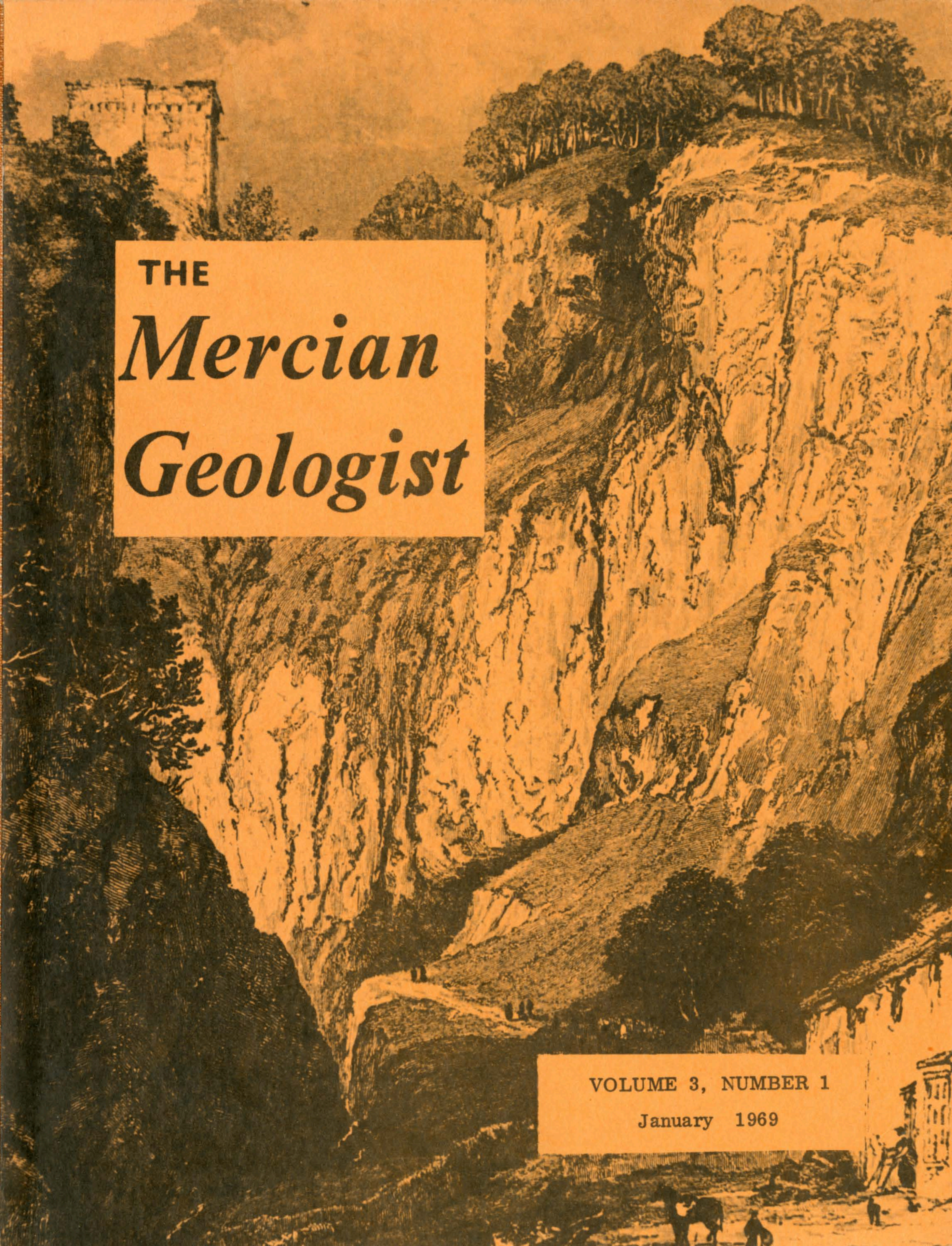
THE *Mercian Geologist*



VOLUME 3, NUMBER 1
January 1969

THE MERCIAN GEOLOGIST

JOURNAL OF
THE EAST MIDLANDS
GEOLOGICAL SOCIETY

VOLUME 3. NUMBER 1.

JANUARY 1969.

CONTENTS

Address for correspondence:

The Secretary, East Midlands Geological Society,
Department of Geology,
The University,
Nottingham, NG7 2RD,
England

Price of this issue: 15/-

Subscription rates and other information may be obtained from the Secretary.

The Front Cover: Reef limestones of the Eyam Limestone Series (Uppermost Carboniferous Limestone Zone B_2), with the narrow cleft leading to Peak Cavern and, on the hilltop, Peak (Peveril) Castle; Castleton, Derbyshire. From a 19th - Century print.

(Photo: J. Eyett)

ALCIDE D'ORBIGNY AND THE STAGES OF THE JURASSIC

by

Michel Rioult

Translated from the French by William A.S. Sarjeant,

assisted by Anne Margaret Sarjeant

Summary

The work and ideas of Alcide d'Orbigny (1802-57) in the formulation of the concepts of stratigraphy, and especially in their application to the Jurassic, are examined in their historical context and reconsidered in the light of modern knowledge. It is shown that to regard d'Orbigny simply as an advocate of the long-abandoned theory of catastrophism is to severely undervalue his work: his studies, in fact, anticipated many of the ideas today current in stratigraphy. In a postscript, the recent assessment of d'Orbigny's work by a Belgian writer, C.L.V. Monty, is critically examined.

(Translators' Preface. This paper was presented, and distributed in preprint, in the original French, to the 2nd International Colloquium on the Jurassic, held in Luxembourg, 1967. It is considered to be of great potential interest to English readers, in view of d'Orbigny's importance in the history of stratigraphical palaeontology and in view of the fact that the Jurassic has come to be the test-case for the establishment of internationally acceptable stratigraphic subdivisions. England has perhaps the World's finest, and faunistically richest, series of exposures of the Jurassic; and fully half of the stages proposed by d'Orbigny have English stratotypes. Two of these, the Kimmeridgian and Portlandian, remain a cause for dispute even after two International Colloquia. Since the "Comptes rendus" of the 2nd International Colloquium have not yet appeared, M. Rioult's work is here published for the first time.

This translation attempts to follow the French text as closely as possible, but a number of passages have needed to be rephrased as a result of differences between French and English idioms or for purpose of clarification. The final text has been checked and approved by the author: it appears by permission of M. P.-L. Maubeuge, Chairman of the two Luxembourg Colloquia).

> "ALCIDE DESSALINE D'ORBIGNY, born on the 6th September, 1802, at Couëron (Loire Inférieure), received his early education in La Rochelle, and devoted himself very early to zoological and palaeontological studies. In 1826 he was sent to South America by the Museum in Paris, and brought back with him splendid collections of zoological, geological, ethnographical, historical and archaeological interest. The results of this journey were afterwards published in a comprehensive work. His later works deal with palaeontological and stratigraphical subjects. In 1853 d'Orbigny was appointed Professor of Palaeontology at the Museum in Paris, the Professorship being established especially for him: died on the 30th June, 1857, at Pierrefitte near Saint Denis".

K.A. VON ZITTEL, 1901:
"History of geology and palaeontology to the end of the Nineteenth Century". London: Walter Scott, 562 pp. (footnote to p.506).
[Date and place of death here corrected].

Introduction

In 1962, the first International Colloquium on the Jurassic, held in Luxembourg, provided the occasion for a large-scale bringing-together of the results acquired during the study of the Jurassic. What characterised the spirit of that international meeting was, without question, the constant search for understanding, which led to numerous agreements and a few compromises. The desire to progress only with caution, in order to avoid enclosing stratigraphy prematurely in a too rigid framework, was expressed by the expounding of very diverse conceptions and the postponement of decisions regarding the limit of certain stages, together with those of subsidiary divisions, the proposed delimitation of which brought about a confrontation between the German, English and French schools of geologists in particular. The extremely rich and positive balance-sheet from the working sessions of this meeting, and the numerous papers presented, served to form the basis for the preparation of the second Colloquium.

However, after reading the contributions to the first Colloquium and on the point of resuming discussions relative to the stages of the Jurassic, it seemed to me vital to return briefly to the sources and to focus attention on certain aspects of the work of Alcide d'Orbigny which are unknown, misunderstood or else forgotten and which constitute, whatever one may think of them, the basis of the first attempt to formulate a general stratigraphic scheme for the Jurassic.

The small divergences which exist between the different national delegations present at Luxembourg express conceptions of stratigraphy different from those expounded by d'Orbigny. I wholeheartedly repudiate any chauvinism, polemics or exclusivism. I will stress only the original characteristics of Alcide d'Orbigny's method, placing it into its historical context; and I hope to show in conclusion that the diverse points of view expressed, far from being incompatible, are to be placed on two planes which are different, but subordinate one to another, and finally, that these conceptions are complementary.

The place of d'Orbigny's work in the history of the geological sciences

At the beginning of the nineteenth century, in Europe, two of the great geological disciplines - stratigraphy and palaeontology - were developing in parallel fashion at an accelerated momentum.

Between 1794 and 1817, William Smith, working in the region of Bath, focussed attention on a classification of the Jurassic strata, when he rediscovered the principle of the superposition of strata and the fossils they contained; these principles he used for the first time in the simultaneous elaboration of a stratigraphical scale and a geological map. Very quickly, the English geologists applied this method in the study of the strata of diverse regions; for example, Roderick Murchison in the Palaeozoic of Wales, John Phillips in the Jurassic of Yorkshire, and Richard Fitton and Gideon Mantell in the Cretaceous of southeast England. The travels of William Buckland and Henry de la Bèche on the Continent, the exchanges between European geological societies and between the great national museums, combined to make the results obtained in Great Britain better known.

During this period, France and Germany were not inactive. Alexandre Brongniart and Georges Cuvier studied the succession of the various Tertiary beds of the Paris basin, extending step by step the horizontal and vertical correlations. In Germany, the schools of Fuchsel and Werner developed the study of mineralogy and applied geology, whilst Alexander von Humboldt and Leopold von Buch respectively subdivided the Jurassic beds of Württemburg and Swabia. F.A. Quenstedt was beginning his geological and palaeontological researches.

At this same period, France was witnessing the Golden Age of palaeontology. At the Natural History Museum in Paris, J.-B. de Lamarck was formulating the broad outlines of transformism, sustained and developed by E. Geoffroy Saint-Hilaire. On the other hand, Cuvier was establishing vertebrate palaeontology on the solid bases of comparative anatomy, whilst Adolphe Brongniart undertook the publication of his palaeobotanical studies.

This ferment of natural sciences was fostered in England and in France by actualism, which was a new scientific mentality rather than a new doctrine; its roots were very ancient, but it seems to have taken form, in France, as a consequence of the Revolutions, the social upheavals which they brought about and the shaking of Christian dogma. In Austria, the actualist outlook had known a period of favour in geological circles, but it was above all in Britain that James Hutton, John Playfair, Charles Lyell and their pupils, and, after Buffon, in France, Constant Prévost and his disciples, perceived certain analogies between past worlds and living Nature. Little by little, they came to realise that certain natural phenomena, observable in our time, could explain a large number of phenomena of the past, without need for recourse to mysteries and catastrophes. This fecund hypothesis, which had already given birth to comparative anatomy, yielded equally good results in geology.

It is at this crossroads of ideas, and in this current of renewal of concepts and scientific methods, that the work of Alcide d'Orbigny must be placed. Initiated very young into the natural sciences by his father, a learned scholar of Charente, and by his elder brother Charles d'Orbigny, Alcide d'Orbigny was always to be both zoologist and actualist. His work, poorly understood by his contemporaries, remained unfinished, cut short by an early death. His successors very quickly placed his "doctrine" in the shadow of that of the great Cuvier and preserved only two important ideas: the theory of "global revolutions" (catastrophism) and that of "successive creations" (creationism). Branded by these two "tags", Cuvier and d'Orbigny have been represented to posterity as the two principal adversaries of Lamarck's transformism; this does not entirely express the truth. This very cursory view of the work of d'Orbigny is, in fact, merely a very schematic reflection of the ideas of this visionary, forever contemplating both the present and the past, both space and time. His principal stratigraphical publications are the "Prodrome de Paléontologie stratigraphique universelle des animaux Mollusques et Rayonnés" (1850-1852), the volume "Céphalopodes" of the "Paléontologie Française - Terrain Jurassique" (1842-1851) and in particular his "Cours élémentaire de Paléontologie et géologie stratigraphiques" (1849-1852).

But these "classic" works were only a small part of his scientific output; he in fact added to them numerous palaeontological and zoological studies on the Foraminifera, crinoids, cephalopods, etc., and a certain number of less well-known works, among which one may mention the 9 large volumes and 500 plates relating to his "Voyage en Amerique méridionale" and his important natural history monographs dealing with the Canary Islands, the Antilles, Cuba, Colombia, the Argentinian Pampas, and Patagonia and with the margins of the Caspian Sea, the Caucasus, the Crimea and European Russia. The majority of his works were published between his return to France and the year which preceded his death, when he fell ill with a cardiac disease. With his collections, his classes and his travels in France, his scientific writings combine to bear witness to 22 years of exceptionally frantic work, in which d'Orbigny sought consolation from the mockery, the jealousies and the lack of understanding, even the hostility, of the contemporary scientific world.

What appears to me essential, in any examination of the conclusions presented by d'Orbigny, is the necessity of accommodating our twentieth-century minds to the realities of his epoch, to the ideas which served as bases for his thinking and which have necessarily changed and developed, from the very meaning of the vocabulary to the whole scientific outlook. Moreover, it is not always easy to take into account this shift of meaning and outlook, brought about by the development of the sciences and the scientific world, when trying to obtain a conception of the work of a scientist. However, I have striven my utmost to keep as close as possible to his texts and to continually distinguish between d'Orbigny's own thoughts and the ideas I might personally have of his work.

Alcide d'Orbigny, actualist

In his zoological and geological researches, Alcide d'Orbigny was very broadly receptive to all concerning the present-day marine domain. On the philosophical plane, there can be no doubt, from the reading of his works, that the theory of natural causation orientated his researches - as much the "actualist" principles of his colleague Constant Prévost as the ideas expounded by Charles Lyell and Charles Darwin, to which he makes allusion several times.

But, first of all, what does one understand by actualism? Prévost defines the theory himself.

> "The doctrine of actual causes ("causes actuelles") does not assume, according to my interpretation and contrary to the ideas of many geologists, the identity and eternity of the same causes and the same effects, but instead the necessary and natural connexion between causes and effects which mutually modify each other in such a way that the successive facts produced, not only may, but must vary; that new things may manifest themselves whilst others cease to be produced, without one having the right to suppose, for this reason, any alterations in the great immutable laws of Nature or any upheavals, cataclysms or revolutions which would not be the consequences of these same laws."

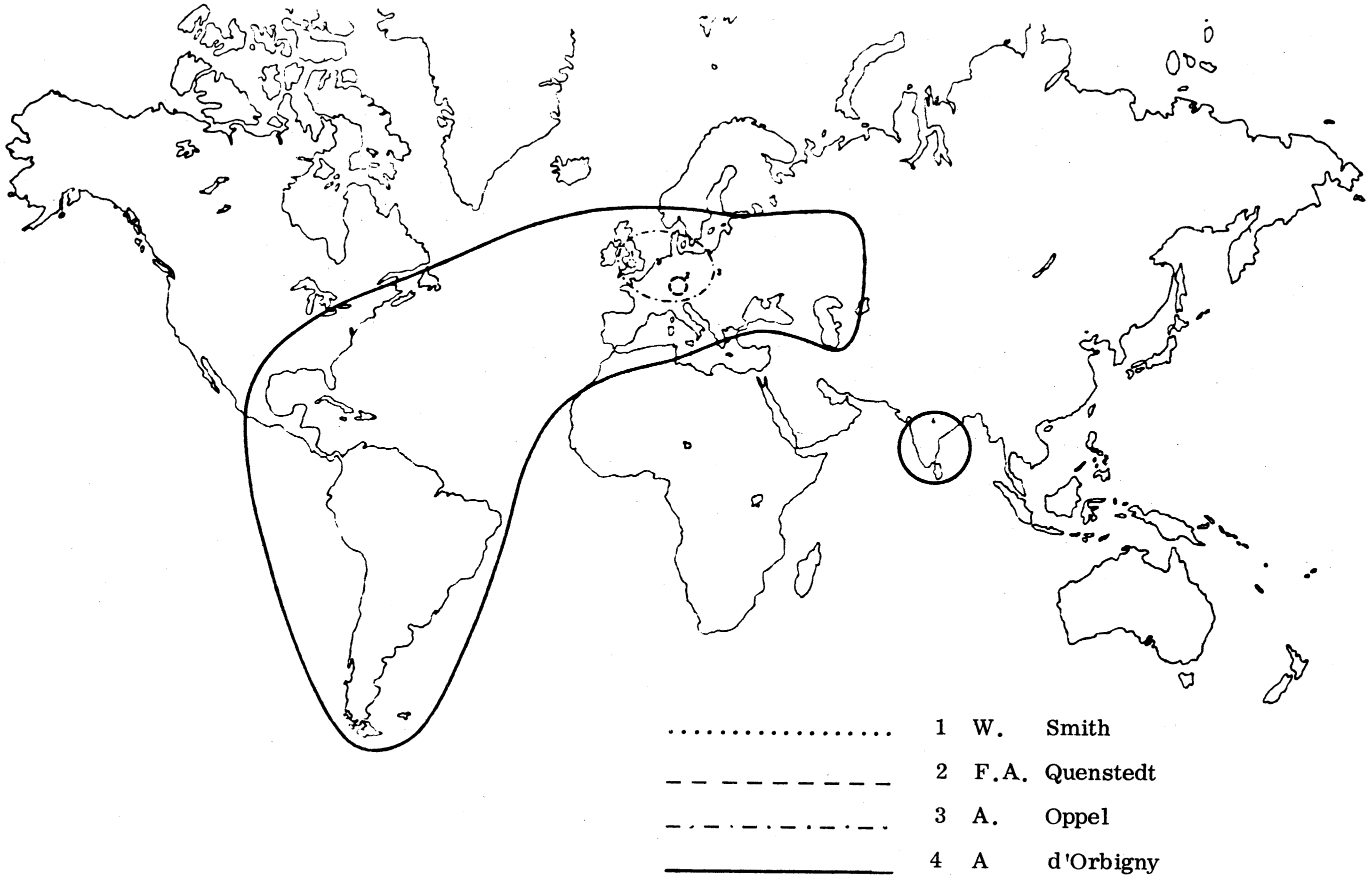
It would be more exact to speak of the doctrine of "natural causes".

From the beginning of his researches, Alcide d'Orbigny visualised geology and palaeontology on a universal scale ("Cours élémentaire," II, 1851, pp. 264-6), invoking great planetary phenomena governing the oceans, the atmosphere, and the crust of the earth (currents, rotation of the earth, the tectonic theories of Elie de Beaumont and of Cordier, etc.). Several times, he writes that "present-day causes may alone explain many past events." From his youth onwards, d'Orbigny accumulated observations on natural phenomena and living organisms. From the Atlantic coasts of Charente to the remote shores of South America, he constantly enriched his understanding of the marine and terrestrial environment.

As zoologist and palaeontologist, he studied the invertebrates, from the coasts of the Atlantic, the Pacific, the seas of the Antilles and the English Channel. Their systematics, their modes of life, the conditions of death, decay and burial were examined turn by turn. As a consequence of the researches of Alexander von Humboldt, he studied the geographic distribution of organisms as a function of currents, climates and remoteness from coasts, in the coastal, littoral, pelagic and deep-water zones. The meticulous study of the fauna of molluscs from the Atlantic and Pacific shores of South America showed him the differences between two oceanic basins, whilst that of the invertebrates from the shores of Charente, Cuba, the Antilles, the Canary Islands, etc., made evident to him the variation in the population of the marine bottoms in the same ocean. He did not study only the distribution of living animals, but also devoted special attention to the distribution of dead organisms floated or shifted along the bottom. These researches dealt with the distribution of terrestrial organisms as a function of Continental configuration, latitude, altitude, and the living environments, as well as those of the marine organisms as a function of the morphology of coasts and sea bottoms, latitude, depth and environment. Finally, the influences of environment and mode of life on the organisms themselves were considered ("Cours élémentaire", I, 1849, pp. 5-7).

As geologist d'Orbigny studied present-day sediments, their composition, their provenance and their distribution in the sea according to the relief of the Continents and the outline of the coasts, the hydrodynamic conditions and the shape of the sea-floor.

"Molecules and sediments animated and deposited by the waters which overlap



Text-fig. 1 Comparative fields of geological experience for some pioneers in stratigraphy.

> the land and which, in all the ages of the World, have tended to level the irregularities of the terrestrial and marine surface".

He treats equally with sediments as a milieu for life and for fossilisation. He is concerned with textures of mechanical origin (horizontal and oblique stratification), ripples and imprints of raindrops, and textures of biological origin, such as footprints, borings and impressions of diverse character. To cite some examples of observations which would not be repudiated by modern sedimentologists: he described the cross-stratifications in the sandy levées of a delta, he was the first to note the constant direction of the cross-stratification in the Pierre de Langrune (Upper Bathonian of Normandy), as well as the orientation of floated logs and of shells parallel to the line of the Bathonian shore in Normandy. He wrote on this subject that one found "in scrutinising the bottoms of the shores many points capable of being applied in geology" and further noted:-

> "We should also recognise that the mineralogical character of the beds has served only to deceive observers little acquainted with the elements of stratigraphy drawn from present-day causes, which often made them see quite erroneous parallelisms".

