Amer. J. Sci. 14 [1828]: 203-204.)

——— 1827D Relation d'une découverte récente d'os fossiles faite dans la partie orientale de la France à la grotte d'Osselles ou Quigney, sur les bords du Doubs, cinq lieues au-dessous de Besançon. Ann. Sci. Nat. 10: 306-319.

——— 1828A On the Cycadeoideae, a new family of fossil plants, specimens of which occur silicified in the tree-stone quarries of the Isle of Portland. Proc. Geol. Soc. 1 (8): 80-81; [Abstract: Phil. Mag. 4: 225-227.]

——— 1828B Notes sur les traces de Tortues observées dans les Grès rouges. Ann. Sci. Nat. 13: 85-86.

——— 1828C On a collection of vegetable and animal remains, and rocks, from the Burmese Country, presented to the Geological Society by J Crawfurd Esq. Proc. Geol. Soc. Lond. 1(7): 71-73.

——— 1829A On the Formation of the Valley of Kingsclere and other Valleys by the Elevation of the Strata that enclose them; and on the Evidences of the original Continuity of the Basins of London and Hampshire. Trans. Geol. Soc. Lond. (Ser. 2), 2: 119-130.

——— 1829B Geological Account of a Series of Animal and Vegetable Remains and of Rocks, collected by J Crawfurd Esq. on a Voyage up the Irawadi to Ava, in 1826 and 1827. Trans. Geol. Soc. Lond. (Ser. 2) 2 (3): 377-392.

——— 1829C On the Cycadeoideae, a Family of Fossil Plants found in the Oolite Quarries of the Isle of Portland. Trans. Geol. Soc. Lond. (Ser. 2) 2(3): 395-401.

——— 1829D Appendix to Mr De la Beche's paper, on the Geology of Nice. Proc. Geol. Soc. 1: 94; Phil. Mag. 5: 384-385.

——— 1829E On the discovery of a new species of Pterodactyle; and also of the Faeces of the Ichthyosaurus; and of a black substance resembling Sepia, or Indian Ink. Proc. Geol. Soc. Lond. 1: 96-98; Phil. Mag. 5: 387-388.

——— 1829F On the Discovery of a new species of Pterodactyle, and of Fossil Ink and Pens, in the Lias at Lyme Regis; also of Coprolites or Fossil Faeces in the Lias at Lyme Regis, and Westbury-on-Severn, and elsewhere, in formations of all ages, from the Carboniferous Limestone to the Diluvium. Edinb. N. Phil. J. 8: 21-26.

——— 1829G A letter dated March 14, 1829, from Dr Prout to Professor Buckland. Proc. Geol. Soc. Lond. 1: 57.

——— 1829H On the occurrence of agates in the dolomitic strata of the new-red-sandstone formation in the Mendip Hills. Phil. Mag. 6: 136-137.

——— 1829I Viscount Cole and Mr Philip Egerton's Account of the Destruction of the Cave of Kühloch, in Franconia. Phil. Mag. 6: 92-93.

——— 1829J On the supposed Petrifying Quality of the Irawadi. Edinb. New Phil. J. 5: 67-70.

——— 1830A On the discovery of the bones of the Iguanodon, and other large reptiles, in the Isle of Wight and Isle of Purbeck. Phil. Mag. 7: 54-55.

——— 1830B On the Discovery of Coprolites in North America. Phil. Mag. (N.S.) 7: 321-323.

BUCKLAND, W 1831 On the Occurrence of the Remains of Elephants, and other Quadrupeds, in cliffs of frozen mud, in Eschscholtz Bay, within Beering's [sic] Strait, and in other distant parts of the shore of the Arctic Seas. pp. 593-612 in Beechey, F W 1831. Narrative of a Voyage to the Pacific, and Beering's Strait performed in His Majesty's Ship Blossom, ... in the Years 1825, 1826, 1827, 1828. Part I. (London).

——————— 1832 On the Vitality of Toads enclosed in Stone and Wood. Edinb. New Phil. J., 13: 26-32. (Reprinted and/or translated in: Frooriep. Notizen 34: 321-326; Liebeg Annal. 4: 109-115; 314-320; Amer. J. Sci. 23 [1833]: 372-377.

——————— 1833A On the Fossil Remains of the Megatherium, recently imported into England from South America. Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1832): 104-107.

——————— 1833 B [Opening Address of the President] Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1832): 96-98.

——————— 1833C [Closing Address of the President] Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1832): 109-110.

——————— 1833D A Scale of Geological Colours. Rept. Trans. Brit. Advmt. Sci. (for 1832): 592.

——————— 1833E On the adaption of the structure of the Sloth to its peculiar mode of life. Lond. Edinb. Dublin Phil. Mag. (3rd Ser.) 2: 307-309.

——————— 1834A On the Vitality of Toads enclosed in Stone and Wood. J. Zool. 5: 314-320.

——————— 1834B A Description of fossil remains .... by Professor Buckland and Mr Clift in Crawfurd, J 1834. Journal of An Embassy .... (London).

——————— 1834C Uber die fossilen Megatherium-Reste [Abstract]. N. Jahr. fur Mineral. Geognoscie, Geol. 2: 112-113.

——————— 1835A On the Discovery of a New Species of Pterodactyle in the Lias at Lyme Regis. Trans. Geol. Soc. Lond. (Ser. 2) 3: 217-222.

——————— 1835B On the Discovery of Coprolites, or Fossil Faeces, in the Lias of Lyme Regis, and in other Formations. Trans. Geol. Soc. Lond. (Ser. 2) 3: 223-238.

——————— 1835C Observations on the Secondary Formations between Nice and Tendi. Trans. Geol. Soc. Lond. (Ser. 2) 3: 187-190.

——————— 1835D On the occurrence of Agates in the Dolomitic Strata of the New Red Sandstone Formation in the Mendip Hills. Trans. Geol. Soc. Lond. (Ser. 2) 3: 421-424.

——————— 1835E Notice of a newly discovered gigantic Reptile. Proc. Geol. Soc. Lond. 2 (40): 190.

——————— 1835F Notice of a newly discovered gigantic Reptile. Lond. Edinb. Phil. Mag. (3rd Ser.) 7: 327-328.

——————— 1835G On the Discovery of the fossil bones of the Iguanadon in the Iron Sand of the Wealden formation in the Isle of Wight. Trans. Geol. Soc. (2nd Ser.) 3 (3): 425-432.

——————— 1836A Notice on the Fossil Beaks of four extinct Species of Fishes, referrible to the Genus Chimaera, that occur in the Oolite and Cretaceous Formations of England. Lond. Edinb. Phil. Mag. (3rd Ser.), 8: 4-7.

——————— 1836B Geology and Mineralogy Considered with Reference to Natural Theology Bridgewater Treatise No. VI. 2 vols. (London).

——————— 1836C Notice on some very curious recent discoveries of fossil footsteps of unknown quadrupeds in the New Red Sandstone of Saxony, and of fossil birds in sandstone of the same formation in the valley of the Connecticut. Proc. Ashmolean Soc. Oxford 1 (11): 21.

BUCKLAND, W 1837A On the Adaptation of the structure of the Sloths to their peculiar Mode of Life. Trans. Linn. Soc. Lond. 17: 17-27.
—————— 1837B Notice on the Fossil Beaks of four extinct Species of Fishes, refferible to the Genus Chimaera, that occur in the Oolite and Cretaceous Formations of England. Proc. Geol. Soc. Lond. 2: 205-206.
—————— 1837C On the occurrence of Keuper-Sandstone in the upper region of the New Red Sandstone formation or Poikilitic system in England and Wales. Lond., Edinb. Phil. Mag. (3rd Ser.), 11: 106-107.
—————— 1837D Geology and Mineralogy Considered with Reference to Natural Theology. Bridgewater Treatise No. VI. (2nd edition) 2 vols. (London).
—————— 1837E On the occurrence of silicified trunks of large trees in the new red sandstone formation or Poikilitic series, at Allesley, near Coventry. Lond. Edinb. Phil. Mag. (3rd Ser.) 10: 475-476.
—————— 1837F On the occurrence of silicified trunks of large trees in the new red sandstone formation or Poikilitic series, at Allesley, near Coventry. Proc. Geol. Soc. Lond. 2 (48): 439-440.
—————— 1838A On the occurrence of Keuper-Sandstone in the upper region of the New Red Sandstone formation or Poikilitic System in England and Wales. Proc. Geol. Soc. Lond. 2 (48): 453-454.
—————— 1838B On the discovery of Fossil Fishes in the Bagshot sands at Goldnorth Hill, 4 miles north of Guilford. Proc. Geol. Soc. Lond. 2 (58): 687-688.
—————— 1838C On the discovery of a fossil wing of a Neuropterous Insect in the Stonesfield Slate. Proc. Geol. Soc. Lond. 2 (58): 688.
—————— 1838D De la Géologie et de la Minéralogie considérées dans leurs rapports avec la Théologie naturelle (trans. Doyère). (Paris).
—————— 1839A Geologie und Mineralogie in Beziehung auf die natürliche Theologie. (trans. Agassiz). (Neufchâtel).
—————— 1839B On the action of Acidulated Waters on the surface of the Chalk near Gravesend. Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1838): 76-77.
—————— 1839C On the Discovery of the Wing of a Neuropterous Insect in the Stonesfield Slate. Proc. Geol. Soc. Lond. 2: 688.
—————— 1839D An Account of the Footsteps of the Cheirotherium and five or six smaller Animals in the Stone Quarries of Storeton Hill, near Liverpool. Rept. Trans. Brit. Assoc. Advmt. Sci. for 1838: 85.
—————— 1839E An Inquiry whether the Sentence of Death pronounced at the Fall of Man included the whole Animal Creation, or was restricted to the Human Race. (London).
—————— 1839F On fossil impressions of rain, ripple marks produced by wind and water, and fossil footsteps of Cheirotherium and other unknown animals recently discovered on strata of the New Red Sandstone formation, in the counties of Cheshire, Salop and Warwick. Proc. Ashmolean Soc. Oxford 1 (16): 5-7.
—————— 1840A Anniversary Address to the Geological Society, 21 February 1840. Proc. Geol. Soc. Lond. 3 (68): 210-267.
—————— 1840B On the agency of animalcules in the formation of limestone. Proc. Ashmolean Soc. 1: 35-39.
—————— 1841A On the Evidences of Glaciers in Scotland and the North of England. Proc. Geol. Soc. Lond. 3 (72): 332-337; 345-348.
—————— 1841B Anniversary Address to the Geological Society, 19 February 1841. Proc. Geol. Soc. Lond. 3 (81): 469-540.
—————— 1842A On Diluvio-Glacial Phaenomena in Snowdonia and the adjacent parts of North Wales. Proc. Geol. Soc. Lond. 3: 579-584.

BUCKLAND, W 1842B On the Agency of Land Snails in corroding and making deep Excavations in compact Limestone Rocks. Proc. Geol. Soc Lond. 3: 430-431.

———— 1843A On other modes of locomotion than swimming in the family of fishes. Proc. Ashmol. Soc. 2: 20-23.

———— 1843B On Ichthyopatolites, or Petrified Trackways of Ambulatory Fishes upon Sandstone of the Coal Formation. Proc. Geol. Soc. Lond. 4 (95): 204.

———— 1844A On Artesian Wells. Edinb. N. Phil. J. 37: 318-331.

[————] 1844B Agriculture. Quarterly Review 73: 477-509.

———— 1844C Leading points of the Glacial Theory lately proposed by Professor Agassiz. Abs. Proc. Ashmolean Soc. 1 (17 for 1840): 22-24.

———— 1844D [Further communication on the glacial theory]. Abs. Proc. Ashmolean Soc. 1 (18 - for 1841): 17-19).

———— 1845A A notice of several gigantic bidental fossil lizards, of extinct genera, lately discovered near the Cape of Good Hope. Proc. Ashmolean Soc. Oxford 2 (22): 81-85.

———— 1845C The Potato Disease and its Remedies. (Oxford).

———— 1846A On the Agency of Land Snails in forming holes and trackways in Compact Limestone. Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1845): 48-49.

———— 1846B On the Mechanical Action of Animals on Hard and Soft Substances during the Progress of Stratification. Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1845): 52.

———— 1847 On the Applicability of M. Fauvelle's Mode of Boring Artesian Wells to the Well at Southampton, and to other Wells, and to Sinkings for Coal, Salt and other Mineral Beds. Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1846): 56.

———— 1848A Proceedings at the Annual General Meeting, 18th February, 1848. Award of the Wollaston Medal ... Quart. J. Geol. Soc. Lond., 4: xviii-xxi.

———— 1848B A Sermon Preached in Westminster Abbey on Easter Sunday Evening, April 23, 1848, on the occasion of the reopening of the Choir. (London).

———— 1849A On the Causes of the general Presence of Phosphates in the Strata of the Earth, and in all fertile soils; with Observations on Pseudo-Coprolites, and on the Possibility of converting the Contents of Sewers and Cesspools into Manure. J. Roy. Agric. Soc. 10: 520-525.

———— 1849B Sermon preached in Westminster Abbey, on Easter Sunday Evening, April 23, 1849, being the Day of Thanksgiving to God for the Removal of the Cholera. (London).

———— 1850 On the Cause of the general presence of Phosphorus in Strata and in all fertile soils; also on Pseudo-Coprolites, and the Conversion of the Contents of Sewers and Cesspools into Manure. Rept. Trans. Brit. Assoc. Advmt. Sci (for 1849): 67-68.

———— 1851 [Dean of Westminster's Address to First Annual Meeting, 26 September, 1849]. Proc. Somerset Archaeol. Nat. Hist. Soc. 1: 9-20.