The factors of disturbance of sedimentation, contemporary to or later than its deposition, were attentively examined - waves, tempests and tides, but also earthquakes, tectonic movements, tiltings, foldings and dislocations.

Like Alexander von Humboldt, he treated both with climatology and comparative geography, from Primary to Tertiary, and considered the role of currents and of isothermal zones ("Cours élémentaire" 1851, II, pp. 239-43). As early as 1852, d'Orbigny wrote with regard to the Jurassic (ibid., 1852, II, pp. 432-3):

> "The presence, in this period, of the same genera and the same species of animals, from the Torrid Zone to the Polar Circle, would prove that the temperature was uniform on the globe, in consequence of the central heat, and that no isothermal line yet existed on the globe. The composition of these faunas would show also that they were analogous to the present-day tropical faunas".

Volume 1 of his "Cours élémentaire de Paléontologie et de Géologie stratigraphiques" (1849) contains a second section (pp. 70-157) which is, in fact, a veritable précis of actualist ideas.

This zoologists' outlook, very receptive to observations of the earth, and this wide experience with present-day Continental and marine environments, confer a great originality on the works of Alcide d'Orbigny and show a marked contrast with many of his contemporaries and successors, in particular with those who were to critize his work.

Alcide d'Orbigny, zoologist and palaeontologist

Already very advanced in the study of the different branches of the natural sciences, d'Orbigny began to complete his learning, as soon as he arrived in Paris, in particular at the Museum of Natural History, where he followed the courses given him by E. Milne-Edwards and met the specialists of the period. He studied anatomy, physiology, embryology and the ecology of marine invertebrates, as Cuvier had studied the vertebrates. Ontogenetic development, ecology and systematics held his attention longest. He fixed his attention, first of all, on those characteristics of living organisms which do not disappear in fossilization. He experimented on the environmental conditions disadvantageous to marine organisms, showing in particular that cuttlefish and squids die rapidly in turbid waters and even in waters charged with black produced by their own ink-sacs.

The conchological observations made on the rich collections of the Museum gave him a wide experience with living invertebrates, an experience increased and renewed in the course of a long journey which he undertook in America, from north to south, from east to west (1828-36); and from which he returned at the same time as Darwin, who had left for America in 1831.

In his palaeontological researches, d'Orbigny was able to put into practice all his zoological knowledge. He personally studied almost all classes of marine invertebrates.

His admirable work on the Foraminifera made him the foremost micropalaeontologist and represent a considerable addition to our knowledge of these organisms, which have acquired such a great place in stratigraphical studies since the nineteenth century. He studied them from the Jurassic, Cretaceous, Tertiary and Recent. He imposed his own classification and showed, for the first time, the stratigraphical value of the Foraminifera.

He treated in the same degree the sponges, the coelenterates, the molluscs (pelecypods, gasteropods and cephalopods), the Bryozoa, the brachiopods and the echinoderms (crinoids and echinoids). He always made his own original contributions, notably in the domain of their systematics and stratigraphical distribution.

In the phylum of sponges, he noted the importance of tissues and of spicules for the fossil forms.

In the classification of the pelecypods, he laid stress on the variation of the pallial line and introduced the distinction between integripallial and sinupallial, explicable in terms of the particular modes of life.

He applied geometric methods to the gasteropods, inventing the helicometer for measuring the spiral angle of the shells; he stressed the ontogenetic variations of the ornamentation and the systematic value of the characters of the peristome.

For the cephalopods, he took count of the different ontogenetic stages, gerontic degeneration, sexual dimorphism, the teratological cases and the ecological variations ("Cours élémentaire" 1849, I, pp. 266-7). He tried to define, for each class of molluscs, the limits of variation according to the zoological knowledge of the time (ibid., 1849, I, p. 269).

He did not neglect ichnology and the conditions of fossilization in their chemical aspects (diagenesis, favourable environments) and mechanical aspects (deformation of the fossils).

His method of comparative anatomy of invertebrates, inherited from Cuvier and Alexandre Brongniart, caused him to revise the systematic criteria and to introduce a new spirit into stratigraphical palaeontology.

On a more elevated plane, he attempted to define statistically, following the tremendous systematic revision undertaken in the "Prodrome", the periods of "growth" and of "decline" of the various groups of fossil invertebrates, just as the modern evolutionists are doing once more.

Not only did he study the rich French and foreign palaeontological collections in the official Parisian and provincial establishments, but also he collected fossils in the field, himself, from the classic localities, guided by the best regional geologists. He thus explored all the provinces of France, in addition examining the local collections. Foreign material at his disposal came from Europe

(England, Germany, Norway, Sweden, Russia from north of the Urals to the Crimea, Italy and Spain), Asia (the Indies, Cutch and Pondicherry) and South America (notably Colombia, Chile, Peru and the Magellan Strait).

In brief, he amassed a quantity of observations in the field, and palaeontological documents which, together with bibliographical compilations comprising the summation of all the zoological and geological literature at his disposal, were to constitute the basis for his revisions and his syntheses.

As zoologist and palaeontologist, he was always to show the double concern of the systematist and the stratigrapher.

Alcide d'Orbigny, systematist

After the work of the Encyclopaedists and that of Lamarck, Alcide d'Orbigny entered palaeontology at a time when, throughout Europe and in America, the great catalogues of fossils for each region were being undertaken; most often hampered by territorial considerations, these voluminous inventories, rarely illustrated, were arranged sometimes in geological order, sometimes in zoological order, sometimes even in alphabetical order. In the course of his travels in America, he discovered the American and Canadian geological work: the fossils collected in these regions, only newly accessible to geology, added further to the nomenclatural chaos which had not ceased to build up in every country of old Europe.

Confronted by this state of things, d'Orbigny reacted immediately and undertook the revision of the nomenclature of living and fossil invertebrates, from the base of the Silurian to the present day; he hoped to find a solution leading to systematic unity and stability. He thus attacked the most urgent problem, taxonomy. Not only was he the first palaeontologist to give family names a uniform and euphonious suffix, -idae, and to resume the critical definition of names of genera and species, but also he introduced detailed lists of synonyms and applied the principle of priority. He founded his critiques on examination of figures and of topotypes (i.e. specimens obtained from the type locality of the species in question). Unfortunately, he incorrectly applied the principle of priority to the genus as well as to the species; this is expressed in his studies by the substitution of his name for that of the first describer of the species which he is redescribing and classing, and it drew upon him lasting enmities. D'Orbigny refused to adopt the precedent advocated by contemporary English systematic zoologists, which consisted of adding the word species or the abbreviation sp. after the name of the author of the genus, to clarify the fact that the latter was not the author of the species (which procedure is today replaced by the writing of the name of the author in parenthesis).

The strict application of the Linnaean binomial nomenclature and of the rule of priority; the employment of uniform and euphonious suffixes for higher systematic categories; the precise diagnosis of genera and species, their resemblances and differences; the discussions of the history of taxonomic terms; details of the place of lodgement, the place of collection and of the stratigraphical horizon; usable illustrations; all this mass of data demanded by the modern palaeontologist truly commenced to appear in palaeontology through Alcide d'Orbigny and the "Paléontologie Française". Certainly, not all is perfect in the realisation of these ideas, but the concept, the spirit and the plan of the undertaking are beyond criticism.

Fourteen years of researches into zoological and geological literature, in collections and in the field, were necessary for him in order to understand the value of the stratigraphic, as well as geographic, distribution of the different species of fossils. D'Orbigny compiled a list of 200,000 species names, of which 40,000 were those of fossil species. A stringent critical revision reduced the number to 18,000 names of species, distributed into 1,440 genera. The spirit which guided d'Orbigny in the systematic chapters of his "Cours élémentaire de Paléontologie et de géologie stratigraphique" (I, 1849, pp. 158-294; II, 1851, pp. 1-258) is identical to that which guided the elaboration of the treatises of Karl von Zittel, Jean Piveteau and Raymond C. Moore. In the wearisome labour which is represented by the "Prodrome", d'Orbigny attempted to formulate a language, a code for an international nomenclature, universal in application, internally consistent, with its own rules and units.

Above all, he was plainly aware that fossils represent only a part of the living organisms ("Prodrome", 1850, p. XXVIII) and that their classification can only be attempted on the basis of the palaeozoological study of their remains, i.e. essentially their morphology and internal structure - from this he drew his ideas regarding the generic form and specific form.

In his studies of invertebrates, he advocates the acquisition of a thorough knowledge of these organisms in present-day Nature, in order to use the method of comparative palaeontology. He warns against morphological groupings proposed without appropriate examination of the tests and skeletons.

For him, the classification of fossil invertebrates is important at the level of genera and species. But it must be stressed that in relation to our present-day knowledge, the systematic categories of d'Orbigny are much larger - for example, most ammonites were still grouped into the genus Ammonites Bruguière and the single species Ammonites margaritatus (d'Orbigny) contained the whole extent of the genus Amaltheus de Montfort, as it is understood today.

[The genus (or the generic form) was, for d'Orbigny, a systematic division of order higher than the species, but it was not just any kind of grouping of species (in the sense which he understands them), for in his definition, stratigraphical distribution plays an essential role, alongside external similarities. For him, the attribution of a generic name needed to be thoroughly discussed in a determination, because of the importance of the genus in stratigraphy. The generic name must be treated in the same way as a species name, according to the principle of priority, with a concern for fairness and stability. In subdividing an older genus, one must take care to religiously preserve the original name for one of the divisions established, whatever the number of divisions, and as far as possible for the species which combines the most distinctive characters indicated by the proposer of the original genus. D'Orbigny also emphasises the necessity of knowing precisely the age of appearance and disappearance of the genera.

The species (or the specific form) is a concept which d'Orbigny allies to the notion of the species in zoology.

> "The natural division of species, based on extended studies, on the minute examination of many specimens of all ages, collected in the best geological conditions, accords in every respect with the most stringent zoological requirements and leads to the most positive geological results, when applied to the recognition of the age of stages". (Cours élémentaire", 1849, I, pp. 5-6).

And again:-

> "When one has no other guide than the conchological characteristics, which is the case for all fossil species (of molluscs), it is advisable to compare a large number of individuals collected from the same horizon, in order to make sure of the diverse variations, so as not to erect species that are based simply on growth stages, on varieties, on deformations or on states of fossilization. In general, with regard to the Cephalopods, one must take especial account of age and of pathological cases. For the gasteropods, age differences, pathological cases, and local influences are even more important in their effects. For the bivalves and brachiopods, age and local influences must above all be studied with care". (Cours élémentaire", 1849, I, p. 269).]

D'Orbigny lays stress on the range of variation of the species in the molluscs in particular; with regard to the ammonites, one must not confuse true species with the various phases of individual growth (ontogeny) with morphological modifications of the shell determined by the environment (ecophenotypes), by sex if these organisms prove to be separated into sexes (sexual dimorphism), or by simple accidents of mechanical, pathological or teratological origin ("Cours élémentaire", 1849, I, pp. 267-9; "Prodrome", p. XLIX). The limits to adopt in specific determinations vary according to the organisms considered: they are proportionately more restricted as the organism is more advanced in organisation and "as it enjoys more liberty in its existence, and conversely, proportionately wider as the organism is less free in its movements and as it is more sedentary" ("Cours élémentaire", 1849, I, p. 6).

> "The name of the species must be as sacred as that of the genus. It must be, likewise, always the oldest and, in this respect, it is good to go back as far as 1757, that is to say to the works of Adanson and Linné, who instituted the specific name and placed it as adjective to the genus. Starting from the same principle of justice and fairness as for the generic name, species must invariably bear the oldest name with which a description was published." ("Prodrome", p. L.).

Alcide d'Orbigny was a supporter of the binomial nomenclature of Linné and an adversary of the trinomial nomenclature utilised by J.A. Eudes-Deslongchamps for varieties:

> "If these so-called varieties are constant, if they have well-defined limits, if, in a word, they may be always circumscribed and distinguished, then these are no longer varieties but veritable species ("Prodrome", p. XXVIII).

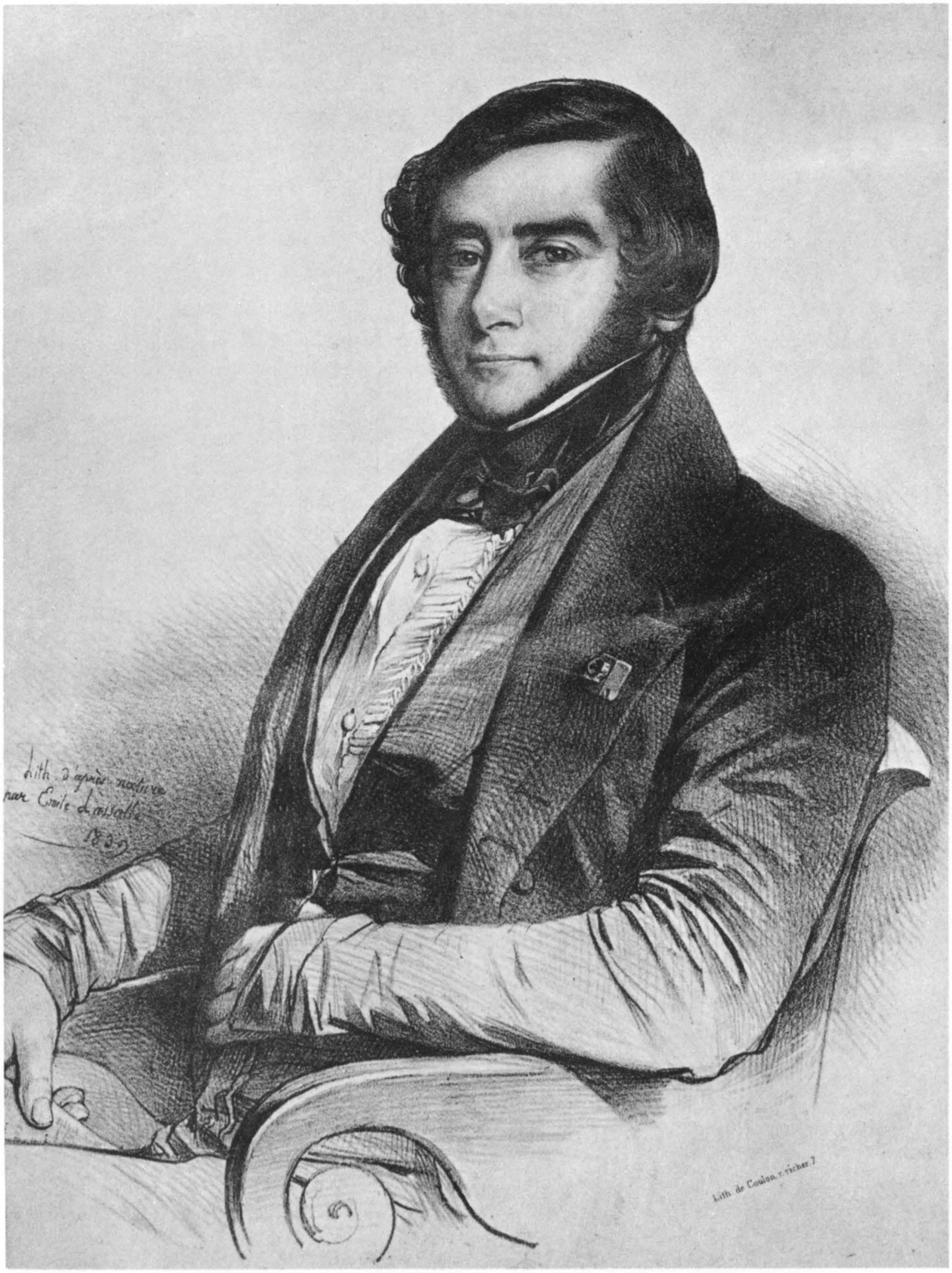
In systematics, d'Orbigny thus introduced and applied a method of classification whose concept and broad principles are still vigorously surviving in our own age.

Alcide d'Orbigny and the "global revolutions"

In the course of his researches, Alcide d'Orbigny ascertained that each of the characteristic faunas, which he recognises as a stable unit across numerous countries, is separated from the subjacent and superjacent fauna by two lines of demarcation, representing two natural upheavals. As these lines of demarcation are constantly found at the limits of the same faunas, he concludes from them that "catastrophes" have affected the whole surface of the globe and that they have quickly made the rounds of the earth. He thus arrived at the idea that the succession of living beings were intercalated into a succession of planetary upheavals, the "global revolutions".

In our Jurassic series, a hiatus occurs periodically between the successive stages, which may be more or less important and well marked according to whether one is in the epicontinental or geosynclinal regime. This discontinuity is often made manifest, either by an angular discordance, or by an erosional surface, or by a conglomerate or a condensed deposit, which may be glauconitic, phosphatic or ferruginous. Alcide d'Orbigny speaks only of "discordance", but he distinguishes three types ("Cours élémentaire", 1849, I, pp. 148-157):-

> discordances of stratification or discordances of isolation, suggesting a dislocation between the deposition of the beds.
>
> discordances of denudation, with a phase of erosion between the the deposition of the beds.
>
> discordances of superposition, when two inshore deposits, separated by a line of demarcation, are superposed at the same point; this indicates epeirogenetic movement between the two.



Alcide D' Orbigny (1802 - 1857)

"The line of demarcation between two stages is, let us say, marked by a discordance of stratification in the beds, by denudations, by polishing, attrition of the surface of the older stage of the two, by ferruginous deposits, by beds of pebbles, by surface inequalities of the ground, finally by differences in colour and mineralogical composition of the succeeding rocks". ("Cours élémentaire", 1849, I, p. 152).

However, the relative importance of these lines of demarcation must be confirmed by study of the faunas. In order to illustrate these phenomena, d'Orbigny cites as examples "the ferruginous bed at the base of the Bajocian stage of Bayeux, Moutiers and Sainte-Honorine" - and "the small pebbles which one finds often at the base of a stage, as for example at Thouars (Deux - Sèvres) in the Toarcian Stage". ("Cours élémentaire", 1849, I, p.151).

These discontinuities are thus marked in sedimentation by a change of facies and in the fossil population by a change of fauna, one fauna disappearing to be replaced by another that is quite different.

"The oscillations of the Earth's surface are exceptionally well marked in the Jurassic system. Their traces are particularly discernible by littoral deposits superposed at several points. On ten successive occasions, geological disturbances of greater magnitude than the oscillations came to interrupt the life of land and seas, and destroyed almost all living beings. After each of these great world catastrophes, calm returned once again; the whole of Nature was repeopled by her plants and her animals. On each occasion, if the genera in part remained the same, the species changed entirely, as one can see from the respective systematic categories represented". ("Cours élémentaire, 1852, II, p. 433). [NOTE: It is necessary to remember here that d'Orbigny's "genera" would now be systematic categories of the order of families, or larger, and that his "species" would now be subgenera or even genera.]

For d'Orbigny, it was necessary to establish the hierarchy of tectonic phenomena, to differentiate between general disturbances, global revolutions and simple oscillations.

The observations obtained on the occasions of the earthquakes and tidal waves on Peruvian and Chilian coasts and at Lisbon in 1755, and the memory of a "deluge" common to almost all the ancient civilizations, gave to d'Orbigby an idea of destructive phenomena capable of identification with the catastrophes that he invoked, in particular regarding their speed of propagation, their distribution and their incidence in coastal regions. In contrast, the recent movements of depression and elevation on the coasts of the Netherlands and South America, Colombia in particular, illustrated the oscillations. ("Cours élémentaire", 1852, II, pp. 834-5)

D'Orbigny discussed the origin of global revolutions on the basis of study of the Anglo-Parisian, Aquitaine and Rhodanian Basins of the Jurassic, as well as on the history of the Russian Platform of the Upper Jurassic. For him, it was not possible to invoke a vertical movement of a continent. Starting from a simple experience, he showed that the sudden retreat of the sea could result from a sinking of the ocean bottom (sinking linked with a contraction of the globe caused by cooling, as visualised in the theories of Elie de Beaumont and Cordier), whilst any upheaval of a part of the bottom could produce the inundation by marine waters of the continental margins, in proportion to the continental area upheaved. Thus d'Orbigny found in this eustatic hypothesis, controlled by geosynclinal evolutions, a mechanism for the changes of faunas. ("Cours élémentaire" 1852, II, pp. 430-2).

As an actualist d'Orbigny recognised, in the events of contemporary geology, two great classes of phenomena:-

a) Passive, constantly operative conditions, during which continental and marine sediments are deposited slowly to form stratified beds, except when their effects are modified by (b).

b) Other chance, momentary circumstances, which, as a result of dislocations of the terrestrial crust, cause plutonic rocks, or rocks of subsurface igneous origin, to appear on the surface of the earth. There is thus synchronism between stratified rocks and plutonic rocks, in the sense that these latter, according to their nature and chemical composition, appear to have arisen at distinct epochs, corresponding to the relative age of the sedimentary rocks. ("Cours élémentaire," 1851, I, pp.262-3).

Here one finds ideas expressed earlier by James Hutton. D'Orbigny considers that each suite of crystalline or volcanic rocks has its own special characters, permitting correlations with the sedimentary rocks. In the Jurassic, he instances notably suites of basalts, pyroxenic porphyries and even granites ("Cours élémentaire", 1852, II, p.433).

The global revolutions are thus reference points for d'Orbigny, dates in the history of the Earth. Between these lines of demarcation, the faunas have sufficiently well-marked characteristics to enable the identification of a clear-cut period in the history of the planet.

This discovery of the existence of relationships between the geological phenomena, involving the entire terrestrial globe and the history of life, is presented in an original and detailed fashion by d'Orbigny; it is the basis for his concept of the stage.

Alcide d'Orbigny and the "Successive creations"

For the majority of zoologists and palaeontologists, Alcide d'Orbigny is, together with Cuvier, merely one of the principal representatives of the "fixist" school, opposed to the "transformist" school of J.B. de Lamarck. However, he was unaware neither of the researches of Lyell nor of those of Darwin, to which he refers in his works; he questions certain conclusions of Lamarck and, in his fashion, he supports the idea of a certain degree of improvement, which is not without certain common features with the modern doctrine of evolution.

From the outset, one must note that Cuvier, d'Orbigny, Lyell and Darwin all employed the term "creation" to designate the totality of organisms populating the continents and seas at a given time; moreover, d'Orbigny uses, in the same sense, "peuplement" (peopling) and "animalisation". The biblical sense of "creation" was reserved for the first populating of the earth. Alcide d'Orbigny, recognising that, at the very base of his Silurian stage, the fauna was already very diversified, concluded that this first fauna was "created" and that the subsequent faunas were "renewed". The distinction had the merit of taking into account both the origin of life on Earth and the appearance of new populations on the planet, which subsequently succeeded one another during the diverse epochs of the Earth's history. Moreover, Cuvier himself made, in this context, a very interesting remark when he wrote:-

> "Besides, when I maintain that the pebble beds contain the bones of several genera, and the unconsolidated beds, those of several species which do not now exist, I do not claim that there must have been a new creation to produce the species existing today; I say only that they did not exist in the places where one sees them now and that they must have come here from elsewhere". [From "Discours sur les révolutions de la surface du globe et sur les changements qu'elles ont produits dans le régne animale"; quoted by A. Lacroix in his speech to the Academy of Sciences on the centenary of the death of Cuvier, 12 July 1932 (C.R. Acad. Sci., Paris, p.6.).]

In these words, he expresses two important facts; first, he introduces a distinction of time between the evolution of genera and that of species, comparable with the time taken for lithification of the sediments; secondly, he states that the new fauna which replaces the fauna of a given place, in the course of geological time, has not been 'created' by special divine intervention, but that it had come from elsewhere to replace the pre-existing fauna. This proposition is the key to the theory of Cuvier and d'Orbigny.

As a matter of fact, Alcide d'Orbigny states that few common points exist between the successive faunas of ammonites at the different periods of Jurassic history, each of these periods having its characteristic fauna, the observation valid for the ammonites being equally valid for the remainder of invertebrates and the flora. Considering only the ammonites, and working from the lists quoted by d'Orbigny, one can show, by reallocating the species according to the principles of present-day systematics, that each stage is characterised by distinct groups:-

Sinemurian:	Psilocerataceae (Psiloceratidae, Schlotheimiidae, Arietitidae, Oxynoticeratidae, Echioceratidae).
Liasian :	Eoderocerataceae (Phricodoceratinae, Coeloceratinae, Polymorphitidae, Liparoceratidae, Amaltheidae).
Toarcian :	Hildocerataceae (Harpoceratinae, Hildoceratinae, Grammoceratinae, Graphoceratidae, Hammatoceratidae, Sonniniidae).

Bajocian :	Stephanoceratidae, Sphaeroceratidae, Parkinsoniidae, Morphoceratidae, Leptosphinctinae.
Bathonian :	Oppeliidae (pars), Tulitidae, Zigzagiceratinae, Clydoniceratidae.
Callovian :	Macrocephalitidae, Proplanulitinae, Kosmoceratitidae, Reineckeidae, Pachyceratidae.
Oxfordian :	Cardioceratidae, Perisphinctinae.
Corallian :	Aspidoceratinae.
Kimmeridgian :	Ataxioceratinae, Pictoniinae, Aulacostephaninae.
Portlandian :	Gravesia, Virgatosphinctinae, Dorsoplanitinae.

The replacement of the fauna of a given stage by a new fauna, in the following stage, is readily intelligible in terms of the 'global revolutions", explaining both the abruptness of the disappearance and appearance of faunas in the regions where the marine pulsations were felt, on the one hand, and, on the other hand the very wide distribution of ammonites in harmony with the great world-wide marine transgressions, in the Bajocian and in the Callovian, for example.

But let us examine more profoundly d'Orbigny's ideas on the mechanism of "improvement". D'Orbigny systematically opposes his arguments to the theory of Lamarck. He states firstly that the "improvement", observable in the faunas of a stage, is not comparable to the transformations of the animal world brought about by the global revolutions. During the stages, there are often only "improvements", not progressing beyond the level of the genus (in the sense which he understands it); they are expressed by a multitude of slight modifications of organisation, such as changes in position or form of the elements of the skeleton or of the organs, etc. However, d'Orbigny recognises that there is occasionally a true filiation of species (in the sense of Lamarck) when, in an interval of geological time, one can establish the direct connexion of morphological relationships; but he adds immediately that certain morphological characteristics may well be repeated at different epochs, without it being possible to find any interconnexion whatsoever ("Prodrome", pp. XXXVII - IX):

> "Why does one want to preclude Nature from repeating similar faunas several times over in the ages of the World, if they are not identical and especially when space and time separate them?" (Prodrome, 1850, p. XXIX).

These remarks clearly show that he was no fixist, in the sense that one normally understands the word; indeed, his "improvement" is akin to the ideas developed by Darwin and he shows that he was, in the domain of the invertebrates, one of the first to recognise what we now term the phenomena of convergence and of homeomorphy.

At the limit of stages defined by global revolutions, there are on the other hand phenomena of greater magnitude, which the geologist comes across; the annihilation of species and of genera (in d'Orbigny's sense) and their replacement by new forms. Clearly, d'Orbigny distinguishes between a slow improvement, within the limits of stages, and a parallel, accelerated improvement recurring at the confines of two stages; was this not an early recognition of the distinction now made between micro- and macro- evolution? Thus, d'Orbigny takes a census of the great changes interposing in the history of the molluscs, annelids, Radiata and vertebrates. For him, as for Buffon, Lyell and others, species are doomed to disappear; there is only transition between one and another within stages, whereas, on either side of a line of demarcation between two stages, there is parallel improvement affecting "bodily organs, species and classes". "Nowhere does one encounter a transition from one specific form to another, at the contact of two successive ages".

D'Orbigny charges the Lamarckian theory with a too marked finality and anthropomorphism. Progress or regression of organisation may each be favourable to the species, in particular environmental conditions. For d'Orbigny, as an actualist, the majority of the natural environments known in our day existed also during the geological past. Such environments were not able to exert direct influence on the extinction and the renewal of successive faunas. In contrast, the changes of environment following the global revolutions, the general regressions and transgressions, have played a primary role in this direction, for the great systematic breaks, like the great stratigraphic breaks, are tied up with the major crises in the history of the Earth. In a sense, d'Orbigny attributes a place in "improvement" to natural selection brought about by the upheavals of the marine and continental domains, at the time of tectonic crises. D'Orbigny brought together observations on these drastic environmental changes, and he experimented in this field ("Cours élémentaire", 1849, I, pp. 132-4). Almost all organisms disappear at the time of these catastrophes. The breathing of air, commencing in the earliest times of our planet's biologic history (in the Primary), appears to him as a particular instance of adaption to environment : "In short, it is a new mode of existence, which is related, not to true improvement, but to special circumstances" ("Cours élémentaire", 1851, I, pp. 232-8). Thus, global revolutions control adaptions.

To summarise, the stage, in its palaeontological expression, is, for Alcide d'Orbigny, a period of biological equilibrium between two tectonic disequilibria.

Alcide d'Orbigny and the concept of the stage

"In brief, stratigraphical geology, which is of the greatest importance since it is the positive part of this science and since it comprises the chronological history of the terrestrial globe, was most certainly born on the soil of England". Alcide d'Orbigny thus pays homage to English geologists who were the first to discover the essence of stratigraphy ("Prodrome", p.XXXI). But, confronted by the chaos of stratigraphical nomenclature at the beginning of the 19th Century, d'Orbigny attempted to restore order. As he had proceeded for systematic palaeontology, so also he attacked the matter of a stratigraphical nomenclature for the Jurassic in the selfsame spirit, seeking a clear, practical and universal language (ibid., p. XXIV : "Cours élémentaire", 1852, II, p. 418). He does not set himself up as a reformer, but as an interpreter of nature : "It is from nature itself that one must obtain the general bases of a stratigraphical solution".

After having travelled over America for 8 years and roamed through France for 6 years, after having studied palaeontological material in innumerable collections derived from the greater part of the regions of the World known at that period, after having widely analysed geological and palaeontological literature, d'Orbigny concludes that faunas everywhere succeed one another in the same order and that "discordances" everywhere separate them at the same levels.

> "The partial facts which I unceasingly study in all details lead me inevitably to general facts, to the consequences of the whole. I seek to present them methodically by laying down firm guidelines for the application of zoological types to the recognition of beds".

Taking as his basis both the sequence of global revolutions and the sequence of successive invertebrate faunas, d'Orbigny comes to form the concept of the stage, of which he gives several definitions which do not permit of any ambiguity.

Stages are "the expression of the boundaries which Nature has drawn with bold strokes across the whole globe", boundaries which are not arbitrary ("Paléontologie française, Céphalopodes", p.603). He studies ammonite faunas and takes into account particularly the vertical distribution of these organisms, from their appearance to their disappearance : he shows that their horizontal distribution is independent of lateral variations of facies, which conforms with observations made of living nature ("Prodrome", p.XXXIV).

> "It is certain that such stages as present exact superposition, and the limits of the faunas they contain, are as clear-cut in the Jurassic formations as are, for example, the Silurian, Devonian and Carboniferous stages in the Palaeozoic formations".

This comparison serves well to throw light on the importance which d'Orbigny accorded to tectonic crises, in the subdivision of geological epochs.

The study of the Jurassic of countries as far apart as France, Russia, India and Chile had led d'Orbigny to claim not only common characters in the ensemble of faunas, but even the presence of identical species which attested to their contemporaneity.

> "These confirmations from afar which, for the Jurassic formations, came to corroborate my observations, at the same time made me certain that all the causes of separation of stages have been universal."

> "A stage is, for us, an epoch exactly the same as the present epoch; it is a state of rest in Nature's past, during which there existed, as in present-day Nature, continents and seas, marine plants and animals: and, in the seas, pelagic animals and neritic animals in all depth zones". ("Cours élémentaire," 1851, II, pp. 256-7).

Two principal elements thus interpose in the definition of his stages; firstly, a characteristic fauna which always enables the stage to be recognised, in whatever facies it is represented, and secondly, definite limits which separate this fauna from those subjacent and superjacent.

> ". . . . I take for starting-point, with the limits of the zoological types, the annihilation of a series of organisms to be replaced by another. I proceed solely according to the identity in composition of the faunas, with the extinction of genera or of families".

The definition of each one of his Jurassic stages comprises:-

a. The naming of the stage, with an explanation of the origin of the name.

b. The list of genera which appear therein; the reign or period of predominance of the dominant groups, both marine and continental; information on the "growth" or "degeneration" of certain other groups; and, finally, the list of species constituting the zone or zones.

c. A synonymy of the formations according to the fossils or mineralogical composition.

d. The designation of types, in general, in the vicinity of localities renowned for their richness in fossils, chosen in France or in Europe.

e. D'Orbigny mentions afterwards a whole series of localities or regions in France, in Europe or outside Europe, whose sections or fossils he had studied and which he classes in this stage. He gives some details of the contacts with the stages above and beneath, of lithology, sedimentology (bathymetry of the deposits), the thickness of the beds, the fauna and flora and, finally, palaeogeographic conclusions on the European and global scale.

There are thus few aspects left obscure; and afterwards, few stratigraphers were to take as many precautions before defining a stage.

The stage is a generalisation, but d'Orbigny was in a position to generalise; this was the result of twenty-five years of personal researches, palaeontological and stratigraphic studies, effected in very widespread geographical regions, on very important collections and which took into account a very extensive bibliographic documentation.

The stage, according to d'Orbigny, is a tangible unit, accessible to the hammer, founded both on biological evolution and on the tectonic history of the globe. It is the materialisation of geological time, although sedimentation or evolution vary with time. Nevertheless, its general applicability still makes it the best tool for long-distance correlations, after more than a century of application.

Conclusions

Since d'Orbigny's time, geological researches have greatly developed. What is our opinion, nowadays, of the fundamental data used by d'Orbigny in his definition of the "stage"?

a) D'Orbigny's stratigraphic units and global revolutions.

In reconsidering the stratigraphic units distinguished by d'Orbigny, in the Jurassic of the northwest of the Paris Basin, one remarks that the boundaries which he invokes correspond frequently to orogenic phases or to major transgressions linked to these latter. Thus, below the Purbeckian, whose middle part is denoted by the Osterwald (Dorset) phase, one finds:-

THE PORTLANDIAN of the Pays de Bray, the Boulonnais and Dorset (from the Gravesia gravesiana Zone to the Titanites giganteus Zone) shows a tendency to regression in its upper part; and its transgressive base is a continuation of the Deister phase (the Nevada and Pre-Tithonian phases are parallel with this latter). Within the stage, two minor divisions exist: the lower, below the Pectinatites pectinatus Zone, characterised by the arrival of the species of Pavlovia and the deposition of a conglomerate, whilst the Upper is marked by the appearance of the large Perisphinctids (Titanites, Glaucolithites) and a second conglomerate.

THE KIMMERIDGIAN of Normandy (from Decipia decipiens to Aulacostephanus autissiodorensis) begins with an important transgressive phase, but the Pictoniinae appear at the very base. The major phase occurs higher, following the regression of the Ringsteadia frequens Zone, with the transgressive Pictonia baylei beds. Above, the ammonite fauna is renewed with the successive arrival of the species of Rasenia, then of Aspidoceras. Amoebites disappears in the upper part.

THE CORALLIAN of Normandy (Perisphinctes cautisnigrae) is a more or less well-marked unit according to locality, intimately linked with the Oxfordian. It is likely that in the choice of this stage, d'Orbigny had been strongly influenced by the development of this "stage" in Charente, his home area.

THE OXFORDIAN of Normandy (from Cardioceras cordatum to Perisphinctes plicatilis). The C. cordatum Zone shows an important condensation of the sedimentation and the fauna. Above, a ferruginous and oolitic horizon is present at the base of the P. plicatilis Zone; then, a minor oscillation is marked by an intraformational conglomerate. In the course of the Oxfordian, foldings have been recorded in other regions.

THE CALLOVIAN of Normandy and Maine, France (from Clydoniceras discus to Quenstedtoceras mariae). At the base, the argillaceous facies of the Cornbrash is sharply transgressive on the western border of the Paris Basin: the lower part, with C. discus, is only locally developed – sometimes, as in Maine, condensed at the base of the Macrocephalites macrocephalus Zone, which oversteps the Upper Bathonian in this region. Everywhere, an erosional phase and a regression mark the top of the calcareous Bathonian. Within the stage, the principal pulsations are marked by the zones of Proplanulites teysseiri and of Sigaloceras calloviense, Kosmoceras (Gulielmites) jason, Peltoceras athleta and Q. mariae. In other regions, the American Agassiz orogeny and the Yaila orogeny of the U.S.S.R. are accompanied by transgressions in the upper part of the Callovian, whilst the base is generally marked by a great Callovian transgression (M. macrocephalus Zone) which brings in a number of new forms.

THE BATHONIAN (from Procerites [Gracilisphinctes] progracilis to Clydoniceras hollandi). The transgression becomes more marked in the Bathonian, covering a maximum area, with sediments of the Tulites subcontractus zone which may rest on the Palaeozoic. Accessory pulsations mark each zone of this stage. A tectonic phase is known at the very top of the Bathonian in Tunisia (Matmatian phase).

THE BAJOCIAN of Normandy (from Stephanoceras humphriesianum to Oppelia yeovilensis) begins with the Bajocian transgression: the humphriesianum Zone rests on eroded Toarcian and on Palaeozoic. The paroxysms of the Cotswolds and Donetz phases occur at this level. The subfurcatum-garantiana and parkinsoni zones continue the transgression and small pulsations coincide with the convergens and zigzag zones.

THE TOARCIAN of Normandy (from Dactylioceras tenuicostatum to Otoites sauzei) oversteps the Pliensbachian (i.e. the Liasian of d'Orbigny). At the base, the transgression of the tenuicostatum zone follows a slight regressive tendency in the upper Pliensbachian and corresponds to the American Dunlap phase. There are subsequently pulsations associated with the mulgravium, variabilis, Dumortieria and opalinum beds, after concava, after discites, and after Witchellia; these horizons are marked by erosion surfaces and by reworked fossils and pebbles.

THE LIASIAN of Normandy (from Uptonia jamesoni to Pleuroceras spinatum) oversteps the limits of the Sinemurian onto the Palaeozoic basement quite sharply in the jamesoni beds; then a secondary transgressive phase is marked by the davoei beds and a conglomerate marks the base of the spinatum zone (the margaritatus subzone is eroded to a greater or lesser degree). In England, there is a transgression at the base of the Pliensbachian onto the Palaeozoic.

THE SINEMURIAN of Normandy (from the top of Psiloceras planorbis to Echioceras raricostatum). At the base, the first marine beds have the fossils of the pre-planorbis beds. The topmost Valognes Limestones, containing Caloceras torus, are truncated by an erosion surface; and at Osmanville, a slight angular discordance has been reported below the Coroniceras rotiforme beds. Generally there is a lacuna in the upper Hettangian. In England, the bucklandi zone may rest on the Rhaetian (uppermost Triassic) in the Mendips. Above this discontinuity, the Sinemurian spreads widely over the Primary basement, with two stronger pulsations, one associated with semicostatum and one with oxynotum. At the Rhaetian-Hettangian boundary, a transgression takes place in the Salghir or early Cimmerian phase.

Sedimentation has thus recorded a certain number of water movements and it is a question of classifying them. Alcide d'Orbigny advocates that one make use of the fauna in order to determine, among these movements, those which are of major importance, the revolutions which involve the whole surface of the globe and which bring in train destruction of the fauna, whereas local oscillations cause only minor changes.

A certain number of orogenic "phases" have been recorded in the Jurassic System of Europe (Alps, U.S.S.R., and England), America (Nevada, Texas and Canada), and China; and attempts have been made at world correlation. [Important volcanic phenomena were developing at the same period, particularly in America (from Patagonia to Canada).]

The data from geophysics show that certain seismic waves, engendered during earthquakes, make the round of the earth several times; they generally produce tsunamis, which profoundly affect the littoral populations and, more significantly, they are the prime cause of important redistributions of material by turbidity currents and give rise to phenomena of resedimentation. Earthquakes also set in motion great faults, which can slowly continue their development before our very eyes. There certainly thus exist, in present-day Nature, sudden, paroxysmal phenomena which affect the whole surface of the Earth and also slow, much more localised phenomena, as d'Orbigny observed.

The transmission of series of orogenic waves in the Earth's crust and waters evidently occurred in different directions, according to the particular period of the Jurassic. Whilst at the beginning, in the Hettangian and Sinemurian, the general tendency of transgressions in Normandy was from west to east, it seems that from the upper Pliensbachian, S.E. - N.W. directions, from Boreal to Tethyan, were predominant until the Lower Callovian; boreal N.E. - S.W. influences then briefly appeared, to take the place, temporarily in the Upper Callovian and above all in the Kimmeridgian, of Tethyan influences.

The Dunlap, Donetz, Agassiz and Nevada paroxysmal orogenic phases were relatively swift and took place, according to Crickmay (1933), during a lapse of time that did not exceed a single ammonite zone. This is very important, for the crystalline or volcanic synorogenic episodes may provide absolute dates. These orogenic phases have left traces in the Jurassic formations and, from a general point of view, the correlation of these traces, whether diastrophism or orotaxy, has given rise to very interesting researches on the part of Anglo-Saxon (T.C. Chamberlin and Umbgrove) and German (H. Stille) geologists. As far as stratigraphers in particular, are concerned, following the work of E. Hebert (1857), the researches of W. Klupfel, H. Frébold, W.J. Arkell, P.L. Maubeuge and A. Hallam have shown the vast horizontal extent of the phenomena of erosion and condensation in the whole European area.

The orogenic crises always show paroxysmal phases, which give rise locally to folds and to displacements of considerable volumes of sediments and marine waters; they are preceded and followed by periods of instability of sea level. The universality and amplitude of the great Jurassic transgressions onto numerous epicontinental regions express eustatic rather than epeirogenic causes; regressions are associated with the periods of expansion and subsidence, transgressions associated with lateral compressions, raising up the sea bottoms or reducing the marine basins and thus bringing about a phase of overflow by the oceans, according to the utterances of Pierre Pruvost.

Epeirogenic deformations and localised vertical movements occur regionally to complicate the phenomena and, for example, give rise to minor transgressions in a regressive regime, or the converse.