———— 1858 Geology and Mineralogy Considered with Reference to Natural Theology. New Edition, with Memoir of the Author edited by Francis T. Buckland. (London).

———— 1869 Geology & Mineralogy Considered with Reference to Natural Theology ... (4th edition). (London).

BUCKLAND, W & CONYBEARE, W D 1820 On the Coal Fields adjacent to the Severn. Ann. Philos., 15: 212-215; 299-301; 450-454.
———————— 1824 Observations on the South-Western Coal District of England. Trans. Geol. Soc. Lond. (Ser. 2), 1 (2): 210-316.
BUCKLAND, W & DE LA BECHE, H T 1830 On the Geology of Weymouth, and the adjacent parts of the coast of Dorsetshire. Phil. Mag. 7: 454-458.
———————— 1830B On the Geology of Weymouth, and the adjacent parts of the coast of Dorsetshire. Proc. Geol. Soc. 1 (16): 217-221.
———————— 1835 On the Geology of Weymouth, and the Adjacent Parts of the Coast of Dorsetshire. Trans. Geol. Soc. (Ser. 2) 4 (1): 1-46.
BUCKLAND, W & MILNE, J 1844 Report of the Committee appointed in 1842 for registering the Shocks of Earthquakes. Rept. Trans. Brit. Assoc. Advmt. Sci. (1843): 120-125.

BUCKLAND-WRIGHT, J C 1969 Craniological observations on Hyaena and Crocuta (Mammalia). J. Zool. Lond. 159: 17-29.
BULLERWELL, R G A 1910 On the superficial deposits at the foot of the Cheviot Hills between Wooler and Glanton. Geol. Mag. (N.S.) 5 (8), 452-458.
BUNSEN, F 1868 A Memoir of Baron Bunsen. Vol. I. (London).
BURD, V A 1973 The Ruskin Family Letters. (Ithaca).
BURGESS, G H O 1967 The curious world of Frank Buckland. (London).
BYNUM, W F 1984 Charles Lyell's Antiquity of Man and Its Critics. J. Hist. Biol. 17 (2): 153-187.

CANNON, S F (= W F) 1978 Science in Culture: the Early Victorian Period. (New York).
CANNON, W F 1969 The Uniformitarian - Catastrophist Debate. Isis 51: 38-55.
———————— 1976 Charles Lyell, Radical Actualism, and Theory. Brit. J. Hist. Sci. 9 (2): 104-120.
CARRUTHERS, R G et al 1927 Geology of Belford, Holy Island, and the Farne Islands. N.S. Sheet 4. Mem. Geol. Surv. Engl. & Wales.
———————— 1930 The Geology of the Alnwick District. N.S. Sheet 6. Mem. Geol. Surv. Engl. & Wales.
CATCOTT, A 1761 A Treatise on the Deluge. (London).
CATT, J A & PENNY, L F 1966 The Pleistocene Deposits of Holderness, East Yorkshire. Proc. Yorks. Geol. Soc. 35 (3) (16): 375-420.
CHADWICK, O 1966 The Victorian Church. Part 1. (London).
CHARLESWORTH, J K 1926 The glacial geology of the Southern Uplands, west of Annandale and Upper Clydesdale. Trans. R. Soc. Edinb., 55: 1-23.
———————— 1957 The Quaternary Era. (London).
CHARPENTIER, J G F 1835 Notice sur la cause probable du transport des blocs erratiques de la Suisse. Ann. Mines, 8: 219-236.
CHEVREUL, M 1825 Chemical Examination of two Specimens of the Soil of the Cavern of Kühloch. Ann. Plutos. 25: 284-297.
CHORLEY, R J, DUNN, A J & BECKINSALE, R P 1964 The History of the Study of Landforms or the Development of Geomorphology. Vol. 1: Geomorphology before Davis. (London).

CLAPPERTON, C M 1971 The location and origin of glacial meltwater phenomena of the Eastern Cheviot Hills. Proc. Yorks. Geol. Soc. 38 (3) (17): 361-80.
CLARK, J W & HUGHES, T McK 1890A The Life and Letters of Adam Sedgwick. Vol. I. (Cambridge).
——— 1890B The Life and Letters of Adam Sedgwick. Vol. II. (Cambridge).
CLARKE, E 1901 Sir John Bennett Lawes, 1814-1900. Dictionary of National Biography Supplement 1: 79-82.
CLIFT, W 1828 On the fossil remains of two new Species of Mastodon, and of other vertebrated animals, found on the left bank of the Irawadi. Proc. Geol. Soc. Lond. 1 (7) 69-71.
——— 1829 On the Fossil Remains of two New Species of Mastodon, and of other vertebrated Animals, found on the left Bank of the Irawadi. Trans. Geol. Soc. Lond. (Ser. 2) 2 (3): 369-375.
CLUBE, S V M 1982 Episodic Catastrophism. Syllogeus (Nat. Mus. Canada) 39: 136-137.
COCKBURN, W 1838 A Letter to Professor Buckland, concerning the Origin of the World. (London).
——— 1839 A Remonstrance, Addressed to His Grace the Duke of Northumberland, upon the Dangers of Peripatetic Philosophy. (London).
——— 1844B A Sermon on the Evils of Education without a Religious Basis. (London).
COLBERT, E H 1968 Men and Dinosaurs. The Search in Field and Laboratory. (London and Toronto).
CONYBEARE, W D 1816 Descriptive Notes referring to the Outline of Sections Presented by a part of the coats of Antrim and Derry, Collected by the Rev. W. Conybeare, M.G.S., From the joint Observations of the Rev. W. Buckland, M.G.S., Reader in Mineralogy in the University of Oxford, And himself, during a Tour in the Summer of 1813. Trans. Geol. Soc. Lond. (Ser. 1), 3: 196-216.
——— 1824A Additional Notices on the Fossil Genera Ichthyosaurus and Plesiosaurus. Trans. Geol. Soc. (Ser. 2) 1 (1): 103-123.
——— 1824B On the Discovery of an almost perfect Skeleton of the Plesiosaurus. Trans. Geol. Soc. (Ser. 2) 1 (2): 381-389.
——— 1829 On the Hydrogeological Basin of the Thames, with a view more especially to investigate the causes which have operated in the formation of the valleys of that river, and its tributary streams. Proc. Geol. Soc. Lond. 1: 145-149; Phil. Mag. 6: 61-65.
——— 1833 Report on the Progress, Actual State, and Ulterior Prospects of Geological Science. Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1832): 365-414.
——— 1840 Extraordinary Land-Slips and great Convulsion of the Coast of Culverhold Point, near Axmouth. Edinb. New Phil. J. 29: 160-164.
CONYBEARE, W D & PHILLIPS, W 1822 Outline of the Geology of England and Wales ... (London).
CORNISH, R 1982 Glacier flow at a former ice-divide in S.W. Scotland. Trans. Roy. Soc. Edinb. Earth Sciences 73 (1): 31-41.
CRAWFURD, J 1829 Journal of an Embassy from the Governor General of India to the Court of Ava. (2 vols.). (London).
CURWEN, E C 1940 The Journal of Gideon Mantell, Surgeon and geologist covering the years 1818-1852. (Oxford).
CUVIER, G 1812 Recherches sur les Ossemens Fossiles où l'on établit les caractères des plusieurs animaux dont les Révolutions du Glôbe ont détruit les espèces; (4 vols.) (Paris).