In this regard, d'Orbigny recommended with good reason the categorisation of the diverse traces recorded by sedimentation, in the course of movements by crust and waters: the disturbances marking the ending of a stage and the beginning of another being more important than the oscillations observed within the stage. I will add that, on a larger scale, the limit of subdivisions of systems must be even more marked than the limit between two stages; the Middle Jurassic is well delimited by the lower boundary of the Bajocian and the upper boundary of the Bathonian. Only the echoes of these major dynamic phenomena in the marine and continental populations can indicate the scale of the phenomena.

b) <u>D'Orbigny's stratigraphical units and the "successive creations"</u>

At the boundary of two stages, the hiatus which is materialised by the sedimentary lacuna bears witness to a lapse of time, short or long, during which sediments were not deposited. For modern palaeontologists, the discontinuity observed between the characteristic faunas of successive stages need not be misleading, for the ammonites continued to evolve in the calmest regions However, if the ammonite faunas were widely distributed in all marine environments in the course of transgressions, it certainly seems that these free-swimming shallow-water organisms living in our epicontinental basins were swept away like the unconsolidated sediments, far from the platforms, at each major regression and that the subsequent population was brought in during a new phase of oceanic inundation (Tethyan, Boreal, Atlantic, Indo-Pacific, etc., according to the region). The variation of the limits of the marine domain may have played a motive role in the selection of the forms best adapted to the new conditions of life offered in the course of a transgression or regression. The abruptness of the dynamic phenomena eliminated the forms too closely tied to particular environmental conditions.

It seems that one can henceforward define some tendencies in the ammonites.

The study of the composition of the entire fauna of ammonites from a given horizon shows that the development of families is not synchronous and that there is displacement in space and time of the period of their dominance, in the fauna, as a function of the general or local transgressions or regressions. For example; the Parkinsoniids travelled apparently from the west to east, the Cardioceratids from north to south, and the Perisphinctids from south to north. The Hammatoceratids appear earlier in Italy than in Normandy and the acmes of the various genera are not synchronous in the two countries. At each level, each region contains an assemblage which, in its composition, is different (the works of B. Ziegler are very interesting in this respect). Regressions tend to force back the vagile marine faunas towards the ocean depths, whilst transgressions push back the vagile continental faunas towards the high land; the theory of "refuges" is based on this.

In the epicontinental basins, one frequently notes, at the limits of two stages, the following facts; in the upper part of the lower stage, alongside numerous representatives of Family A, there exist a small number of forms - emissaries of Family B which arrived in these regions in the course of the earliest phases of a revolution, before the orogenic paroxysm and the great eustatic variations with which it is associated; whilst in the lower part of the upper stage, Family A is no longer represented except by a few rare specimens, whereas Family B evolves explosively in its turn. Some examples: Xipheroceratinae - Eoderoceratinae play a subsidiary role in the Upper Sinemurian, whilst the Eoderoceratidae dominate the Pliensbachian; it is the same for the Dactylioceratidae and Hildocerataceae in the Pliensbachian and the Toarcian. Numerous Sonniniidae and rare Stephanocerataceae in the Upper Toarcian give place to rare Sonniniidae and numerous Stephanocerataceae in the Bajocian. Let us in addition cite the Tulitidae and Macrocephalitidae of the Upper Bathonian and Lower Callovian; the Cardioceratidae, Peltoceratinae and Aspidoceratinae of the Upper Callovian and Oxfordian; the Cardioceratidae and Aspidoceratinae of the Upper Oxfordian and Kimmeridgian; the Perisphinctids of the Upper Kimmeridgian and Portlandian.

The emissary forms were not able to enter into competition with the populations there already, but at the time of the regression and transgression, they rapidly attained dominance over forms too closely tied to littoral conditions.

Within the stage, the phenomena are in proportion identical, but occurring at the level of species rather than at that of genus; thus H. Frébold has pointed out that the zonal ammonites do not cross the "Dachbänke" (the last beds of a sedimentary cycle) and R. Brinkman has demonstrated that the Kosmoceratidae evolved slowly between the "Dachbänke" and "Sohlbänke" (first beds of the next cycle): similarly one may add that, at the scale of the sub-system, these phenomena are placed at the level of the superfamily. The hierarchy and the proportions are inscribed in Nature, as d'Orbigny has well said.

In the vicinity of these discontinuities, condensed beds or sedimentary lacunae, one finds frequently associated with the dominant ammonite faunas, shells with a certain number of special characters:-

i) Either shells of small size, the representatives of whose family in the lower horizon showed, if anything, a tendency to increase in size. These small shells are globular or carinate, or exhibit a scaphitoid or spiroceratoid mode of coiling, or again they may exhibit an aberrant ornamentation with a complex aperture funished with apophyses, a rostrum, a collar, with ventral crenulations, with a degenerate suture-line, etc.

ii) Or shells with little ornamentation or quite smooth, when the members of the family showed, in the lower horizon, a rich ornamentation made up of ribs, tubercles, spines, etc. Here again, the suture-line is degenerate, simplified and inconstant in form.

These two morphological types seem to relate to troubles in metabolism. These forms would simply be degenerate branches of the family represented in the lower horizons, which had survived upheavals of the sea-bottoms on which they lived, which would have developed alongside species well adapted to the new environment and which would have been the prelude to the elimination of the family by vital competition. If it were a question of sexual dimorphism, one does not see why the males should only have been represented in certain populations and by forms whose development could only lead to the disappearance of the branch. Again, does one have to be sure that the sexes were separate in the ammonites ? It is more probable that dimorphism, if it exists, is marked by small differences in the height or thickness of the living chamber of the shell; these animals having to lodge in their shells the appendages of their reproductive apparatus, If one takes account of the anatomy of living Cephalopods.

The new forms which appear at the time of transgressions and occupy the different ecological niches, often belong to two associated morphological types, which are: either oxycones with a solid, strongly carinate shell, reinforced by undulose septae and having a "hydrodynamic form", or cadicones and sphaerocones with a floating globulous shell, with large chambers filled with gas. These two solutions to the mechanical problem of transport in the aquatic environment (reduction to a minimum or augmentation to a maximum of the effects of friction) are the result of a "mechanical" selection in the oceanic stock. The serpenticones are also good floating shells and appear in same conditions. One may thus cite: Oxynoticeras of the Upper Sinemurian; Becheiceras and Amaltheus of the Upper Pliensbachian; Nodicoeloceras and Orthodactylites of the Lower Toarcian; Oxycerites and Tulites of the Bathonian; Macrocephalites and Cadoceras of the Lower Callovian; Lamberticeras and Eborariceras of the Upper Callovian; Cardioceras and Goliathiceras of the Lower Oxfordian; or Balticeras and Prionodoceras of the Upper Oxfordian; Orthaspidoceras of the Kimmeridgian or Gravesia of the Portlandian, etc.

Involute, flattened forms, with sides converging ventrally, tend to be dominant at the maximum period of agitation of the waters, giving place to more evolute forms in more stable conditions; for example Psiloceratidae, Amaltheidae, Graphoceratidae, Sonniniidae, Kosmoceratidae, and Cardioceratidae. Finally, the arrival of new forms with Tethyan affinities is generally accompanied by the arrival of Phylloceratidae and Lytoceratidae. The first appear in the Middle Pliensbachian in Normandy, the last in the Upper Callovian.

In summary, it certainly seems that, as d'Orbigny noted, the changes of faunas, at the boundaries of stages as at the boundaries of other stratigraphical subdivisions, are sufficiently marked to serve as reference points, if one also takes count of the major revolutions. The displacement of the vagile faunas at the time of regressions and transgressions obliges the palaeontologist to envisage evolution both in space and in time. [Note: Archaic organisms which have scarcely evolved are either sedentary, intertidal forms with a great capacity for resistance to changes of the external environment (e.g. Cyanophyceae) or "refugee", geographically restricted forms. The organisms which are the most evolved are those which live on either side of the strand line, those of the continental maritime regions and those of the infra- and circa- littoral regions]. As the majority of types of ornamentation were developed amongst the ammonites as early as the Trias, it would be interesting to examine the relationships between morphology, hydrodynamic conditions and environmental conditions; it certainly seems that the morphology of the whole of a fauna is strongly influenced by a sort of "mechanical" selection at the time of transgressions. The living world is in equilibrium with the environment which encloses it; each modification of this equilibrium inevitably brings readjustments in its train. During stable periods, marine and continental organisms evolve slowly in a particular direction. The monographs of genera, advocated by d'Orbigby, thus have great stratigraphic interest (R. Brinkmann, M.K. Howarth, B. Ziegler, H. Tintant, etc.) If an upheaval takes place, the organisms introduced into these new conditions will disappear if the conditions are too unfavourable or sometimes will survive, enfeebled, until eliminated by competition; or in contrast will occupy all ecological niches if they are well adapted. Variations within populations widely distributed by transgressions could be fixed by geographical or physiological isolation. The role of natural selection, under eustatic control, accounts for the palaeontological facts. If there is a finality in evolution, this can only be a planetary finality.

The concept of the stage is thus primarily a zoological and actualist idea. This chronological division of the geological history of our planet was essentially worked out on the basis of stratigraphical analyses of the Jurassic of Europe. Unfortunately, a premature death prevented Alcide d'Orbigny from developing his work with all the fullness that it demanded.

The contemporaries and successors of d'Orbigny have accorded a variable reception to his conclusions. Three principal attitudes have been adopted with regard to d'Orbigny's system; that of French-speaking geologists, that of German and Slavic geologists, and that of Anglo-Saxon geologists.

a) The first-named believed that progress consisted in the creation of new stages (very often with no more justification than to make known a regional, lithological or palaeontological stratigraphic unit), allotted a name ending in "-ien" or "-in". The "recipe" found favour, but rare are those who consulted the scale given by d'Orbigny to see whether there was any synonymy. Fortunately the endeavours of A.de Lapparent and E. Munier-Chalmas, of E. Renevier and of E. Haug have brought the necessary clarifications; but these authors have not truly adopted the concepts of d'Orbigny; rather, they have been influenced in their conclusions by the work of Oppel and of S.S. Buckman. Each wished to create his own "standard" and the stages were extended, or shortened, at the inclination of each particular author.

b) The German geologists reacted first. In "Der Jura", F.A. Quenstedt stigmatised, in scoffing terms, the conclusions advanced by d'Orbigny. His principal complaints were taken up and expounded with more rigour and less passion by one of his pupils, Albert Oppel. The long and patient researches of Alexander von Humboldt and Leopold von Buch, carried further by Quenstedt, had led to a very detailed knowledge of the Jurassic of Swabia and Württemburg. D'Orbigny, in discussing these geological researches, showed that the divisions adopted by the German geologists, although accurate and useful, were not readily applicable outside their country of origin and were inadequate for a universal stratigraphy. Oppel, accompanied by Edward Suess, had travelled and studied in certain regions of France and England between 1854 and 1855. He visited mainly the periphery of the Paris Basin; and met d'Orbigny. Following these travels, he published his classic "Die Juraformation Englands, Frankreichs und des südwestlichen Deutschlands, nach ihren einzelnen Gliedern eingetheilt und Verglichen", in which he attempted to make a synthesis of the researches of German, English and French geologists. He opposes to the concept of the stage his idea of the zone, without however taking the trouble to define it. Now, for d'Orbigny, the zone is constituted by the faunal content, chronologically delimited, of the stage. With regard to the 4,000 species of Jurassic invertebrates, d'Orbigny states precisely:-

> ". . . . that this number is divided into ten superposed zones, forming, throughout the Jurassic terrains, as many chronologic faunas or epochs which regularly succeed one another. That, further, each zone showed a particular fauna distinct from those of the zones above and beneath, which constitutes a stage, a well-characterised epoch, as well defined as the present epoch". ("Cours élémentaire, 1852, II, p.426).

In his definition of the aims of palaeontology, he writes also:-

> "It is necessary to study these beds in their order of superposition, in their relative age, in their geographic and geologic circumscription, in the composition of the faunas they contain, so as to follow the organisms across different deposits and to recognise the points at which they cease to exist, to be replaced by others". ("Cours élémentaire", 1849, I, p.7).

But yet, for d'Orbigny, it is difficult to imagine stratigraphic units of universal value smaller than a stage:-

> "There is, regarding the limits of the stage, a trap that one must be careful to avoid; it is that of attaching too much importance to the local distribution of fossils by bed, before being certain whether these details are the same in all parts of the world. Most frequently, in fact, when one finds, in a geological basin, that a certain bed contains a certain series of species, one is naturally inclined to regard this as a fact important to stratigraphy, as constituting a special distinct epoch, when it is most often, as we have perceived by comparison, only a purely local feature, which enables no generalisation whatever and which results solely from the composition of the sediments or local oscillations of the crust, as we will try to demonstrate for stages in particular".

Thus d'Orbigny stresses the geographically restricted value of possible subdivisions of the stage.

Oppel in contrast puts the accent on the value of zones for correlation between the Anglo-Parisian Basin and southwest Germany; that does not mean that the comparison may extend further, for even in the two basins, the zones may not be the same in the north and in the south, in the Upper Jurassic, for example. Oppel has no time for global revolutions; for him, geological disturbances are purely local. What he calls "zones" are, in fact, biostratigraphic units within sedimentary formations. He maintains, for the easy manipulation of the zones, groups of zones; he thus adopts the Semur-Group, the Pliensbach Group, the Thouars Group, the Bayeux Group, the Bath Group, the Kelloway Group, the Oxford Group, the Kimmeridge Group, rejecting Liasian, Corallian and Portlandian.

For him, the stage is convenient because it permits the parallelising of groups of zones, containing poorly determined or poorly described fossils. Never did Oppel regard his stratigraphical scale as definitive, but, like the English geologists, he sought to adapt his zonal analyses to the stages rather than to analyse the zonal content of d'Orbigny's stages. He did not hesitate to modify the boundary of the Thouars Group and of the Bayeux Group, without knowing the geology of the region of Thouars, using as basis only German work. The "zone" of Oppel brought progress in the field of regional stratigraphic analysis. Furthermore, his palaeontological revision, illustrated in 1862-1863, and the creation of the Tithonian Stage (1865), subsequently completed his writings on the Jurassic. He too was prevented by a premature death (1865) from carrying his work further.

c) Finally, taken as a whole, the English geologists preferred to retain their traditional lithostratigraphic units, until William J. Arkell, in 1933, then in 1946 and 1956, adjusted certain of the conclusions of d'Orbigny to accord with very detailed stratigraphic analyses made in England, following close upon the work of S.S. Buckman, A.E. Trueman, W.D. Lang, L.F. Spath and others. Arkell possessed very great experience in the palaeontology and geology of the Jurassic. His discussion takes into account only two of the works of d'Orbigny ("Paléontologie française, ... Céphalopodes", 1842-1851 and "Cours élémentaire," 1852, II). His principal criticisms are those of Oppel, but, without alluding to d'Orbigny, he accords more credit to diastrophism. Firstly, he deplores the fact that the types for stages chosen in England, were selected when d'Orbigny knew the stratigraphic data of the type localities only through study of English geological publications and fossil collections; and secondly, the fact that the faunal assemblages which serve to define these stages were derived in part from northern France. D'Orbigny himself conformed to priority by using certain stratigraphic terms published by Brongniart in 1829 in order to name his stages; in so doing, he paid homage to the English geologists by taking five types in France and five in England.

The criticisms directed at d'Orbigny have never, to date, taken account of the whole of his work.

The fact that he connected tectonic and biologic data proves that he was conscious that neither the one nor the other, taken separately, would be sufficient to define his subdivisions. The geographical distribution and evolution of marine organisms are dependant upon eustatic phenomena, affecting the whole globe. The types of the stages, chosen deliberately in regions on the edge of the ancient massifs, recorded in better fashion the variations in level of the sea, complementary types being present to enable the possible specification of the biostratigraphic and diastropic data. In designating the faunal content characteristic of each stage under the name "zone", d'Orbigny conferred on these assemblages the value of a tool in correlation. That it might be possible, regionally or locally, to distinguish smaller units within the stage is not incompatible with the concept of the stage, but is subordinate to it. Finally, in the choice of the majority of index-species, d'Orbigny has made it clear that his selection was at least as strict as that of Oppel and that he accorded a greater value to the ammonites.

In the quantity of precautions with which he surrounded his work, I do not think he has ever been surpassed.

Finally, it seems to me that the differences of opinion which subsisted at Luxembourg, arose from three fundamentally different concepts of stratigraphy:-

i) That set forth by d'Orbigny, which is the quest for a clear, intelligible, rational and universal language, based upon geological data and observations on living Nature.

ii) That of Quenstedt and Oppel, the detailed and laborious analysis of geological facts, but too particularist and which does not aim at an immediate generalisation.

iii) That of William Smith, Sidney S. Buckman and William J. Arkell, the assembling of definite facts, independently of any "system".

There is no opposition between those methods, there is only a difference in scale, and all the observations are complementary, the zones of Oppel and Arkell being subordinate to the stages of d'Orbigny. Just as d'Orbigny indicated, if one takes into account the hierarchy of phenomena periodically interrupting sedimentation and the results of modern biostratigraphy, it seems possible to use, as regional basis, the replacement of species in order to establish sub-zones and that of sub-genera and genera to establish zones; thus also, on a more general plane, the replacement of certain subfamilies or families would serve to define stages and that of certain families or super-families to provide limits for sub-systems.

Postscript (1968)

In a recent paper (J. Paleont., May 1968), C.L.V. Monty, a Belgian geologist working at Princeton University, U.S.A., examined d'Orbigny's concepts of stage and zone. Successively employing several of d'Orbigny's definitions, he focuses attention on the stage as an uniformitarian approach, a sort of "paleo-today" (p.690); as a natural chronological division of the Earth's history (p.690); an accumulation of rock strata (p.691); and as a part of a biostratigraphical unit (p.692). Monty considers that, in the definition of stages, the physical criteria are regarded by d'Orbigny as subordinate to the palaeontological ones: each stage starts from the appearance of newly created organisms and finishes with their catastrophic extinction in a geological "revolution". On the other hand, the zones are chronological indices, characterised by given species selected from among the fossils of the stage on the basis of their palaeoecological significance, their wide geographical distribution, and their vertical range in the strata. After his analysis of d'Orbigny's definitions of these two stratigraphical concepts, Monty concludes that "attempts to read very precise meanings into his terminology and religiously follow certain subsequent interpretations of his concepts are scarcely justifiable in view of inconsistencies in his writings and in the light of progress in stratigraphic understanding since his day" (p.699).

Monty assigns importance more to the form than to the spirit of d'Orbigny's stratigraphical researches; never does he consider d'Orbigny in his historical context. At the beginning of his paper, he emphasises that one should not be misled by the traditional judgement on d'Orbigny's works; and yet subsequently he is himself unable to forget this caricature of the truth.

After such an attentive reading of A. d'Orbigny's works, it seems to me equally difficult for Monty to claim (p.689) that this geologist stood aside from the current of scientific thought in the first half of the 19th century, as it is for him to represent d'Orbigny as the last obstacle to the rise of Evolutionism. D'Orbigny did not ignore the studies of James Hutton, Charles Lyell, Charles Darwin and John D. Hall - he quoted and discussed them; he was fully conversant with J.B. de Lamarck's transformism before ever he read J.B. d'Omalius d'Halloy's publications on this theory.

I believe that Monty did not take into account d'Orbigny's attempts to arrive at a synthesis of catastrophism and uniformitarianism and to consider stratigraphical concepts in their historic and taxonomic perpectives. Moreover Monty separates out each aspect of the concepts of stage and zone, without attempting to show how closely they are linked and how they are classified together by A. d'Orbigny.

Personally, I don't like the term "paleo-today", as it is presented by Monty. I agree with Monty that uniformitarian, ecological and geographical approaches were used by d'Orbigny, but I am sure that the duration of time, and especially the historical epoch characterised by a relative equilibrium in natural conditions at the world scale, was more important to d'Orbigny than the pictures, landscapes or frescoes visualised by Monty. In brief, I believe that the historical concept was basically prevailing over the geographical aspect in d'Orbigny's writings.

D'Orbigny's concept of stage is essentially of a chronological division of the Earth's history, delimited by two dates marked by cataclysms (i.e. inundations) which modified the mutual relations between continents and seas. During these intervals of geological time, stratified sedimentary deposits incorporating organic remains, were forming; the fossils they contain are historically and geographically characteristic. But all these natural, simultaneous phenomena are just so many aspects of a single reality, the <u>chronological history of the Earth.</u>

Never did d'Orbigny suggest that physical criteria should be subordinated to biological ones: he claimed emphatically that both criteria are strictly dependent upon cataclysmic changes (i.e. transgressions). These are what he termed "global revolutions". He observed a lateral gradation in the sedimentological and palaeontological evidences of these changes.

Because of its palaeoecological and palaeogeographical basis, the <u>zone</u> concept is much more limited in space and time. The value of a zone is restricted by the distribution of organisms in "provinces". D'Orbigny conceded a regional value to the zone, but never a general value as a universal standard. But a yet more important aspect of this concept is neglected by Monty: it is the conclusion reached by d'Orbigny that, in the selection of biological indices for zones, one should not descend below a certain systematic level; beneath such a level, the differentiation encountered is too geographically limited to be stratigraphically meaningful on a world scale. In these stratigraphical correlations, it is necessary to fully recognise the geographical limits of the distribution of each systematic unit. The true content of the "genus" and of the "species" in d'Orbigny's time, much larger than today, is forgotten by Monty.

At no stage does Monty in fact make a thorough analysis of d'Orbigny's concepts "in the light of progress in stratigraphic understanding"; this I regret. I fear even that Monty found in d'Orbigny's writings nothing other than what he sought - arguments to confirm his conviction of d'Orbigny's recognition of three separate stratigraphical fields, comparable to those visualised in the works of Dr. Hollis D. Hedberg. Thus Monty intentionally separates the chronological, lithological and biological aspects of the concepts of stage and zone to reinforce his demonstration. Unfortunately, however, d'Orbigny never separated these aspects of his concepts; he defined only one stratigraphy, chronostratigraphy, resulting from the natural expression of the (wholly interdependent) tectonic, lithologic and biologic histories of the Earth's surface. In conclusion, I concur with Monty's assertion that d'Orbigny's stratigraphical concepts are richer than is generally assumed in geological literature; and I hope that these concepts will be reconsidered in the light of modern geological knowledge.

Acknowledgements

I should like to express my sincere thanks to my friend Dr. William A.S. Sarjeant, in his triple capacity of translator, referee and editor; to Mrs. A. Margaret Sarjeant, for her assistance with the translation; and to Monsieur M. Lys (Institut Française du Pétrole, Rueil) for furnishing me with the portrait of d'Orbigny for reproduction.

Michel Rioult,
Laboratoire de Géologie et de Paléontologie
(C.N.R.S.),
Faculté des Sciences de l'Université de Caen,
CAEN, Calvados,
France.

REFERENCES

ARKELL, W.J. 1933. The Jurassic system in Great Britain. Oxford: Univ. Press. 681 pp., 47 pls., 97 text-figs.

1946. Standard of the European Jurassic. Bull. Geol. Soc. Amer., Vol. 57, pp. 1-34.

1956. Jurassic geology of the World. Edinburgh; Oliver & Boyd 806 pp., 46 pls., 28 tabs., 102 text-figs.

BERRY, W.B.N. 1966. Zones and zones, with exemplification from the Ordovician. Bull.Amer. Assoc. Petrol. Geol., Vol. 50. no.7, pp. 1487-1500, 2 tabs.

BRINKMANN, R. 1929. Monographe der Gattung Kosmoceras. Abh. Ges. Wiss. Göttingen, Math.- Phys. Kl., N.F., Vol. 13, no.4, VII + 123 pp., 1 pl.

BUCH, L.von — 1837. Über den Jura in Deutschland. Abh. K. Akad. Wiss., Berlin, 1837, p.49.

BUCKMAN, S.S. — 1898. On the grouping of some divisions of so-called "Jurassic" Time. Quart. J. Geol. Soc. Lond., Vol.54, pp. 442-62.

1902-1903. The term Hemera Geol. Mag., ser.4, vol.9, pp.554-7 (1902): Vol.10, pp. 95-6 (1903).

1917. Jurassic chronology. Quart. J. Geol. Soc. Lond., Vol.73, pp. 257-327.

1920. Jurassic chronology. Quart. J. Geol. Soc. Lond., Vol.76, pp. 62-103.

1922-1925. Chronology (Jurassic) in Type ammonites. Vol. 4, pp. 5-54; Vol.5, pp. 34-55, 71-8.

CHAMBERLIN, T.C. — 1909. Diastrophism as the ultimate basis of correlation. J. Geol., Vol. 17, pp.685-93.

CRICKMAY, C.H. — 1933. The North American Jurassic unconformities. Amer. Midland Nat., Vol. 14, p.355.

DIENER, C. — 1925. Grundzüge der Biostratigraphie. Leipzig: F. Denticke, 304 pp., 40 figs.

DUNBAR, C.O. & J. RODGERS — 1957. Principles of stratigraphy. New York: Wiley. 356 pp., 123 text-figs., 20 tabs.

FISCHER, P. — 1878. Notice sur la vie et les travaux d'Alcide d'Orbigny. Bull. Soc. Géol. Fr., sér.3, Vol. 6, pp. 434-53.

FRÉBOLD, H. — 1927. Die palaeogeographische Analyse de epeirogenen Bewegungen und ihre Bedeutung für die Stratigraphie Geol. Arch., Vol. 4, pp.223-40.

GAUDRY, A. — 1859. Alcide d'Orbigny, ses voyages et ses travaux. Revue des Deux-Mondes, 15 Février 1859, pp. 1-35.

GOODCHILD, J.G. — 1904. On unconformities and palaeontological breaks in relation to geological time. Trans. Edinburgh Geol. Soc., Vol. 8, pp.275-314.

HALLAM, A. — 1961. Cyclothems, transgressions and faunal change in the Lias of northwest Europe. Trans. Edinburgh Geol. Soc., Vol. 18, pt. 2. pp. 124-74.

HAUG, E. — 1907. Traité de Géologie. Paris: A. Colin, Vol.2, pp.929-1152.

HEBERT, E. — 1857. Les mers anciennes et leurs rivages dans le Bassin de Paris. in Terrains Jurassiques, Pt.1. Paris: Hachette, 87 pp., 11 figs., 1 pl.

HERON-ALLEN, E. 1917. Alcide d'Orbigny, his life and his work. J. Roy. Microsc. Soc. Lond., pp. 1-105, pls. 1-13.

HÖLDER, H. 1964. Handbuch der Stratigraphischen Geologie. IV. Jura. Stuttgart: F. Enke. 603 pp., 43 tabs., 158 text-figs.

HUPÉ, P. 1960. Les zones stratigraphiques. Bull. Trim. Serv. Inf. Géol. B.R.G.M., Paris, 12ième Année, no.49, pp. 1-20, 8 figs.

KLUPFEL, W. 1916. Über die Sedimente der Flachsee im Loth. Jura. Geol. Rundschau, Vol. 7, pp.97-109.

LYS, M. 1958. Alcide d'Orbigny (1802-1857). Micropaleontology, Vol. 4, pt. 1, p.115, 1 portrait.

MAUBEUGE, P.- L. 1957. Les données actuelles sur la tectonique pendant le Jurassique dans l'est du Bassin de Paris. Relations avec la sédimentation et conséquences pour la recherche des hydrocarbons. C.R. 19 ième Cong. Géol. Int., Mexico 1956, Vol.5, pt. 1, pp. 152-67.

MONTY, C.L.V. 1968. D'Orbigny's concepts of stage and zone. J. Paleont., Vol.42, no.3, pp.689-701.

MUNIER-CHALMAS, E. & A. de LAPPARENT. 1894. Note sur la nomenclature des terrains sédimentaires. Bull. Soc. Géol. Fr., Sér.3, Vol. 21, pp. 438-93.

NEWELL, N.D. 1952. Periodicity in invertebrate evolution. J. Paleont., Vol.26, no.3, pp. 371-85. (and see the whole of the symposium: Distribution of evolutionary explosions in geologic time).

OPPEL, A. 1856-8. Die Juraformation Englands, Frankreichs und des südwestlichen Deutschlands. Württt. Naturw. Jahr., Jg. 12, pts. 2-3, 13 pt. 2 and 14 pt. 3, 857 pp., 1 map, 1 pl.

1862-3 Über jurassische Cephalopoden. Paläont. Mitt. Mus. Kg. Bayer. Staates., vol.3 (1862) pp.127-62, Vol. 4 (1863). pp. 163-266, pls. 40-74.

1865. Die Tithonische Etage. Z. Deutsch. Geol. Ges., Vol.17, pp.535-58.

ORBIGNY, A.d' 1840-2. Paléontologie française. Terrains crétacés. Céphalopodes. Paris: Masson. 2 vols. - text 662 pp. and Atlas 148 pls.

1842-51. Paléontologie française. Terrains jurassiques. Céphalopodes. Paris: Masson, 2 vols.; text 642 pp. and atlas 234 pls.

1849-52. Cours élémentaire de Paléontologie et de Géologie stratigraphiques. Paris: Masson, 3 vols, 847 pp., 628 figs., 17 pls.

ORBIGNY, A.d' 1850-52. Prodrome de Paléontologie stratigraphique universelle des animaux mollusques et rayonnés. Paris: Masson. 3 vols. I: 394 pp., II: 427 pp., III: 189 pp.

QUENSTEDT, F.A. 1843. Das Flozgebirge Württembergs. Tübingen: H. Laupp, 558pp.

1858. Der Jura. Tübingen: H. Laupp, 842 pp., 100 pls.

RENEVIER, E. 1897. Chronographie géologique. 2 ième Edit. du "Tableau des terrains sédimentaires" suivi d'un "Répertoire stratigraphique polyglotte". C.R. Cong. Géol. Inter., 4 ième Sess., Zürich (1894) pp. 523-95.

SCHINDEWOLF, O.H. 1950. Grundlagen und Methoden der paläontologischen Chronologie. Berlin: Bornträger, Viii + 152 pp. 5 pls., 47 text-figs.

SHAW, A.B. 1964. Time in stratigraphy. New York: McGraw Hill, 365 pp.

SIMPSON, G.G. 1950. Rythme et modalités de l'évolution. Paris: Albin Michel, 354 pp.

STEPANOV, D.L. 1958. Principes et méthodes de recherches biostratigraphiqes. Trudy V.N.I.G.R.I., Moscow, no. 113, 180 pp., 18 figs. (Trad no.2231, M. JAYET, Serv. Inf. Géol. B.R.G.M., Paris).

STILLE, H. 1924. Grundfragen der vergleichenden Tektonik. Berlin: Borntraeger. 443 pp.

(ed.) 1950. Struktur und Zeit. Geol. Rundschau, Vol. 38, p.89.

TEICHERT, C. 1950. Zone concept in Stratigraphy. Bull. Amer. Assoc. Petrol. Geol., Vol.34, pp. 1585-88.

TINTANT, H. 1963. Les Kosmoceratidés du Callovien inférieur et moyen d'Europe occidentale. Essai de Paléontologie quantitative. Publ. Univ. Dijon, Vol. 29, Text: 500 pp., 92 figs., 70 tabs. Atlas: 58 pls.

UMBGROVE, J.M.B. 1942. The pulse of the earth. The Hague; Martinus Nijhoff, 2nd Ed., 179 pp.

ZIEGLER, B. 1967. Ammoniten Ökologie am Beispiel der Oberjura. Geol. Rundschau, Vol. 56, pp. 439-64.

Paper presented Luxembourg, July 1967.
(Translation completed 2nd October 1968).
Postscript received 30th October 1968.

CONDITIONS OF DEPOSITION OF TWO BRACHIOPOD BEDS IN THE CARBONIFEROUS LIMESTONE AT BOLT EDGE, NEAR SPARROWPIT, DERBYSHIRE

by

Helen E. Sadler

Summary

Two brachiopod beds from the Carboniferous Limestone at Bolt Edge, Derbyshire, are described. Tracings of the positions of shells suggest that they were built up into cross-bedding structures. These probably indicate that there were currents flowing from the shallow water of the shelf region to the deeper water of the basin.

Introduction

On the Buxton to Sparrowpit road (A 623) lies Bolt Edge Quarry (SK 088798), in the Carboniferous Limestone just north-east of the Ebbing and Flowing Well. This quarry has been used for dumping rubbish from the Ferodo Works at Chapel-en-le-Frith for about ten years now, so it was thought to be worthwhile to record some observations made before the evidence was obliterated.

This quarry was excavated on the edge of the Carboniferous Limestone massif in the Monsal Dale Beds (H.M. Geological Survey. Sheet 99, Chapel-en-le-Frith), which are D_2 in age; the unconformity with the Edale Shales lies just on the other side of the main road to the north-west. The position of the quarry corresponds with the postulated position of the edge of the shelf region, where shallow water is believed to have given way to deeper water of the basin to the north-west (Hudson & Cotton, 1945).

Barnes & Holroyd (1896) recorded small pebbles and fish teeth from this quarry and believed they accumulated on a sea beach similar to the one they envisaged at Castleton.

Jackson (1908), "from the quarry near the Ebbing and Flowing well", found many fish teeth which were very rolled and abraded. These he identified mainly as Psephodus magnus (M'Coy). He also believed they were thrown up on an old sea-beach.

These theories of the presence of a sea beach are not now generally accepted; it is thought instead that the beach-like deposits and comminuted debris are the result oı nighly turbulent water action (Sadler, 1964a, discussing the "Beach Beds" at Castleton, where a submarine channel is described) or represent a marginal facies, such as the fore-reef as described by Wolfenden (1958).

Stratigraphy

The quarry at Bolt Edge showed three distinct types of lithology. At the top were 20 feet of massive fine-grained limestones, which were calcarenitic in part and contained finely comminuted white shell debris. In thin section, these upper beds showed many rounded shell fragments, numerous well-rounded crinoid ossicles, rounded limestone "pebbles" and occasional foraminifera, indicating they were probably laid down in fairly turbulent water.

Intercalated between these calcarenitic limestones and the beds below were thin, black, shaly lenticles from which the fish teeth were obtained.

Below these shaly beds was a more massive, dark-grey, fine-grained limestone with pockets of crinoid debris, overturned colonies of the Rugose coral Lithostrotion, and very many Gigantoproductid brachiopods. Thin sections of this massive limestone showed numerous brachiopod fragments (many of which were aligned parallel with the bedding), as well as crinoid ossicles and occasional bryozoan fragments. This Gigantoproductus bed was about two feet thick and dipped at 10 degrees towards the north-west. The large brachiopod shells and coral colonies could not be extracted because of the lithology of the limestone, so tracings of them were made straight from the rock face (see Sadler, 1964b, for the method of taking tracings from the Cyrtina septosa Band). Thus a true record of the positions of the shells was made from the north face of the quarry. From these tracings, which were taken over a horizontal distance of 46 feet along a dip section, it was possible to get an overall picture of the distribution and disarticulation of 154 Gigantoproductids. It was found that 97% had their concave sides uppermost and only 3% had their convex sides uppermost. 75% of the shells were disarticulated.

Conditions of Deposition

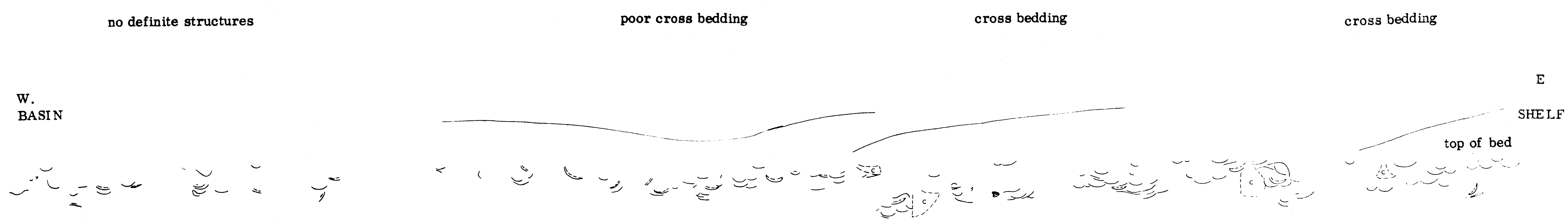
This assemblage of fossils is undoubtedly a death assemblage, the shells having been transported to these positions by moving water and the coral colonies overturned.

The most interesting feature noted from the positions of the shells was their alignment in the form of cross-bedding, the dip of which varies from 5 to 12 degrees; the angle decreases towards the north-west, where the structures become very much less well-defined, although the shells are still grouped in clusters (see diagram). It is thought that these cross-bedding structures were formed by currents flowing from the shallow water of the shelf to the deeper water of the basin. There appears to be an absence of reef and fore-reef beds (Wolfenden, 1958), although a small knoll reef is indicated towards the southern end of the quarry (Geological Survey, Sheet 99). There is no available evidence of a submarine channel similar to that described near Castleton (Sadler, 1964a). Possibly the currents were set up by the tidal ebb and flow between the shelf and the basin.

Four colonies of Lithostrotion (three overturned and one lying on its side) were found amongst the brachiopod debris which was aligned into the cross-bedding structures, giving further evidence of turbulent water.

The high percentage (75%) of Gigantoproductid shells in the apparently unstable position, that is with the concave side uppermost, is thought to have been due to the fact that these large saucer-like shells became embedded in the limy mud on the sea-floor and therefore became more stable than is normal for shells with their concave side uppermost.

Three feet above this Gigantoproductus bed was a four-inch band containing smaller brachiopod shells (probably Dictyclostus) and small crinoid fragments. Two-thirds of the shells were disarticulated and 50% had their convex side uppermost. They were built up into a single small cross-bedding structure.



Text-fig. 1.

Diagram to show the actual positions of the brachiopod shells and coral colonies in the Gigantoproductus bed. Above the section of the bed are suggested lines of the cross-bedding structures.

Key — Articulated shells are shown with two valves, one being represented by a dotted line.

Coral colonies are shown by an approximate cone shape with a C in the middle.

Scale: — Horizontal and vertical 1 inch represents 3 feet.

General Conclusions

These observations are all considered to point to turbulent water conditions occurring on the margin between the shallow water of the shelf and the deeper water of the basin. It is thought that the ebbing and flowing tides over this margin probably set up currents, some of which brought the large *Gigantoproductus* shells from the shelf region and deposited them on the edge of the basin. At times these currents were confined to submarine channels cutting through the reef (Sadler, 1964 a), but at Bolt Edge it is believed that there was no reef wall present and there is no evidence available of any submarine channel. The dip of the beds is thought to be a depositional one, such as was described at Castleton (Wolfenden, 1958), but not nearly so steep. The tidal currents piled the shells into cross-bedding structures, the dip of which decreases towards the basin.

Acknowledgements

I am very grateful to Dr. T.D. Ford for his constructive criticisms when reading the manuscript.

Helen E. Boynton (née Sadler), B.Sc., Ph.D.,
61 Copse Close, Oadby, Leics.
(Department of Geology,
The University of Leicester).

References

BARNES, J. & HOLROYD, W.F. 1896. On the occurrence of a sea-beach at Castleton, Derbyshire, of Carboniferous Limestone age. Trans. Manchr. Geol. Soc., Vol.25, pp.119-132.

HUDSON, R.G.S. & COTTON, G. 1945. The Lower Carboniferous in a boring at Alport, Derbyshire. Proc. Yorks. Geol. Soc., Vol. 25, pp.254-330.

JACKSON, J.W. 1908. Carboniferous Fish-remains in North Derbyshire. Geol. Mag., Vol.5, pp. 309-310.

SADLER, H.E. 1964a. The origin of the 'Beach Beds' in the Lower Carboniferous of Castleton, Derbyshire. Geol. Mag., Vol.101, pp. 360-372, 4 figs.

1964b. Conditions of sedimentation of the *Cyrtina septosa* Band in the Lower Carboniferous of Derbyshire. Mercian Geol., Vol.1, pp.15-22, 1 fig.

WOLFENDEN, E.B. 1958. The paleoecology of the Carboniferous reef-complex and shelf limestones in North-West Derbyshire, England. Bull. Geol. Soc. Amer., Vol. 69, pp.871-898, 12 figs.

Manuscript received 6th August, 1968

OCCURRENCES OF GALENA AND OTHER MINERALS IN THE AREA WEST OF MANSFIELD, NOTTINGHAMSHIRE

by

Kenneth Aldred

Summary

Very thin stringers of galena, siderite and calcite have been found in the lower layers of the Lower Magnesian Limestone. Interstitial galena and barytes is seen in thin sections. The occurrence and origin is compared with that of other Permian mineral deposits of the East Midlands and elsewhere.

Introduction

Various examples of galena, wulfenite and barytes from the Mansfield area have been described by Deans (1961, p. 705). Most of these examples occur at the top of the Lower Magnesian Limestone, their origin being ascribed to ascending hydrothermal fluids trapped by the overlying marl. King (1966, p. 261) describes epi-syngenetic mineralization of the Midlands in the form of Neo-neptunian dykes. The examples given below are not consistent with Deans' ascending fluid theory; and, in fact, the few cases cited allow of no single origin.