CUVIER, G 1825 Recherches sur les Ossemens Fossiles (3rd Edition) (5 vols). (Paris).

DART, R A 1956 The myth of the bone-accumulating hyaena. Amer. Anthrop. 58 (1): 40-62.
DARWIN, C 1839 Observations on the Parallel Roads of Glen Roy, and of other parts of Lochaber in Scotland, with an attempt to prove that they are of marine origin. Phil. Trans. Roy. Soc. Lond., 129: 39-81.
DARWIN, C 1842 Notes on the Effects produced by the Ancient Glaciers of Caernarvonshire, and on the Boulders transported by Floating Ice. Lond. Edinb. Dublin Phil. Mag. 21: 180-188.
DARWIN, F 1903 More Letters of Charles Darwin. Vol. II. (London).
DAVIES, G L 1968 The tour of the British Isles made by Louis Agassiz in 1840. Annals of Sci. 24 (2): 131-46.
———— 1969 The Earth in Decay. A History of British Geomorphology, 1578-1878. (London).
DAVIES, G L H 1980 Richard Griffith - His Life and Character pp. 1-31 in G L H Davies & R C Mollan (editors) Richard Griffiths, 1784-1878. (Dublin).
DE LA BECHE, H T 1848 Award of Wollaston Medal and Donation Fund and Anniversary Address. Quart. J. Geol. Soc. Lond. 4: xviii-cxx.
DE LA BECHE, HT & CONYBEARE, W 1821 Notice of the discovery of a new Fossil Animal forming a link between the Ichthyosaurus and the Crocodile. Trans. Geol. Soc. 5: 559-594.
DELAIR, J B 1968 A History of the Early Discoveries of Liassic Ichthyosaurs in Dorset and Somerset, 1779-1835. Proc. Dorset Nat. Hist. Archaeol. Soc. 90: 115-127.
DELAIR, J B & SARJEANT, W A S 1975 The Earliest Discoverers of Dinosaurs. Isis 66 (231) 5-25.
———— 1976 Joseph Pentland: a forgotten pioneer in the osteology of fossil marine reptiles. Proc. Dor. Nat. Hist. & Arch. Soc. 97: 12-16.
DESMOND, A J 1979 Designing the Dinosaur: Richard Owen's Response to Robert Edmond Grant. Isis 70 (252): 224-234.
DESSAIN, C S 1968 The Letters and Diaries of John Henry Newman, Vol. 18. (London).
DIXON, E E L et al 1926 The Geology of the Carlisle, Longtown and Silloth District. Mem. Geol. Surv. Engl. & Wales.
DOBSON, J 1954 William Clift. (London).
[DAUBENY, C] 1833 Apology for British Science. Lit. Gazette, 1833: 769-771; 789-792.
DUNCAN, H 1828 An Account of the Tracks and Footmarks of Animals found impressed in Sandstone in the Quarry of Corncockle Muir, in Dumfriesshire. Trans. Roy. Soc. Edinb. 9: 194-209.
———— 1831 An Account of the Tracks and Footprints of Animals found impressed on sandstone in the Quarry of Corncockle Muir in Dumfries-shire. Trans. Roy. Soc. Edinb. 11: 194-209.

EDMONDS, J M 1956A William Buckland (1784-1856). Nature (London), 178: 290-291.
———— 1956B William Buckland (1784-1856). The Anglican Catholic.
———— 1978 Patronage and Privilege in Education: A Devon Boy goes to School, 1798. Rep. Trans. Devon. Ass. Advmt. Sci. III, 95-111.

EDMONDS, J M 1979 The Founding of the Oxford Readership in Geology, 1818. Notes & Records Roy. Soc. Lond. 34: 33-51.
EDMONDS, J & DOUGLAS, J A 1976 William Buckland, F.R.S. (1784-1856) and an Oxford Lecture, 1823. Notes & Records Roy. Soc. Lond. 30 (3): 141-167.
ENGEL, A J 1983 From Clergyman to Don. The Rise of the Academic Profession in Nineteenth-Century Oxford. (Oxford).
ESCHER, S 1978 Ignaz Venetz, Begründer der Eiszeit-Theorie, 1788-1859. pp. 222-233 in Kasser, P (editor), 1978. Gletscher und Klima/ Glaciers et climat. (Jb. Schweiz. Naturf. Gessell. wissen. Teil for 1978).
ESMARK, J 1826 Remarks tending to explain the Geological History of the Earth. Edinb. N. Phil. J. 2: 107-121.

FARADAY, M 1932 Faraday's Diary. Vol. I. Sept., 1820-June 11, 1832. (London).
FAREY, J 1811 General View of the Agriculture and Minerals of Derbyshire. (London).
FEATHERSTONHAUGH, G W 1828 Valuable collection in Geology and Mineralogy. Amer. J. Sci. 14: 197-198.
FIGUIER, L 1874 La Terre avant Le Déluge. (7 ième édition) (Paris).
FLEMING, J 1824 Remarks illustrative of the Influence of Society on the Distribution of British Animals. Edinb. Phil. J. 11: 287-305.
——— 1825 Remarks on the Modern Strata. Edinb. Phil. J. 12: 116-127.
——— 1826 The Geological Deluge, as interpreted by Baron Cuvier and Professor Buckland, inconsistent with the testimony of Moses and the Phenomena of Nature. Edinb. Phil. J. 14: 207-239.
FOOT, M R D 1968 The Gladstone Diaries. Vol. 1: 1825-1832. (Oxford).
FORBES, J D 1846 Notes on the topography and geology of the Cuchullin Hills in Skye, and on the traces of ancient glaciers which they present. Edinb. N. Phil. J. 40: 76-99.
FORSTER, W 1821 A Treatise on a Section of the Strata from Newcastle-upon-Tyne to the mountain of Cross Fell. (revised edition). (Alston).
FOSTER, J 1891 Alumni Oxoniensis vol. I. (Oxford).
FOWLER, T 1891 Corpus Christi College. pp. 273-300 in CLARK, A (editor) 1891. The Colleges of Oxford: their history and Traditions. (London).