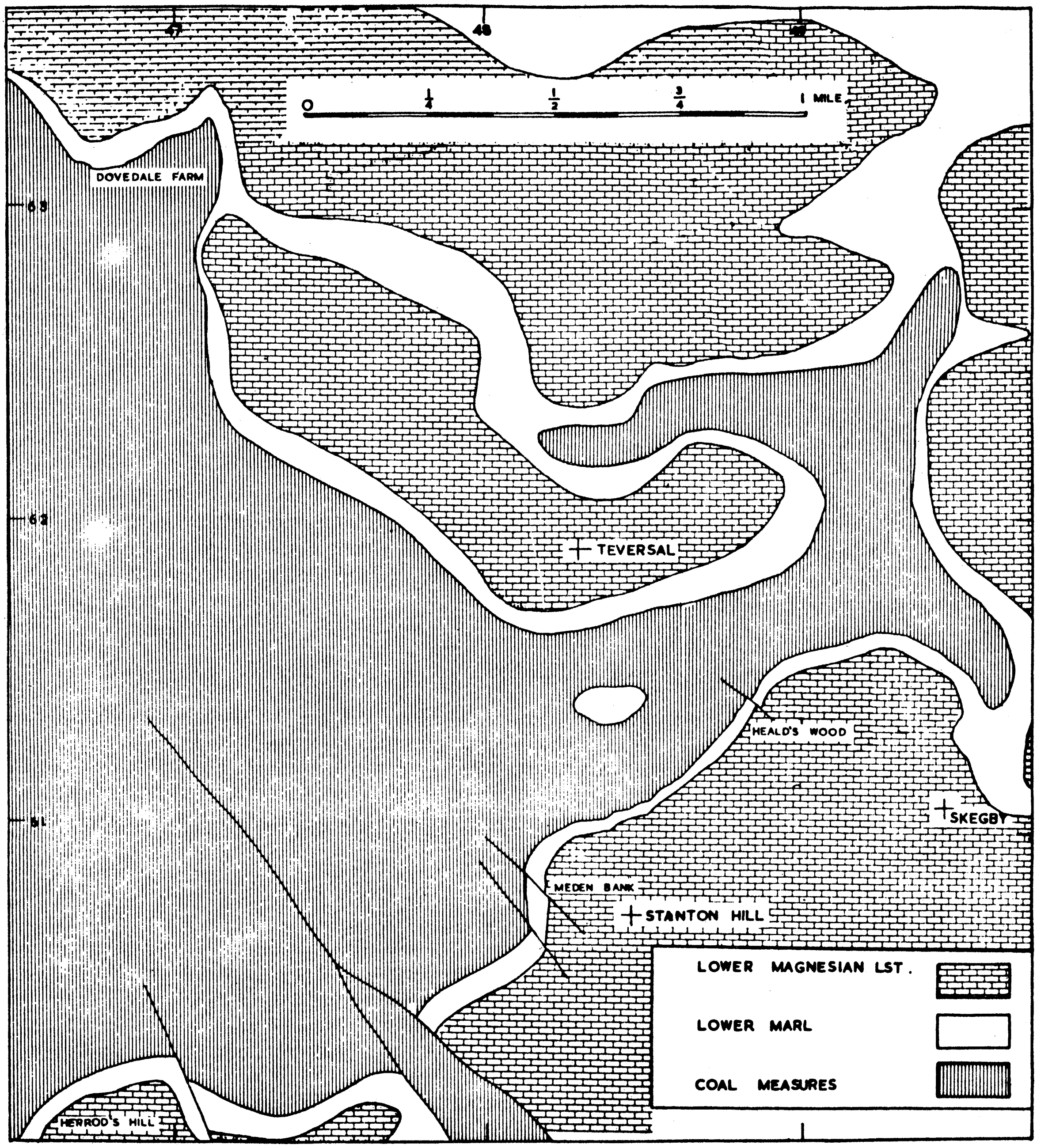
Description of Localities

Most examples under discussion occur near NW trending faults. One reason for this may be that the faulted Permian escarpment has more accessible exposures near the faults; but searches away from the faults have not yielded any mineralization within the Lower Magnesian Limestone. The small amounts of galena and barytes are nearly always interstitial, with larger amounts occurring as veinlets and euhedral crystals, and with galena replacing fossil lamellibranchs and foraminifera. While most of the mineralization occurs at the very base of the Lower Magnesian Limestone, some galena is present in the limestone bands within the Lower Marl. This mineral is found also with the Basal Breccia and nearby Coal Measures.

All National Grid co-ordinates are in 100 km. grid square SK.

Meden Bank, Stanton Hill (48426105)

Fine grained dolomitic limestone with many calcite veins up to 1.5 mm. thick. The calcite appears to fill cracks in the limestone, with extensive crystal continuity. Some of the cracks



Text-fig. 1 Sketch map of the area around Teversal, showing mineral localities.

are bordered with brown limonite. Galena cubes, up to 4 mm. across, are also bordered with limonite. Other galena fills fossil cavities in the limestone, whilst large Productus valves are replaced by calcite.

The thin section (Plate 2 Fig. 1) shows a mainly dolomitic rock containing rounded and subrounded fragments of detrital quartz. Fractures in the rock are often empty, but the vein shown is occupied by siderite which, in places, does not quite fill the void. Rhombs of dolomite protrude into the cavity, suggesting that diagenesis post-dated the fracturing. Coarser dolomite occurs in patches and fine micritic material exists in sparse quantities. The section was stained to distinguish between calcite and dolomite; but there is no calcite present in the section shown and it appears that the only calcite in the rock is that in the veins. The films of galena extend up to 4 cm. in length. The barytes is never extensive, being interstitial between the dolomite rhombs in scattered patches.

Healds Wood (48876139)

Very fine grained dolomitic limestone. Cracks up to 10 mm. wide are partly occupied by beautifully bladed pink and cream barytes. In thin section (Plate 2 Fig. 2) the specimen consists of a mosaic of dolomite with opaque material, possibly haematite, replacing foraminifera. Micrite occurs in patches between the dolomite. Quartz is very sparse. Other specimens from the nearby Fackley Road cutting contain small amounts of angular quartz.

Herrods Hill (46996020)

This limestone is very similar to that above except that colourless calcite crystals, as well as barytes, are present in the cracks. The two minerals never appear together. A drainage trench (47006034), to the north of this exposure, passed through the Basal Breccia. Besides the usual limestone and quartz fragments, the breccia here contained specimens of corroded detrital galena, up to 5 mm. diameter.

Dovedale Farm (47156320)

Two-inch bands of calcareous limestone, separated by similar bands of brown marl, are mapped by the Geological Survey as Lower Permian Marl. These beds have also been recently described as Dolomitic Siltstone. The former name is misleading, as it is of Zechstein age; and in many places between Norwood and Teversal more than 50% of the sequence consists of limestone. The beds correspond to the Marl Slate of Durham.

Freshly broken specimens have a colour layering, the centre being blue grey, with buff to pale grey zoning at the upper and lower surfaces. Galena is present near the middle of the limestone bands, filling cavities completely. Much of the rock is made up of the values of lamellibranchs, which in Plate Fig. 3 are seen to consist of a granular calcite fabric lined with very thin layers of galena. In some cases the space between the two valves also consists of coarse granular calcite. Galena replaces foraminifera.

Other localities where barytes has been found include Skegby Quarry (501612), where course grained dolomitic limestone contains many ill-formed fossils, among them large Productids. Also Mansfield Quarry (534601) contains large crystals of barytes filling, or partly filling, vertical cracks in the limestone. Some single crystals are up to 2 cm. long.

Discussion

Ford and King (1965, p. 1686; Ford, 1966) discuss the breakthrough of mineral-bearing fluids to the ground surface in Triassic times, the fluids depositing minerals at various places in the Midlands. In a similar way these fluids could also be trapped above the Lower Marl after moving downwards. Fowler (1943) considers various possible origins for the minerals present in the Permian rocks of South Durham and favours the view that they were deposited contemporaneously with those of the Coal Measures. The close geographical proximity of the two deposits makes this theory attractive; and a similar connection may be implied for the Mansfield examples. Rushworth (private communication) reports having seen galena veins, up to 6 cm. thick, in various East Midland coal mines. The minerals in the Coal Measures, Lower Marl and Lower Magnesian Limestone and those in the Basal Breccia may have had a single primary source, but their present distribution cannot be accounted for by any single hypothesis.

Acknowledgements

The writer wishes to acknowledge the helpful criticism of Dr. W.A. Cummins and Dr. R.J. Firman (University of Nottingham). Thanks are also due to Mr. M. Smith for assistance with the thin sections; and to Dr. I.D. Starmer and Mr. J. Eyett (University of Nottingham) for taking the photographs.

K. Aldred,
West Nottinghamshire Technical College,
Mansfield, Notts.

REFERENCES

DEANS, T. 1961. A galena-wulfenite-uraniferous-asphaltite horizon in the Magnesian Limestone of Nottinghamshire. Miner. Mag., Vol. 32, pp. 705 - 715.

FORD, T.D. 1966. Some aspects of the structural and mineralization history of the Peak District of Derbyshire. British Association for the Advancement of Science Annual Meeting. (handout given at lecture, but not published).

FORD, T.D. and KING, R.J. 1965. Layered epigenetic galena-barite deposits in the Golconda Mine, Brassington, Derbyshire, England. Econ. Geol., Vol. 60, pp. 1686-1701.

1968. Mineralization of the Triassic rocks of south Derbyshire. Trans. Inst. Min. Met., Section B, Vol. 77, pp. B41-44.

FOWLER, A. 1943. Fluorite and other minerals in Lower Permian Rocks of South Durham. Geol. Mag., Vol. 80, no. 2, pp. 41-51.

KING, R.J. 1966. Epi-syngenetic mineralization of the English Midlands. The Mercian Geologist, Vol. 1, pp. 291-301.

Manuscript received 20th November, 1968

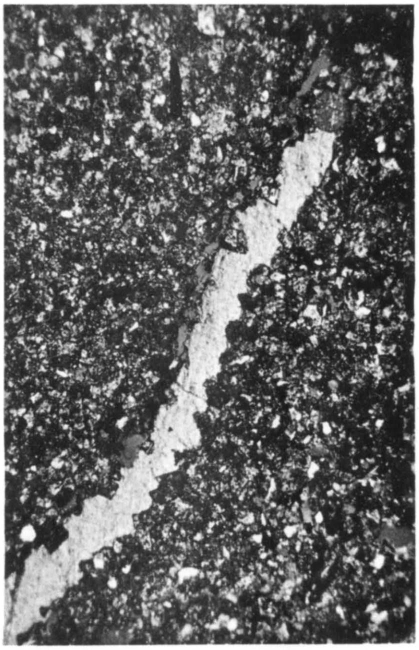


Fig. 1. Meden Bank x 25
Cross nicols. For details see fig.3

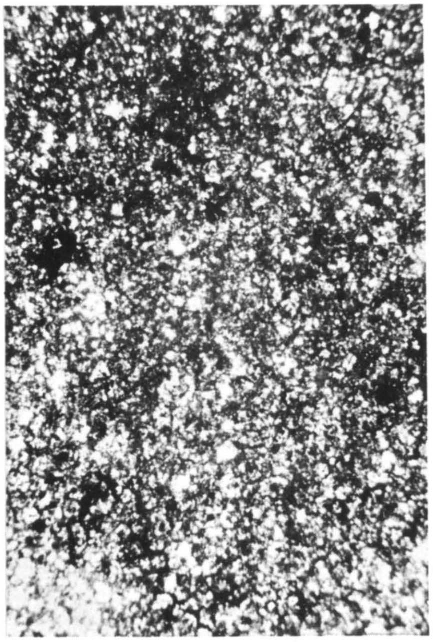


Fig. 2. Healds Wood x 25
Dolomite with galena.

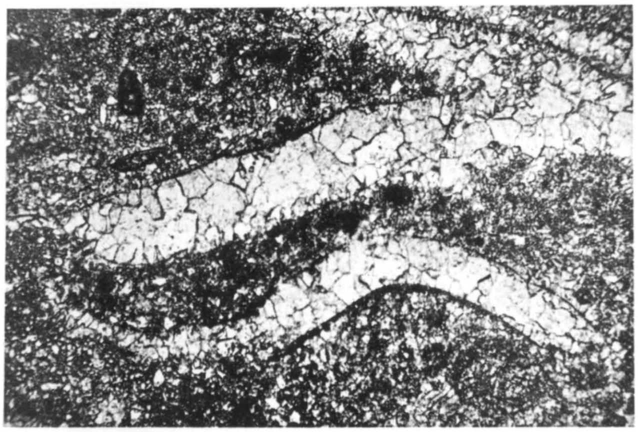


Fig. 3 Dovedale Farm x 25
Galena edge to fossil valves of shells.

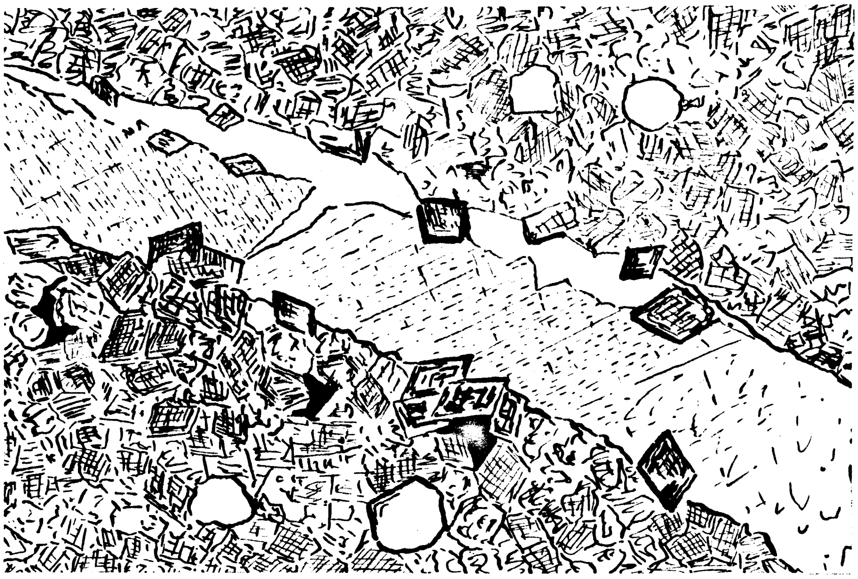


Fig. 4. Meden Bank x 100
Crack in dolomitic limestone edged by rhombs of dolomite. Siderite vein does not quite fill the void. Detrital quartz shown clear. Galena shown black.

Fig. 5. Skegby Quarry x 30
Coarse dolomitic limestone with band of finer dolomite and detrital quartz. Interstitial galena.

KEUPER MARL DETRITUS IN THE BED LOAD OF BRADGATE BROOK, CHARNWOOD FOREST, LEICESTERSHIRE

by

W.A. Cummins

Summary

Keuper Marl is being eroded from a cliff alongside Bradgate Brook in the form of pebbles and sand grains. This Keuper Marl detritus is a major component of the stream sediments below the cliff, but is progressively reduced further downstream as a result of abrasion during transport. Detailed analyses of the Keuper Marl content of the sediments in Bradgate Brook resulted in the discovery of a relationship between grain size and the Keuper Marl content of the sand fraction. Further investigation of this relationship suggests a method of measuring the rate of movement of bed load sediment in Bradgate Brook.

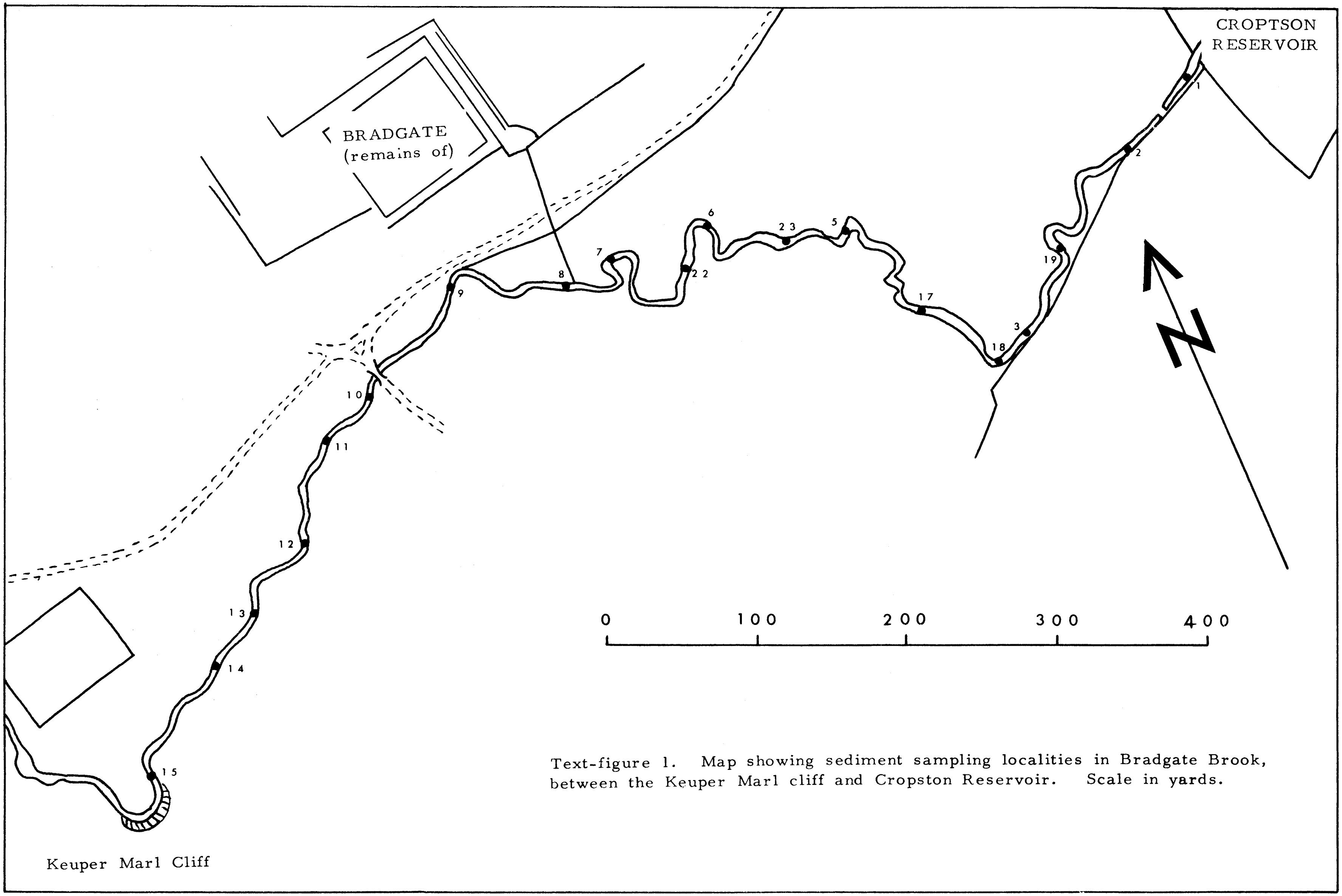
Introduction

Keuper Marl is being eroded along the right bank of Bradgate Brook, about three quarters of a mile upstream from Cropston Reservoir (Text-fig. 1). The marl is exposed in a cliff (SK 532099), about 40 feet high and 200 feet long, round the outside of a sharp meander in the stream. The Keuper Marl in the cliff is being broken down, mainly by mechanical weathering, into angular fragments of various sizes, ranging from several centimetres across downwards. The debris accumulates as a scree at the foot of the cliff. Normally the stream has little effect on this deposit but, when in flood, it cuts into the scree and carries the detritus downstream.

Downstream from the cliff, the bed of the stream is mainly gravel, with local small patches of sand. It is evident from field inspection that the deposits near the cliff contain a much higher proportion of Keuper Marl pebbles than do those further downstream: also the Keuper Marl pebbles in the gravels are rounded, whereas those in the scree at the foot of the cliff are distinctly angular. It is clear that the Keuper Marl pebbles are worn down rapidly by abrasion during transport.

The initial object of the investigation reported in this paper was to study, in greater detail, the rate of abrasion of Keuper Marl detritus during stream transport. With this is view, a series of samples was collected at intervals along Bradgate Brook (Text-fig. 1). They were collected during November 1965 and March 1966, shortly after floods, when the deposits were still fresh. Samples from the stream channel environment of Cropston Reservoir (Cummins and Rundle, 1968), deposited while the reservoir was empty in summer 1965, were also examined. The samples, each weighing a few hundred grams, were dried and shaken through a 2.5 mm. sieve to separate them into coarse (gravel) and fine (sand) fractions*. The two fractions were then examined

* The choice of sieve size was arbitrary. 2.0 mm., the generally accepted upper limit of the sand grade, would have been better from the point of view of naming the fractions.



Text-figure 1. Map showing sediment sampling localities in Bradgate Brook, between the Keuper Marl cliff and Cropston Reservoir. Scale in yards.

separately to determine the percentage of Keuper Marl detritus present. The methods and results of this investigation are given under the headings 'Gravel' and 'Sand'.

Detailed examination of the sand fraction revealed a consistent relationship between grain size and the Keuper Marl content of the sand. In every sample examined, the Keuper Marl content was lower in the medium sand than in coarser or finer sand (Text-fig. 4). This entirely unexpected relationship required an explanation and is considered later in the paper, under the heading 'Grain size and Keuper Marl content of sand fraction'. The explanation advanced involves the rate of supply of sand from upstream of the cliff; and this in turn leads to a possible method of measuring the movement of bed load sediment in the stream. This is discussed at the end of the paper under the heading 'Rate of movement of bed load sediment'.