GEIKIE, A 1875A The Life of Sir Roderick Murchison. Vol. I. (London).
——— 1875B The Life of Sir Roderick Murchison. Vol. II. (London).
——— 1897 The Founders of Geology. (London).
GEIKIE, J 1874 The Great Ice Age. (London).
GEOLOGICAL SOCIETY 1811 Preface. Trans. Geol. Soc. Lond. 1: v-ix.
——— 1814 List of Donations. Trans. Geol. Soc. Lond. (Ser. 1), 2: 533-546.
——— 1816 List of Donations. Trans. Geol. Soc. Lond. (Ser. 1), 3: 421-432.
——— 1817 List of Donations. Trans. Geol. Soc Lond. (Ser. 1), 4: 451-458.
——— 1824 List of Donations. Trans. Geol. Soc. Lond. (Ser. 2): 1 (2): 429-439.
GEORGE, T N 1932 The Quaternary beaches of Gower. Proc. Geol. Assoc. 43: 291-324.

GILBERT, D 1831 Statement respecting the Legacy left by the late Earl of Bridgewater, for rewarding the Authors of Works, to be published in pursuance of his Will, and demonstrative of the Divine Attributes, as manifested in the Creation. Phil. Mag. (Ser. 2) 9: 200-202.
GILLISPIE, C C 1951 Genesis and Geology. A Study in the Relations of Scientific Thought, Natural Theology, and Social Opinion in Great Britain, 1790-1850. (Cambridge, Mass.).
GORDON, MRS [E O] 1894 The Life and Correspondence of William Buckland, D.D., F.R.S., sometime Dean of Westminster, twice President of the Geological Society, and first President of the British Association. (London).
GREENOUGH, G B 1819 A Critical Examination of the First Principles of Geology: in a series of Essays. (London).
GREGORY, J W 1922 The English "Eskers" - their structure and distribution. Geol. Mag. 59: 22-44.
GROVE, R 1976A Coprolite Mining in Cambridgeshire. Agric. Hist. Rev. 24 (1): 36-43.
——— 1976B The Cambridgeshire Coprolite Mining Rush. (Cambridge).

HALL, J 1814 On the Revolutions of the Earth's Surface. Part II. Being an account of the Diluvian Facts in the Neighbourhood of Edinburgh. Trans. Roy. Soc. Edinb. 7: 169-221.
HAMPDEN, R D 1834 Observations on Religious Dissent with particular reference to the use of Religious Tests in the University. (Oxford).
HARE, A J C 1879 The Life and Letters of Frances Baroness Bunsen. Vol. I. (London).
——— 1900 The Story of My Life. (London).
HILL, A G 1982 The Letters of William and Dorothy Wordsworth. Vol. 6. (2nd edition). (Oxford).
HOME, E 1817 An Account of some fossil remains of the Rhinoceros, discovered by Mr. Whitby [sic], in a Cavern inclosed in the lime-stone, from which he is forming the Break-water at Plymouth. Phil. Trans. Roy. Soc. Lond. (for 1817) 107: 176-182.
HOME, E 1818 Additional Facts respecting the Fossil Remains of an Animal. Phil. Trans. Roy. Soc. Lond. 108: 24-32.
——— 1819 An account of the fossil skeleton of the Proteosaurus. Phil. Trans. Roy. Soc. Lond. 109: 209-211.
HOOYKAAS, R 1959 The Principle of Uniformity in Geology, Biology and Theology. (Leiden).
——— 1970 Catastrophism in geology, its scientific character in relation to actualism and uniformitarianism. Med. Konin. Nederlandse Akad. Wetensch. Afd. Letterkunde. (N.R.) 33 (7): 271-316.
HOWE, S R, SHARPE, T & TORRENS, H S 1981 Ichthyosaurs: a history of fossil 'sea-dragons'. (Cardiff).
HSU, K J 1982 Evolutionary and Environmental Consequences of a Terminal Cretaceous Event. Syllogeus (Nat. Mus. Canada) 39: 140-142.
——— 1983 Actualistic Catastrophism. Address of the retiring President of the International Association of Sedimentologists. Sedimentology 30: 3-9.
HUNT, A R 1902 On Kent's Cavern with reference to Buckland and his detractors. Geol. Mag. 9: 114-118.
HUNTER, J 1794 Observation on the Fossil Bones presented to the R.S. by ... the Margrave of Anspach. Phil. Trans. Roy. Soc. 84: 407-417.
HUTTON, J 1795 Theory of the Earth (2 vols.). (Edinburgh).
HUXLEY, L 1900 Life and Letters of Thomas Henry Huxley, Vol. 1. (London).

INGRAM, J 1837 Memorials of Oxford. Vol. III. (Oxford).
JAMESON, R 1804-1808 System of Mineralogy comprehending oryctognosy, geognosy, mineralogical chemistry, and economic mineralogy. (3 vols.). (Edinburgh).
———— 1822 Essay on the Theory of the Earth By M. Cuvier, with Mineralogical Illustrations (4th Edition). (Edinburgh).
JAMIESON, T F 1863 On the parallel roads of Glen Roy, and their place in the history of the glacial period. Q. Jl. Geol. Soc. Lond., 19: 235-59.
JOPLING, A V 1975 Early Studies on Stratified Drift. pp. 4-21 in JOPLING, A V & McDONALD, B C (editors): Glaciofluvial and Glaciolacustrine Sedimentation. Soc. Econ. Paleont. & Mineral. Sp. Publ. No. 23. (Tulsa, Oklahoma).
JORDANOVA, L J & PORTER, R S 1979 Images of the Earth. Essays in the History of the Environmental Sciences. Brit. Soc. Hist. Sci. Monogr. 1.

KEDDIE, W (ed.) 1854 Cyclopaedia of Literary and Scientific Anecdote: illustrative of the characters, habits and conversation of men of letters and science. (Glasgow).
KENDALL, P F 1902 A System of Glacier Lakes in the Cleveland Hills. Quart. J. Geol. Soc. Lond. 58: 471-569.
KENNARD, A S 1945 The Early Digs in Kent's Hole, Torquay, and Mrs Cazalet. Proc. Geol. Assoc. 56 (4): 156-213.
KER, I & GORNALL, T 1978 The Letters and Diaries of John Henry Newman, Vol. 1. (Oxford).
———— 1980 The Letters and Diaries of John Henry Newman, Volume 4. (Oxford).
KIDD, J 1809 Outlines of Mineralogy. (Oxford).
———— 1815 A Geological Essay on the Imperfect Evidence in support of a Theory of the Earth, deducible either from its General Structure or from the Changes Produced on its Surface by the Operation of Existing Causes. (Oxford).
KIRBY, T F 1888 Winchester Scholars. (London).
KOENIG, C 1818 Synopsis of the Contents of the British Museum (13th Edition). (London).
KRUUK, H 1966 Clan system and feeding habits of Spotted Hyaenas. Crocuta crocuta Erxleben. Nature (Lond.) 209 (5029): 1257-1258.
———— 1972 The Spotted Hyena. A Study of Predation and Social Behavior. (Chicago).
KYNASTON, H & HILL, J B 1908 The Geology of the Country near Oban and Dalmally. (Explanation of Sheet 45). Mem. Geol. Surv. Scot. (Glasgow: HMSO).