Gravel

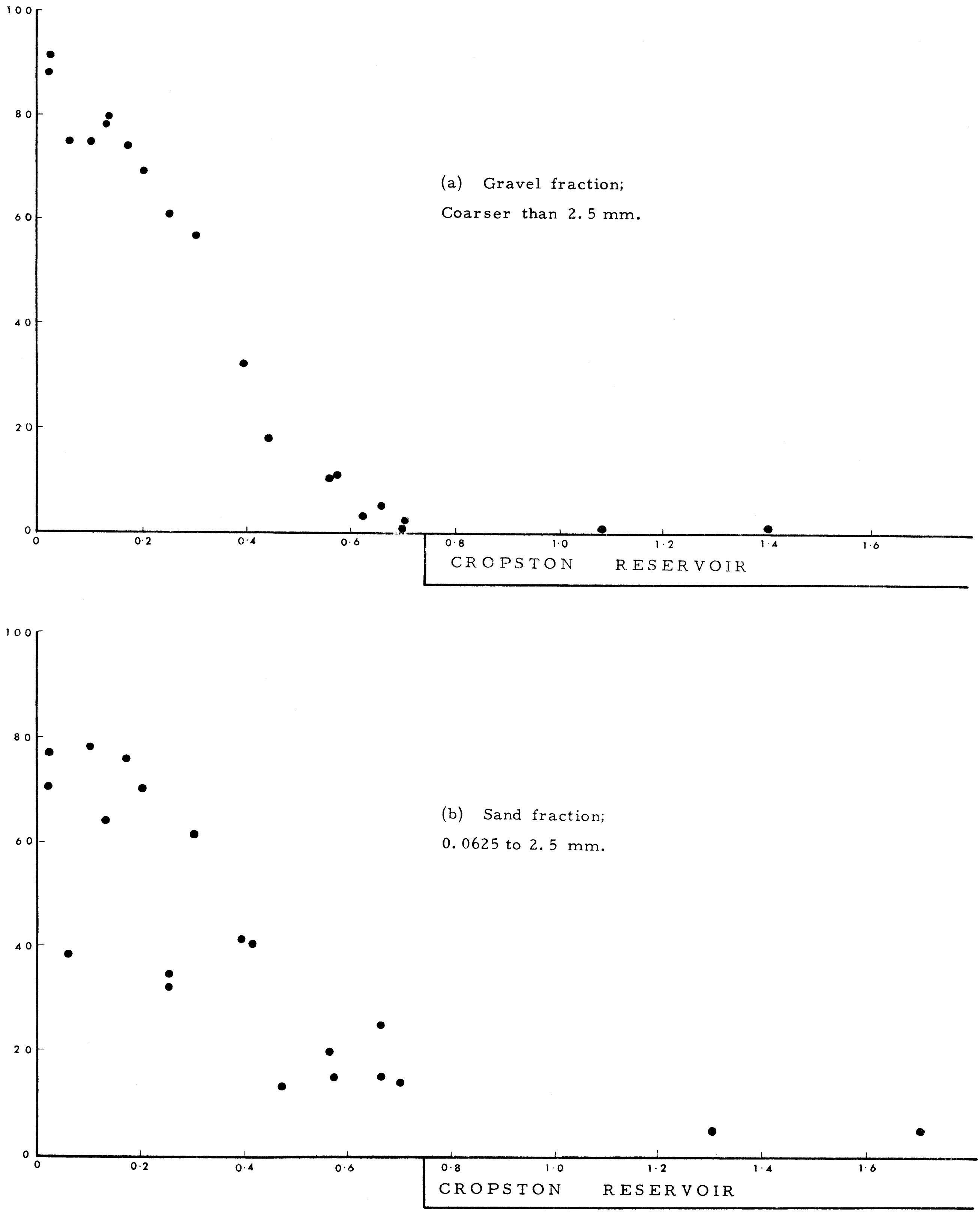
The examination of the gravel fraction was carried out visually. Each sample was spread out on a large sheet of paper and separated by hand picking into two categories: marl pebbles and other (hard) rock and mineral pebbles. The two parts of the sample were then weighed and the percentage of marl pebbles calculated. This percentage was considered as the Keuper Marl content of the sample. It was of course recognised that this does not fully represent the contribution of the Keuper Marl cliff, as skerry beds in the cliff certainly yield hard rock and mineral pebbles: but it is directlv related to the contribution of the cliff, as samples collected upstream of the cliff contained more pebbles at all.

The Keuper Marl content of the gravel fraction of the samples falls from 90% immediately downstream of the cliff to 1% just above the reservoir (Text-fig. 2a), a distance of three-quarters of a mile. Two factors contribute to this downstream decrease in Keuper Marl pebbles; abrasion during transport and weathering during the intervals between transport. Periods of significant movement of bed load (sediment moving close to the bed of the stream by rolling, sliding or bouncing) are of short duration. During the long intervals between movement, the gravels may be subjected to alternate wetting and drying by rising and falling water level in the stream and, when above water level, by rain and sun. This results in the mechanical breakdown of the marl pebbles into finer detritus.

Sand

Visual separation of the sand fraction into marl and non-marl components was impracticable, so an indirect method was used by which the marl grains were disaggregated and washed away as mud, leaving a marl-free sand fraction. The method of analysis described below is most conveniently applied to small samples, of 20 grams or less. The sand fractions of the samples collected weighed anything from 90 to 250 grams. They were accordingly split, before treatment, to more manageable sizes.

The sample to be tested was weighed and then put to soak in a N/100 solution of sodium oxalate (sodium oxalate has been widely used for the dispersion of fine grained sediments in preparation for grain size analysis). After soaking for a day or more, the sample was washed through a 0.0625 mm. sieve (lower limit of sand grade). The residue left on the sieve was then washed into an evaporating dish and rubbed with a rubber bottle stopper to break down any remaining marl grains. It was then again washed through the 0.0625 mm. sieve, and the process repeated until the residue was a clean, marl-free sand. This residue was then dried and weighed. The percentage loss in weight was calculated and taken as the Keuper Marl content of the sample. The relationship between this percentage and the actual contribution of the Keuper Marl cliff is similar to that already discussed in the previous section for the gravel fraction.



Text-figure 2. Keuper Marl content of sediments in Bradgate Brook, plotted against distance (in miles) downstream from Keuper Marl cliff.

The Keuper Marl content of the sand fraction of the samples falls from 77% immediately downstream from the cliff to 14% just above the reservoir. From there on a more gradual decrease is indicated by the samples from the stream channel environment of the reservoir, whose Keuper Marl content is about 5% (Text-fig. 2b). Of all the Keuper Marl grains which left the cliff as sand, over 80% have been lost in the first three quarters of a mile of stream transport and nearly 95% within a mile and a half of their starting point.

The scatter of points on the plots of Keuper Marl content against distance downstream from the cliff is much greater for the sand fraction than for the gravel fraction (Text-fig. 2). Several factors might be thought to contribute to this scatter:- (i) a proportion of the Keuper Marl pebbles in the samples might have broken down during storage and drying, thus adding to the Keuper Marl content of the sand fraction; (ii) the rate of abrasion of the Keuper Marl grains might be significantly different for the different grain sizes within the sand fraction; (iii) the distances shown in Text-fig. 2 are measured along the stream channel but, during times of flood, a good deal of the stream flow (and movement of sand grains) is along short cuts across the necks of meanders. These factors will be considered in turn below.

(i) If the Keuper Marl content of the sand fraction has been increased by the break-down of Keuper Marl pebbles, then it should be too great by an amount proportional to the weight of Keuper Marl pebbles in each sample. Reduction of the Keuper Marl content of the sand fraction by fixed percentages of the weight of Keuper Marl pebbles in the samples does not significantly reduce the scatter of points discussed above (Text-fig. 3a). It is concluded that this is not a main cause of the scatter in the results.

(ii) If the rate of abrasion is different for different grain sizes within the sand fraction, analyses carried out within more closely defined size units should produce less scatter. In order to test this, the sand samples were divided into a number of sub-samples according to grain size. Before treatment, each sample was mechanically shaken through a nest of sieves (1.0 mm., 0.5 mm., 0.35 mm., 0.25 mm., 0.175 mm., 0.125 mm., and 0.0625 mm.) and the portion retained on each sieve was weighed. The resulting sub-samples varied in weight from over 60 grams down to less than a gram. The larger sub-samples were split to more workable sizes and then all were treated in the manner described above (p.39). The Keuper Marl content of the smaller size units within the sand fraction still shows a considerable scatter when plotted against the distance downstream from the cliff (Text-fig. 3b).

(iii) The scatter of points on Text-fig. 2b does not seem to be an artefact resulting from the treatment of the samples (items (i) and (ii) above). It follows that the irregularity of the downstream decrease in the Keuper Marl content of the sand fraction is probably real and due to natural processes. Further field work would be needed to study the possibilities.

Grain size and Keuper Marl content of sand fraction

Treating the sand fraction in sub-samples of different grain sizes resulted in the discovery of an interesting and entirely unexpected relationship between grain size and the Keuper Marl content of the sand. In every sample examined, the Keuper Marl content of the sand was lower in the medium sand than in coarser or finer sand. In most samples the minimum Keuper Marl content was found in the 0.25 to 0.35 mm. grade. This relationship held in all samples, regardless of variations in the grain size distribution or the Keuper Marl content of the sand fraction as a whole. The samples analysed range from gravels, with less than 20% of sand, to sands, with no more than 2% of coarser material. The Keuper Marl contents of the sand fractions range from 77% down to 5%. No matter what the character of the sample as a whole, the relationship between grain size and Keuper Marl content is the same (Text-fig. 4).

Three factors must be considered in an attempt to interpret this relationship:- (i) the relative rate of supply of different grain sizes of sediment from the Keuper Marl cliff; (ii) the Keuper Marl content of the different size fractions derived from the cliff; (iii) the relative rate of supply of different sizes of sand from further upstream.

(i) Material eroded from the Keuper Marl cliff accumulates as a scree at the foot of the cliff and is only removed when the stream is in flood. During floods the stream cuts into the scree deposit and removes the debris completely, without leaving a lag deposit. Therefore, the relative rate of supply of different grain sizes of sediment from the cliff is given by the grain size distribution of sediment in the scree deposit. Grain size analyses were carried out on six samples of the scree sediment, within the limits 0.0625 mm. to 1.0 mm.. This was done by washing the sediment through a nest of sieves and then drying and weighing the portion retained on each sieve. The six samples gave consistent grain size distribution patterns.

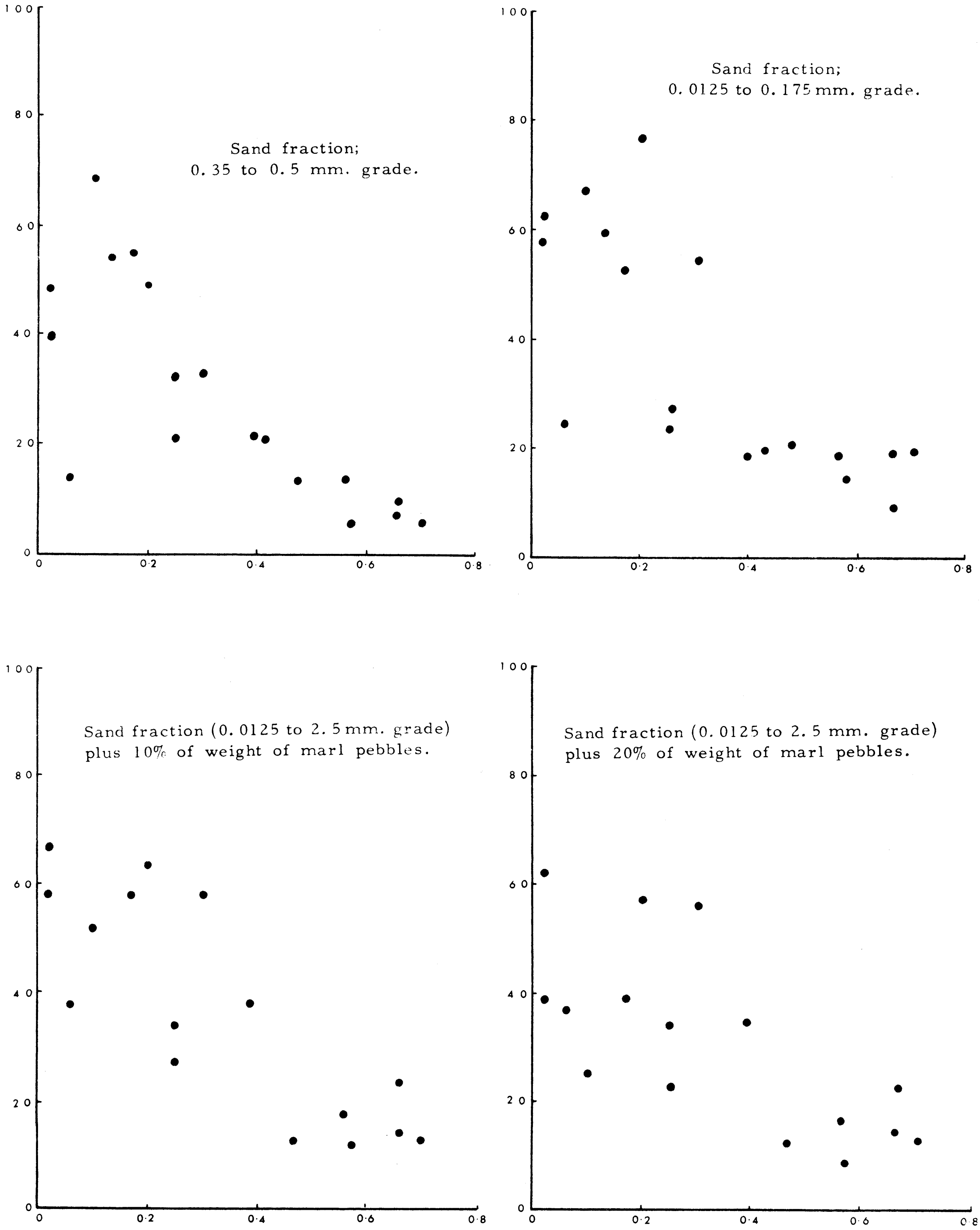
(ii) The Keuper Marl content of the different size fractions of the scree sediment was determined by the method described earlier for the stream sediment samples. The minimum Keuper Marl content, 72%, was found in the 0.175 to 0.25 mm. grade.

The grain size distribution of the scree sediments, within the range studied, is shown in a histogram (Text-fig. 5a). Each bar in the histogram is divided to show the Keuper Marl content (stippled) and the non-marl residue (blank). The stippled portion of this histogram represents the relative rate of supply of the Keuper Marl component to the different sand grades in the sediments of Bradgate Brook. A noteworthy feature of this result is that the maximum rate of supply is in the 0.25 mm. to 0.35 mm. grade, just where the Keuper Marl content of the stream sediments is at a minimum.

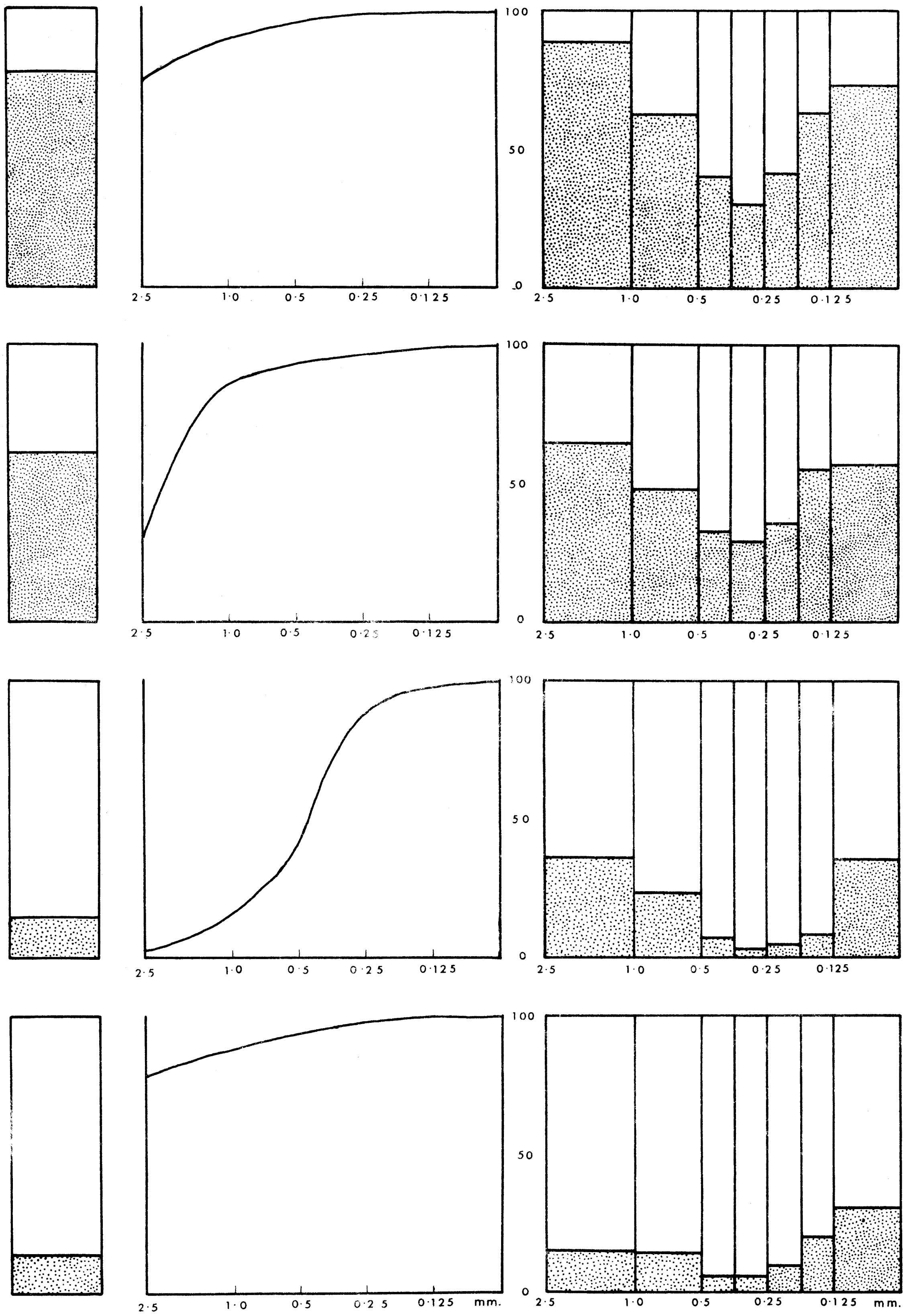
(iii) The relative rate of supply of different sand grades from upstream of the cliff would be difficult to measure. The sediments in the bed of the stream give little indication of this: they are mainly lag deposits, left behind by the more mobile part of the bed load. But, knowing the relative rate of supply of the Keuper Marl component to the different sand grades from the cliff (Text-fig. 5a) and knowing the Keuper Marl content of these sand grades in the sediments of Bradgate Brook below the cliff (Text-fig. 4 and 5b), it is possible to calculate the relative rate of supply of the different sand grades from further upstream (the only remaining unknown factor).

The relative rate of supply of sediment from the cliff is shown in Text-fig. 5a. The Keuper Marl contents of the various sand grades (stippled) are diluted by different amounts, according to the (unknown) relative rate of supply of marl-free sand from upstream. The result of this differential dilution is the relationship between Keuper Marl content and grain size in the sediments downstream of the cliff (Text-fig. 5b). Since the cliff is the sole source of Keuper Marl in the stream, the Keuper Marl contents, shown in Text-fig. 5b, must have been supplied in the ratio shown in Text-fig. 5a. The height of the bars in Text-fig. 5b may therefore be altered so that the stippled portions are the same height (or in the same ratio) as in Text-fig. 5a. In the resulting histogram (Text-fig. 5c), the height of the lower portions of the bars (stippled and unstippled) is related to the rate of supply of sediment from the Keuper Marl cliff (as in Text-fig. 5a); therefore, the height of the upper parts of the bars must be similarly related to the rate of supply of marl-free sand from further upstream. These upper parts are isolated in a separate histogram (Text-fig. 5d), which shows the relative rate of supply of the different sand grades from the stream above the Keuper Marl cliff, in other words the relative rate of movement of these sand grades past the cliff (in terms of weight of sediment per unit time).

The calculation illustrated in Text-fig. 5 made use of the mean Keuper Marl content of all the samples studied. The relative rate of movement of the different sand grades has also



Text-figure 3. Keuper Marl content of sediments in Bradgate Brook, plotted against distance (in miles) downstream from the Keuper Marl cliff.



Text-figure 4. Data from the sand fractions of four samples. Left: Keuper Marl content (stippled) of sand fraction. Middle: Part of cumulative grain size curve in the range 0.0625 to 2.5 mm. Right: Keuper Marl content (stippled) of subdivisions of sand fraction.

been calculated in relation to each sample individually. There is, however, little variation between the results from different samples and no systematic variation with distance downstream from the cliff.

The results of the analyses described above (Text-fig. 5d) show that of all the sand, within the size range 0.0625 to 1.0 mm. passing the cliff in the bed load of the stream, 39% falls within the 0.25 to 0.35 mm. grade, and 84% between 0.175 and 0.5 mm. The finest grades are poorly represented because they are relatively easily taken into suspension and removed from the bed load, together with the silt and clay grades. The coarsest grades are also poorly represented, because they are less easily moved by the stream and tend to be left behind as lag deposits. Apart from the sediment-transporting capacity of the stream, another factor affecting the result is the supply of sediment of different sizes to the stream along its length. In this last respect, the stretch of Bradgate Brook under consideration is distinctly artificial. About six hundred yards upstream from the cliff is the lowest of a series of five settling ponds: between them these trap about 18% of all the sediment coming down Bradgate Brook before it reaches the reservoir (Cummins and Potter, 1967, p. 37), including a very high proportion of the bed load of the stream.

Rate of movement of bed load sediment

The relative rate of movement of the different size grades within the bed load can be determined as described above. It is only a small step from this to a determination of the actual rate of movement of the bed load as a whole, in tons or kilograms per year for example. A discussion of this is included here because, although the results are not yet available for Bradgate Brook, the method may be of more general interest in view of the difficulties encountered in measuring the movement of bed load sediment directly (Hubbell, 1964). The method is summarised below.

(i) Grain size analysis of the scree sediments, over the whole range of sizes involved, gives the relative rate of supply of the different sizes of sediment from the cliff to the stream.