LEVY, M 1824 Account of a new Mineral Substance. Ann. Philos. 23: 134-136.
LOCKE, J 1837 Dr Buckland, the geologist. New-Yorker, 3: 339-340.
LOWE, P 1981 The British Association and the Provincial Public. pp. 118-144 in MacLeod, R R & Collins, P 1981 (q.v.).
LYELL, C 1826 On a recent formation of freshwater limestone in Forfarshire ... Trans. Geol. Soc. Lond. (Ser. 2) 2: 73-96.
[LYELL, C] 1827 State of the Universities. Quart. Rev. 36: 216-268.

LYELL, C 1829 On a Recent Formation of freshwater limestone in Forfarshire, and on some Recent deposits of Freshwater Marl. Trans. Geol. Soc. Lond. (Ser. 2) 2: 73-96.
——— 1830 Principles of Geology. London.
——— 1838 Anniversary Address of the President to the Geological Society, 17 February, 1837. Proc. Geol. Soc. Lond. 2, (49): 479-523.
——— 1840 On the Boulder Formation or drift and associated freshwater deposits composing the mud cliffs of eastern Norfolk. Lond. & Edinb. Phil. Mag. 16: 345-380.
——— 1841 On the Geological Evidences of the former existence of Glaciers in Forfarshire. Proc. Geol. Soc. Lond. 3 (72): 337-345.
LYELL, C & MURCHISON, R I 1829 On the Excavation of Valleys, as illustrated by the volcanic rocks of France. Edinb. New Phil. J. 7: 15-48.
LYELL, MRS (K M) 1881A Life, Letters and Journals of Sir Charles Lyell, Bart. Vol. 1. (London).
——— 1881B Life, Letters and Journals of Sir Charles Lyell, Bart. Vol. 2. (London).

MacLEOD, R 1981A Retrospect: the British Association and its Historians. pp. 1-16 in MacLeod, R & Collins, P 1981 (q.v.).
——— 1981B Introduction. On the Advancement of Science. pp. 17-42 in MacLeod, R & Collins, P 1981 (q.v.).
MacLEOD, R M 1983 Whigs and savants: reflections on the reform movement in the Royal Society, 1830-1848. pp. 55-90 in Inkster & Morrell, 1983 (q.v.).
MacLEOD, R & COLLINS, P 1981 The Parliament of Science. (Northwood, Midx.).
MANTELL, G A 1822 The Fossils of the South Downs. (London).
——— 1825 On the Teeth of the Iguanodon, a newly-discovered Fossil Herbivorous Reptile. Phil. Trans. Roy. Soc. Lond. 115: 179-186.
MAURICE, F 1885 The Life of Frederick Denison Maurice, Chiefly told in his own Letters. Vol. I. (4th edition). (London).
McCARTNEY, P J 1977 Henry De la Beche: observations on an observer. (Cardiff).
McENERY, J 1859 Cavern Researches, edited from the original manuscript notes by E Vivian. (London).
MERRITT, J W & LAXTON, J L 1982 The sand and gravel resources of the country around Callander and Dunblane, Central Region. Miner. Assess. Rep. Inst. Geol. Sci. No 121.
MILTON, Viscount 1833 [Speech of the President]. Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1832): 95-96.
MOLYNEUX, T 1697 A discourse concerning the large horns frequently found under ground in Ireland. Phil. Trans. Roy. Soc. Lond. 19: 489-512.
MORRELL, J B 1971 Individualism and the Structure of British Science in 1830. Hist. Stud. Phys. Sci. 3: 183-204.
MORRELL, J B & THACKRAY, A 1981 Gentlemen of Science: Early Years of the British Association for the Advancement of Science. (Oxford).
MOZLEY, D 1962 Newman Family Letters. (London).
MOZLEY, T 1882 Reminiscences, chiefly of Oriel College and the Oxford Movement. Vol. 2. (London).
MURCHISON, R I 1842 Anniversary Address of the President, 18 February 1842. Proc. Geol. Soc. Lond. 3 (86): 637-687.
——— 1857 Dr. Wm. Buckland (in Anniversary Address of the President). Proc. R. Geogr. Soc. 1857: ciii-cviii.

MURDOCH, W 1975 The geomorphology and glacial deposits of the area around Aberdeen. pp. 14-18 in GEMMELL, A M D (editor) Quaternary Studies in North East Scotland. (Aberdeen: University Dept. of Geography).
MURRAY, J 1919 John Murray III. 1808-1892. A Brief Memoir. (London).

NOLAN, F 1833 The Analogy of Revelation and Science. (Oxford).
NORTH, F J 1934 From the Geological Map to the Geological Survey. Glamorgan and the Pioneers of Geology. Trans. Cardiff Naturalists' Soc. 65 (for 1932): 41-115.
———— 1935 Dean Conybeare, Geologist. Trans. Cardiff Naturalists' Soc . 66 (for 1934): 15-68.
———— 1942 Paviland Cave, the "Red Lady", the Deluge, and William Buckland. Ann. Sci. 5 (2): 91-128.
———— 1943 *Centenary of the Glacial Theory.* *Proc. Geol. Ass.* 54 (1): 1-28.
———— 1956 W.D. Conybeare. *His geological contemporaries and* Bristol associations. Proc. Bristol Nat. Soc. 29(2): 133-146.
OLDROYD, D R 1980 Sir Archibald Geikie (1835-1924), Geologist, Romantic Aesthete, and Historian of Geology: The Problem of Whig Historiography of Science. Ann. Sci. 37: 441-462.
ORANGE, A D 1971 The British Association for the Advancement of Science: The Provincial Background. Science Studies 1: 315-329.
———— 1972A The Origins of the British Association for the Advancement of Science. Brit. J. Hist. Sci. 6: 152-176.
———— 1972B Hyaenas in Yorkshire: William Buckland and the Cave at Kirkdale. History Today 22 (11) (November 1972): 777-785.
———— 1973 Philosophers and Provincials. The Yorkshire Philosophical Society from 1822 to 1844. (York).
———— 1975 The Idols of the Theatre: The B.A.A.S. and its Early Critics. Ann. Sci. 32: 277-294.
———— 1981 The Beginnings of the British Association, 1831-1851. pp. 43-64 in MacLeod, R & Collins, P 1981 (q.v.).
OSPOVAT, A M 1971 Abraham Gottlob Werner: Short Classification and Description of the Various Rocks (translated with introduction and notes). (New York).
OUTRAM, D 1980 The Letters of Georges Cuvier. Brit. Soc. Hist. Sci. Monograph No. 2.
OWEN, R 1838 On the fossils representing the Thylacotherium Prevostii ... and the Phascotolherium Bucklardi. Proc. Geol. Soc. Lond. 3: 9.
———— 1841 Observations on the fossils representing the Thylacotherium Prevostii, Valenciennes, with reference to the doubts of its mammalian and marsupial nature recently prmulgated; and on the Phascoletherium Bucklandi. Trans. Geol. Soc. (2nd ser.) 6 (1): 47-65.
———— 1846 A History of the British Fossil Mammals and Birds. (London).
———— 1894 Life of Richard Owen, Vol. 1. (London).

PAGE, L E 1969 Diluvialism and its Critics in Great Britain in the Early Nineteenth Century. pp. 257-271 in SCHNEER, C J 1969 (editor) Toward a History of Geology. (Cambridge, Mass.).
PARKER, C S 1899 Sir Robert Peel from his Private Papers (Vol. 3). London: John Murray.

PARKINSON, J 1811-1814 The Organic Remains of a Former World. (3 vols.). (London).
——— 1822 Outlines of Oryctology. An Introduction to the Study of Organic Remains, especially those found in the British Strata. (London).
PEACH, B N, et al 1910 The geology of the neighbourhood of Edinburgh. Mem. Geol. Surv. Scot.
PENGELLY, W 1866 The literature of Kent's Cavern, Part II. Including the whole of the Rev. J MacEnery's manuscript. Rept. Trans. Devon. Assoc. Advmt. Sci. 3: 191-482.
——— 1873A The ossiferous caverns and fissures in the neighbourhood of Chudleigh, Devonshire. Rept. Trans. Devon. Assoc. Advmt. Sci. 6: 46-60.
——— 1873B The literature of the cavern at Austy's Cove, near Torquay, Devonshire. Rept. Trans. Devon. Assoc. Advmt. Sci. 6: 61-69.
PERKINS, J 1938 Westminster Abbey: Its Worship and Ornaments. Volume a. (Alcuin Club Collections no. 33). (Oxford: University Press).
——— 1952 Westminster Abbey: Its Worship and Ornaments. Vol. II. (Alcuin Club Coll. no. 28). (Oxford).
[PHILLIPS, J] 1857 Obituary notices of deceased Fellows. The Rev. William Buckland, D.D. Proc. R. Soc. 8: 264-268.
PHILLIPS, J 1871 The Geology of Oxford. (London).
PLAYFAIR, J 1802 Illustrations of the Huttonian Theory of the Earth. (Edinburgh).
PLAYFAIR, J G 1822 The Works of John Playfair Vol. 1. (Edinburgh).
PLOMER, W 1956 The Heart of a King: an incident at Nuneham 1856. The Listener, February 1956.
——— 1960 Collected Poems. (London).
PORTER, R 1976 Charles Lyell and the Principles of the History of Geology. Brit. J. Hist. Sci. 9 (2): 91-103.
——— 1977 The Making of Geology. Earth Science in Britain 1660-1815. (Cambridge).
PORTLOCK, J E 1857 Anniversary Address of the President. Proc. Geol. Soc. Lond 13: xxvi-cxlv.
POWELL, B 1832 The Present State and Future Prospects fo Mathematical and Physical Studies in the University of Oxford, considered in a Public Lecture. (Oxford).
——— 1833 Revelation and Science ... with Some Additional Remarks Occasioned by the Publication of the Bampton Lectures for 1833 ... (Oxford).
——— 1834 Religion in its Connection with Science. Brit. Critic 15: 233-234.
POWELL, H P 1984 James Marmaduke Edmonds (1909-1982). [Obituary: signed with initials only]. Geol. Soc. Lond. Ann. Rept. for 1983: 24-25.
PUGH, R K 1970 The Letter-Books of Samuel Wilberforce, 1843-1868. Oxfordshire Record Soc., 47 (for 1969): 1-438.
REID, W 1899 Memoirs of Lyon Playfair. (London).
RICHARDSON, W 1808 A Letter on the Alterations that have taken place in the Structure of the Rocks, on the Surface of the basaltic Country in the Counties of Derry and Antrim. Phil. Trans. Roy. Soc. 107: 187-222.
RICHIE, J 1952 Natural History and the Emergence of Geology in the Scottish Universities. Trans. Edinb. Geol. Soc., 25: 297-316.
ROBERTSON, J 1794 Parish of Callander. Statistical Account of Scotland 11: 574-627. [N.V. Cited p. 273 in E H Francis et al 1971. The Geology of the Stirling District (Sheet 39). Mem. Geol. Survey: Scotland].

ROSE, J & LETZER, J M 1977 Superimposed drumlins. J. Glaciol., 18: 471-80.
ROSE, W C C & DUNHAM, K C 1977 Geology and hematite deposits of South Cumbria. Econ. Mem. Geol. Surv. G.B.
RUDWICK, M J S 1963 The foundation of the Geological Society of London: its scheme for cooperative research and its struggle for independence. Brit. J. Hist. Sci. 1: 326-355.
——— 1969 The Strategy of Lyell's Principles of Geology. Isis 61 (1): 5-33.
——— 1975 Caricature as a Source for the History of Science: De la Beche's Anti-Lyellian Sketches of 1831. Isis 66 (234): 534-560.
——— 1976 The emergence of a visual language for geological science 1760-1840. Hist. Sci. 14 (3): 149-195.
RUPKE, N 1983 The Great Chain of History. William Buckland and the English School of Geology (1814-1849). (Oxford).
RUSKIN, J 1908 Complete Works (40 vols.). (London).
RUSSELL, J 1856 Memoirs, Journal, and Correspondence of Thomas Moore Vol. VII. (London).
SARJEANT, W A S 1974 A History and Bibliography of the Study of Vertebrate Footprints in the British Isles. Palaeogr. Palaeoclim. Palaeoecol., 16: 265-378.
SARJEANT, W A S & DELAIR, J B 1980 An Irish Naturalist in Cuvier's laboratory. The letters of Joseph Pentland 1820-1832. Bull. Br. Mus. Nat. Hist. (Hist. Ser.) 6 (7): 245-319.
SCHNEER, C J 1984 Ideal Section of a Portion of the Earth's Crust. J. Geol. Educ. 32: 38.
SCROPE, G P 1827 Memoir on the Geology of Central France ... (London).
SEDGWICK, A 1833 A Discourse on the Studies of the University. (Cambridge).
SEDGWICK, A & MURCHISON, R I 1832 A Sketch of the Structure of the Eastern Alps. Trans. Geol. Soc. Lond. (Ser. 2), 3 (2): 301-420.
SHAIRP, J C, TAIT, P G & ADAMS-REILLY, A 1873 Life and Letters of James David Forbes, F.R.S. (London).
SHIPMAN, P 1981 Life History of a Fossil. An Introduction to Taphonomy and Paleoecology. (Cambridge, Mass. & London).
SHOTTON, F W 1976 Amplification of the Wolstonian Stage of the British Pleistocene. Geol. Mag. 113: 241-250.
SIMPSON, S 1948 The glacial deposits of Tullos and the Bay of Nigg, Aberdeen. Trans. Roy. Soc. Edinb. 61 (3) (23), 687-698.
SISSONS, J B 1977 The Glen Roy National Nature Reserve (Reading).
——— 1979A The limit of the Loch Lomond Advance in Glen Roy and vicinity. Scott. Jl. Geol., 15: 31-42.
——— 1979B Catastrophic lake drainage in Glen Spean and the Great Glen, Scotland. Jl. Geol. Soc. Lond., 136-: 215-24.
SISSONS, J B & CORNISH, R 1983 Fluvial landforms associated with ice-dammed lake drainage in upper Glen Roy, Scotland. Proc. Geol. Assoc., 94 (1): 45-52.
SKAE, H M et al 1877 Explanation of Sheet 9, Kirkudbright (North-East Part) and Dumfries-shire (South-West Part). Mem. Geol. Surv. Scotland.
SMILES, S 1891 A Publisher and his Friends. Memoir and Correspondence of the late John Murray Vol. II. (London).
SMITH, S 1810 Public Schools of England. Edinb. Rev. 16 (Aug. 1810), 326-334.

SOLLAS, W J 1905 The Age of the Earth and other Geological Studies. (London).

——— 1913 Paviland Cave, an Aurignacian Station in Wales. J. Anthrop. Inst. 43: 1-50.

SOMNER, J 1701 Chartham News; or an Account of some strange Bones dug up near Canterbury. Phil. Trans. Roy. Soc. Lond. 22: 882-893.

SOWERBY, J 1818 Mineral Conchology Vol. 2. (London).

STANLEY, A P 1844 The Life and Correspondence of Thomas Arnold, DD. Vol. 1. (London).

STEVENS, J C (Auctioneer) 1857 A Catalogue of the very valuable scientific Library of the late Very Rev. Dr. Buckland ... Sold by Auction ... 26th day of January 1857. (London).

STRACHEY, L & FULFORD, D 1938 The Greville Memoirs, 1814-1860. Vol. 5. (London).

STUART, A J 1982 Pleistocene Vertebrates of the British Isles. (London).

SUTCLIFFE, A J 1970 Spotted Hyaena: crusher, gnawer, digester and collector of bones. Nature. Lond. 227: 1110-1113.

SWINTON, W E 1970 The Dinosaurs. (London).

TAYLOR, F S 1952 The Teaching of Science at Oxford in the Nineteenth Century. Ann. Sci. 8: 82-112.

THOMPSON, H L 1899 Henry George Liddell, D.D., Dean of Christ Church, Oxford. A Memoir. (London).

TODHUNTER, I 1876 William Whewell, D.D., An Account of his Writings (2 vols.). (London).

TOWNSEND, J 1813 The Character of Moses established for veracity as an historian: recording events from the Creation to the Deluge. (Bath & Londo

TRISTRAM, H 1956 John Henry Newman: Autobiographical Writings. (London).

TUCKWELL, W 1901 Reminiscences of Oxford. (London).

VENETZ, I 1833 Mémoire sur les variations de la température dans les Alpes de la Suise, rédigé en 1821. (Denkschr. der Schweitz. Naturforsch. Gesell. 1833).

——— 1861 Mémoire sur l'extension des anciens glaciers, renfermant quelques explications sur leurs effets remarquables. [read in 1829]. Denkschr. der Schweitz Naturforsch. Gessell. 18.

VENN, J A 1940 Alumni Cantabrigiensis. Part II. From 1752 to 1900 Vol. 1. (Cambridge).

VIVIAN, E 1847 Extract of a letter from Mr E. Vivian of Torquay, respecting the phenomena of Kent's Cavern. Rept. Trans. Brit. Assoc. Advmt. Sci. (for 1846): 73.

WAINEWRIGHT, J B 1907 Winchester College 1836-1906. A Register. Winchester, P. & G. Wells.

WALKER, H A 1923 Constitutions and Canons Ecclesiastical, 1604. (Oxford).

WALKER, J 1787 Classes Fossilium: Sive, Characteres Naturales et Chymici Classium et Ordinum in Systemata Minerali cum nominibus genericis adscriptis. In Usus Adademicos. (Edinburgh).

——— 1792 Institutes of Natural History being the Heads of the Lectures delivered in the University of Edinburgh. (Edinburgh).

WALKER, J 1803 An Essay on Peat ... Trans. Highland Soc. Edinb. 2: 1-163.
———— 1822 Notice of Mineralogical Journeys, and of a Mineralogical System. [Posthumous]. Edinb. Phil. J. 6: 88-94.
———— 1966 Lectures on Geology (Edited by H.W. Scott). (Chicago and London).
WARD, G R M & HEYWOOD, J 1851 Oxford University Statutes. Vol. II: 1767-1850. (London).
WEAVER, T 1819 Memoir on the Geological Relations of the East of Ireland. Trans. Geol. Soc. 5 (1): 117-304.
WEINDLING, P J 1979 Geological controversy and its historiography: the prehistory of the Geological Society of London. pp. 248-271 in Jordanova & Porter, 1979 (q.v.).
WEINDLING, P 1983 The British Mineralogical Society: a case study in science and social improvement. pp. 120-150 in Inkster, I & Morrell, J, 1983. Metropolis and Province. Science in British Culture 1780-1850. (London).
WHEWELL, W 1839 Anniversary Address of the President. Proc. Geol. Soc. Lond. 3 (1) (61): 61-98.
WHIDBY, J 1823 On some Fossil Bones discovered in Caverns in the Lime-stone Quarries of Oreston. Phil. Trans. Roy. Soc. Lond. 113: 78-90.
WHITE, G W 1970 Announcement of glaciation in Scotland. William Buckland (1784-1856). J. Glaciol. 9 (55): 143-5.
WILLIS, A J 1964 Winchester Ordinations 1660-1829. Vol. 1. (Winchester).
WILSON, L G 1972 Charles Lyell. The Years to 1841: The revolution in geology. (New Haven & London).
WOODCROFT, B 1969 Alphabetical Index of Patentees of Inventions. [Reprint of edition of 1854] (London).
WOODWARD, B B 1901 Mary Anning (1799-1847). Dictionary of National Biography: Supplement 1.
WOODWARD, H B 1883 Dr. Buckland and the Glacial Theory. Midland Nat. 6: 225-229.
———— 1907 The History of the Geological Society of London. (London).

YEO, R 1981 Scientific Method and the Image of Science, 1831-1890. pp. 65-88 in MacLeod, R & Collins, P 1981 (q.v.).
YOUNG, G 1822 On the Fossil Remains of Quadrupeds, etc. discovered in the Cavern at Kirkdale. Mem. Wernerian Nat. Hist. Soc. Edinb. 4 (1): 262-270.
YOUNG, G & BIRD, J 1822 A Geological Survey of the Yorkshire Coast. (Whitby).
———— 1828 A Geological Survey of the Yorkshire Coast. (2nd Edition). (Whitby).