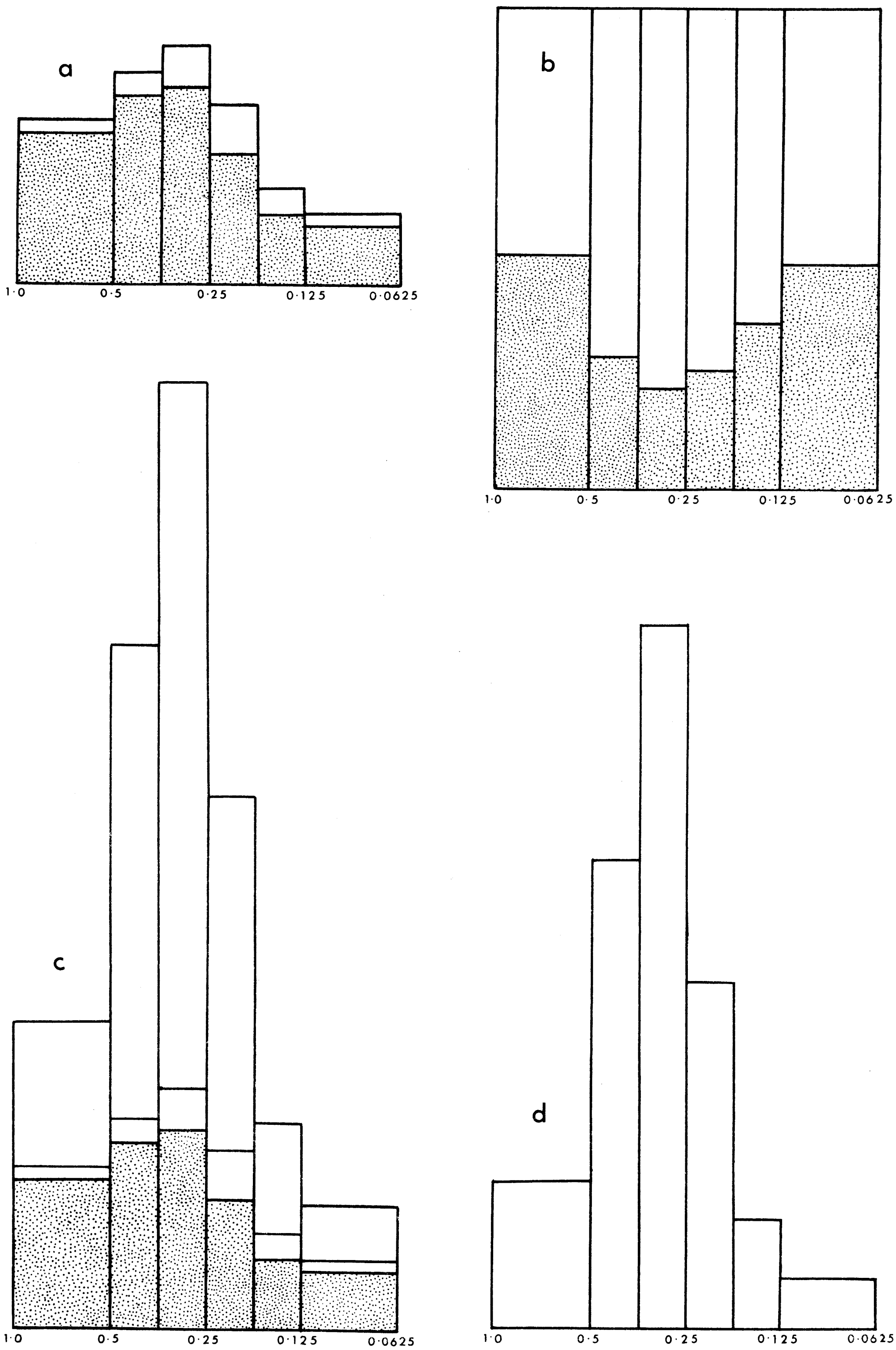
(ii) Keuper Marl content analyses of the different size fractions in the scree sediment gives the relative rate of supply of Keuper Marl grains to the different size grades of sediment in the stream.

(iii) Measurement of the rate of erosion of the Keuper Marl cliff permits the transformation of these relative rates to absolute rates. A study of the rate of erosion of the cliff over a period of two years will be completed early in 1969.

(iv) Keuper Marl content analyses, over the full range of grain sizes, of the stream sediments immediately downstream of the cliff will enable the rate of movement of the bed load to be determined, since the Keuper Marl content of these sediments is entirely derived from the cliff and the rate of supply from this source is known.

Conclusions

The investigation reported in this paper has no clearly defined beginning or end; indeed, as indicated in the previous section, it is not yet finished. It is really a series of investigations, connected by the fact that they are all concerned with the same material and recorded in the order in which they were carried out. The conclusions reached so far are summarised below:-



Text-figure 5. Keuper Marl content (stippled) and grain size, in the range 0.0625 to 1.0 mm. (a) Grain size distribution of Keuper Marl scree sediment; (b) Keuper Marl content of stream sediments; (c) Keuper Marl contents adjusted to the ratio supplied by the cliff; (d) Relative rate of supply of sand grades from further upstream.

(i) Keuper Marl pebbles eroded from the cliff are almost all worn away in the first three-quarters of a mile of stream transport from their source.

(ii) Keuper Marl sand grains suffer over 80% loss by abrasion in the first three-quarters of a mile of stream transport and nearly 95% within a mile and a half of their starting point.

(iii) The relationship between grain size and the Keuper Marl content of the sand downstream of the cliff is largely due to the different rates of supply of the various sand grades from further upstream.

(iv) This last conclusion suggests that, given a measurement of the rate of erosion of the cliff, the rate of movement of the bed load sediment can be determined.

Acknowledgements

I would like to thank Mr. H.R. Potter for assistance in the field and for much helpful discussion about the movement of sediment in streams.

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

References

CUMMINS, W.A. and POTTER, H.R. 1967. Rate of sedimentation in Cropston Reservoir, Charnwood Forest, Leicestershire. Mercian Geologist, Vol. 2, pp. 31-39.

CUMMINS, W.A. and RUNDLE, A.J. 1968. Sedimentary and faunal facies associated with the draining of Cropston Reservoir. Mercian Geologist, Vol. 2, pp. 389-400.

HUBBELL, D.W. 1964. Apparatus and techniques for measuring bed load. U.S. Geol. Surv. Water Supply Paper No. 1748. 74 pp.

Manuscript received 8th October, 1968

THE ORIGIN OF THE SILICA SAND POCKETS IN THE DERBYSHIRE LIMESTONE

by

Trevor D. Ford and Robert J. King

Summary

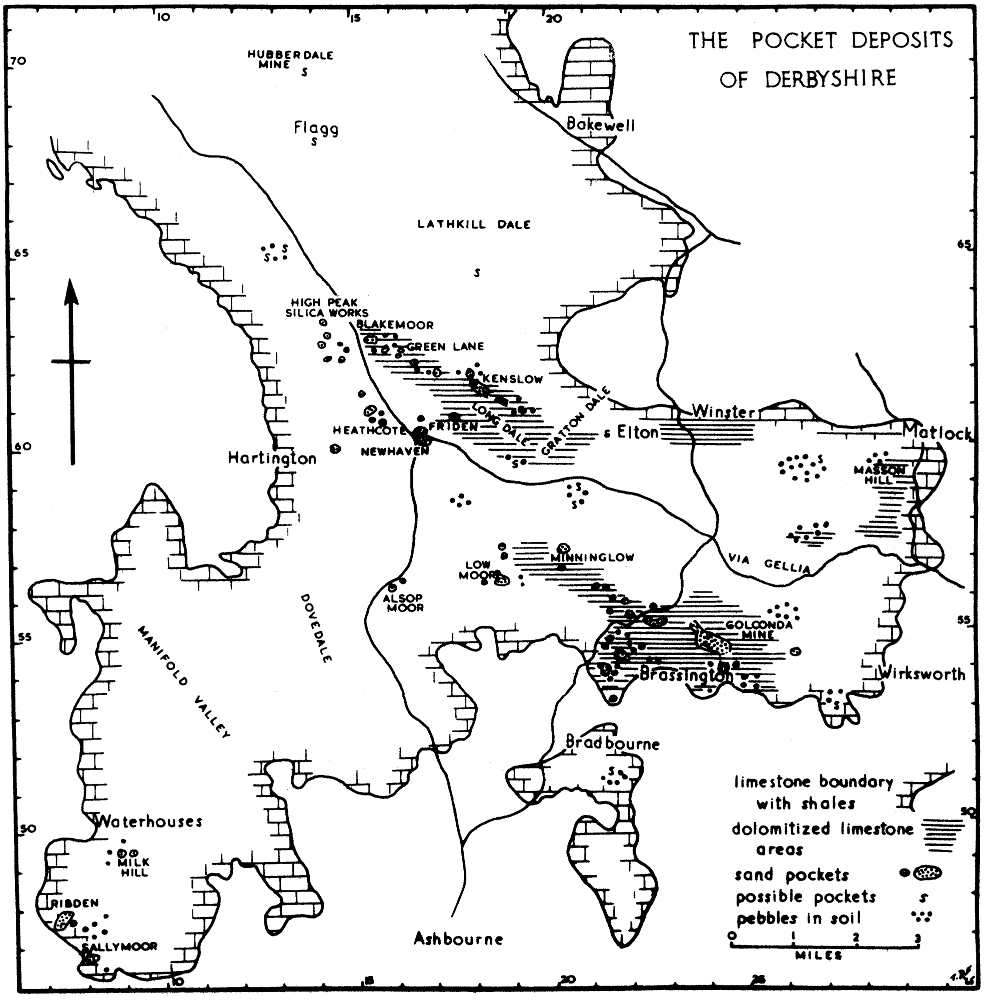
The silica sand and clay-filled solution pockets in the Derbyshire limestone are shown to have a wider distribution than previously noted. Evidence is presented to confirm the hypothesis that the pockets originated by solution subsidence of cave systems; and the existence of related sand-filled caves in various stages of collapse is demonstrated. The distribution of both pockets and caves is shown to be largely controlled by the position of the base of the dolomitized zone of the Carboniferous Limestone; they are shown to post-date mineralization, which is thought to be of late Triassic age. The emplacement of the sands is both contemporary with and post-collapse —but pre-glacial. The sands, though largely composed of Triassic material, are thought to have been deposited in late Tertiary times as a fluvial fan in front of the receding Triassic escarpment.

Comparisons are made with similar deposits elsewhere.

Introduction

The presence of deep hollows on the Derbyshire Carboniferous Limestone plateau, filled with silica sands and clays (often known as "Pocket Deposits"), has given rise to considerable speculation about their possible origin, as either sink-holes or collapsed caverns, and about the provenance and age of the sands. Clay was worked from these deposits for pottery in the late 18th century (Pilkington, 1789, p. 162). The deposits were briefly described by Green *et al.* (1887, p. 163), and by Howe (1896, 1920), Scott (1927), Boswell (1918), and Kent (1957), but the most comprehensive account is a series of private publications by Yorke (1954-61). A summary account has recently appeared in Sylvester-Bradley & Ford (1968). Recent work by the authors in the Golconda Caverns at Brassington has revealed new evidence, not only on the problems of the pockets but also on the mineralization of the district. The latter has been discussed elsewhere (Ford and King, 1965); matters related to the pits themselves are discussed here. The word "pocket" is hereby used to designate a sand-filled hollow; and quarries within these are referred to as "pits".

Yorke has described many of the pockets and their fills in detail; he has discussed various theories about their origin and more particularly about the cover of glacial deposits and their downward intrusion under ice pressure. He concluded (1961, p. 22) that "Triassic


THE POCKET DEPOSITS
OF DERBYSHIRE
HUBBERDALE MINE
Flagg
Bakewell
LATHKILL DALE
HIGH PEAK SILICA WORKS
BLAKEMOOR
GREEN LANE
KENSLOW
LONG DALE
GRATTON DALE
HEATHCOTE
FRIDEN
NEWHAVEN
Hartington
Elton
Winster
Matlock
MASSON HILL
VIA GELLIA
MINNINGLOW
LOW MOOR
ALSOP MOOR
DOVEDALE
MANIFOLD VALLEY
GOLCONDA MINE
Brassington
Wirksworth
Bradbourne
Waterhouses
MILK HILL
RIBDEN
SALLYMOOR
Ashbourne
limestone boundary with shales
dolomitized limestone areas
sand pockets
possible pockets
pebbles in soil
MILES

Text-Fig. 1

sediments were widely spread over the Dome, and that they were trapped in pre-existing limestone hollows, in part solution cavities, and in part great surface watercourses". This view is widely held and partly supported herein, but, as will be seen later, there are several points requiring further explanation. Kent (1957) concluded that the pockets originated as swallow holes on the edge of residual outliers of Upper Carboniferous shales during the denudation of the Southern Pennines in Triassic times, during which time contemporary Triassic sediments were washed in. Kent has argued also for intermittent solution-subsidence through Mesozoic and Tertiary times, with the Mio-Pliocene 1000-foot surface bevelling both the limestones and the pockets with their fills. Parts of Kent's hypothesis are also supported herein. Ford (1963) described the occurrence of dolomite tors in close geographic proximity to the sand pits and outlined the late Tertiary and Pleistocene history of alternating deep weathering and glaciation responsible for the production of tors. In particular it was noted that tor-like features are still present beneath the sands in places, but that the existing tors were probably exposed by being stripped of their weathering product during and since the Last Interglacial.

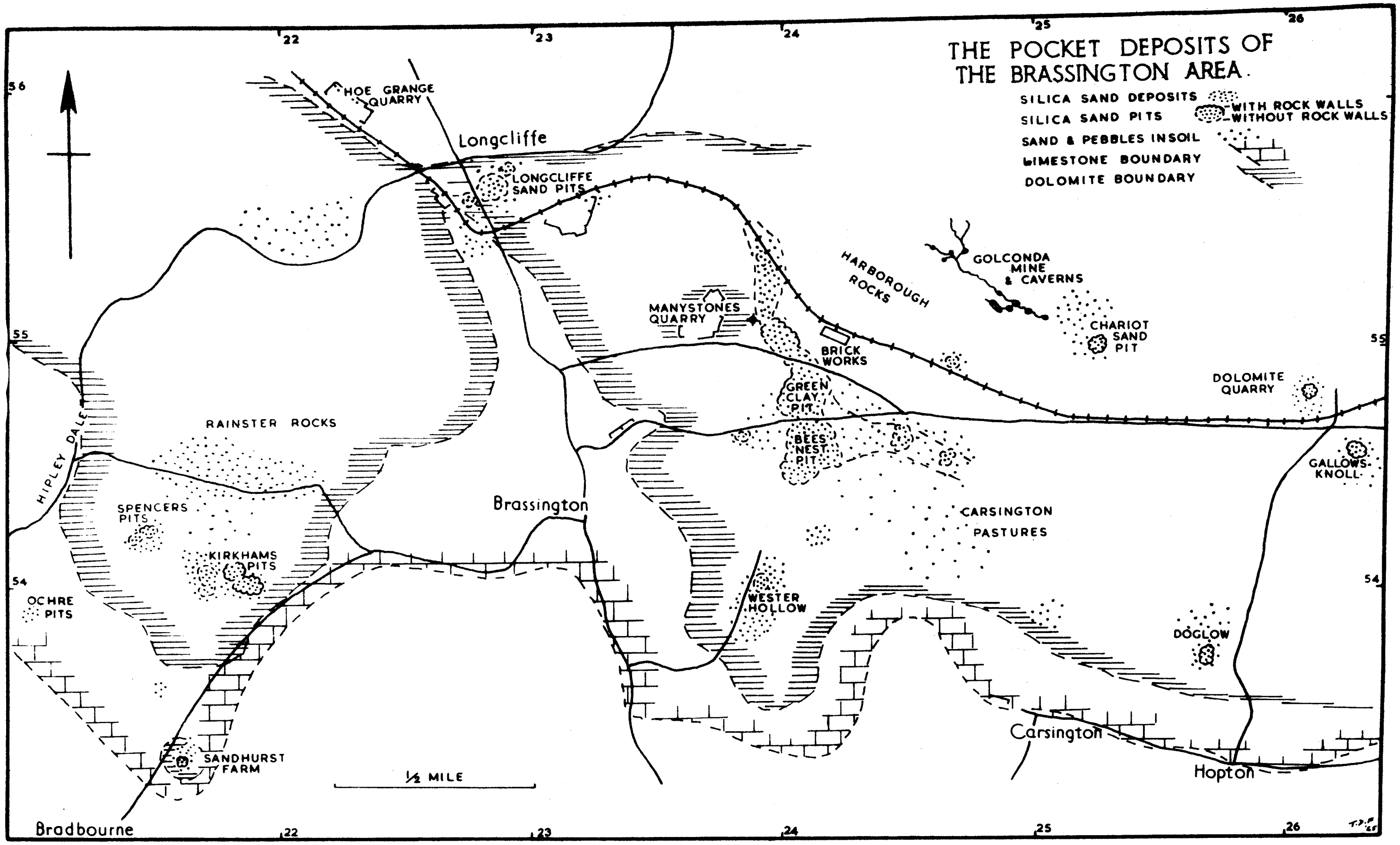
Several factors have been involved in the origin of the pockets and their fills and these will be discussed in turn, as only a full understanding of the interaction between several phenomena can explain the pockets. Of particular importance are dolomitization and its geographical relationship to unaltered limestone, the process of mineral emplacement in the dolomites and adjacent limestones, the provenance of the sands and the history of groundwater movement. In fact, these apparently simple pockets and their fills are but the surface expression of a long and complex geological history; it would be foolish to try to explain them without full appreciation of the implications of all parts of that history.

[NOTE: The greater part of this paper was written in 1964 in connection with a Field Demonstration to the Karst Symposium of the International Geographical Congress. Publication of the "Proceedings" of that Symposium has been indefinitely delayed, so the paper is presented here in a slightly modified form.]

The Pockets and Their Distribution

The distribution of the silica sand pockets is shown on the accompanying map (Text-Fig. 1). Most of the pockets occur along a N.W.-S.E. trend from near Brassington to Parsley Hay, a distance of about 10 miles, in a belt some 3 miles wide. Some pockets are, however, well to the southwest of this trend at Ribden (SK 078474) and near Waterhouses (SK 094492) in Staffordshire. Some other sandy occurrences lie well to the east of the trend, but as they have never been worked their nature is uncertain and they may not belong to the Pocket Deposits proper. These latter are at Hubberdale Mines, near Flagg (SK/137700): Calling Low, near Middleton-by-Youlgreave (SK/182645); and on the Old Moor, west of Castleton (SK/128812). Sandy deposits fill old solution caves at a number of localities on Masson Hill, near Matlock (e.g. SK/285591), but the sands there contain a high proportion of derived fragments of the adjacent rich galena-fluorite deposits, and thus differ in appearance from the sands in the usual pockets. Comparable sands to those of Masson Hill are also known in the open workings of the Royal Mine, Matlock Bath (SK/292579): near Tearsall Farm (SK/265600); and in the Elton-Winster district. The recent Geological Survey 6 inch map (Sheet SK 25 NE) also notes quartzite pebbles and sandy soil in a number of places on and around Masson Hill. Quartzite pebbles are also common near Haven Hill, Bradbourne (SK/215516).

A comparison of the accompanying map with that of Yorke (1954-1961) shows that, whilst he correctly recorded almost all the worked deposits from Brassington to Parsley Hay, he missed some outlying deposits, thus giving a partly false impression. In addition, trial holes and


THE POCKET DEPOSITS OF
THE BRASSINGTON AREA.
SILICA SAND DEPOSITS
SILICA SAND PITS
WITH ROCK WALLS
WITHOUT ROCK WALLS
SAND & PEBBLES IN SOIL
LIMESTONE BOUNDARY
DOLOMITE BOUNDARY
HOE GRANGE QUARRY
Longcliffe
LONGCLIFFE SAND PITS
MANYSTONES QUARRY
HARBOROUGH ROCKS
GOLCONDA MINE & CAVERNS
CHARIOT SAND PIT
BRICK WORKS
GREEN CLAY PIT
BEES NEST PIT
DOLOMITE QUARRY
GALLOWS KNOLL
RAINSTER ROCKS
HIPLEY DALE
SPENCERS PITS
KIRKHAMS PITS
Brassington
CARSINGTON PASTURES
WESTER HOLLOW
DOGLOW
OCHRE PITS
SANDHURST FARM
½ MILE
Carsington
Hopton
Bradbourne
22
23
24
25
26
56
55
54

Text-Fig. 2

borings by the various silica brick companies have shown that sands, too thin to be worked economically, spread beyond the confines of the pockets. Unfortunately many of the records of such holes are no longer available and a map of the full extent of the sands is not possible. In addition, farmers not uncommonly report sand having been found when they were erecting gate-posts etc.

The pockets are almost all at altitudes of 1000 to 1100 feet above sea level, but those in Western Hollow, Brassington (SK/239540) are at 930 feet, and that by Sandhurst Farm, Bradbourne (SK/215532) is at only 780 feet O.D. Spencer's and Kirkham's Pits at Brassington are at about 840 feet O.D., and the sand-filled caverns in the Golconda Mine (SK/249551) extend down to about 760 feet O.D. This seems to indicate that the alleged association with a 1000-foot erosion surface (Kent,1957) is incorrect, but,if it is borne in mind that the pockets are solution collapse features below a pre-existing surface, the 1000-feet association may still be correct.

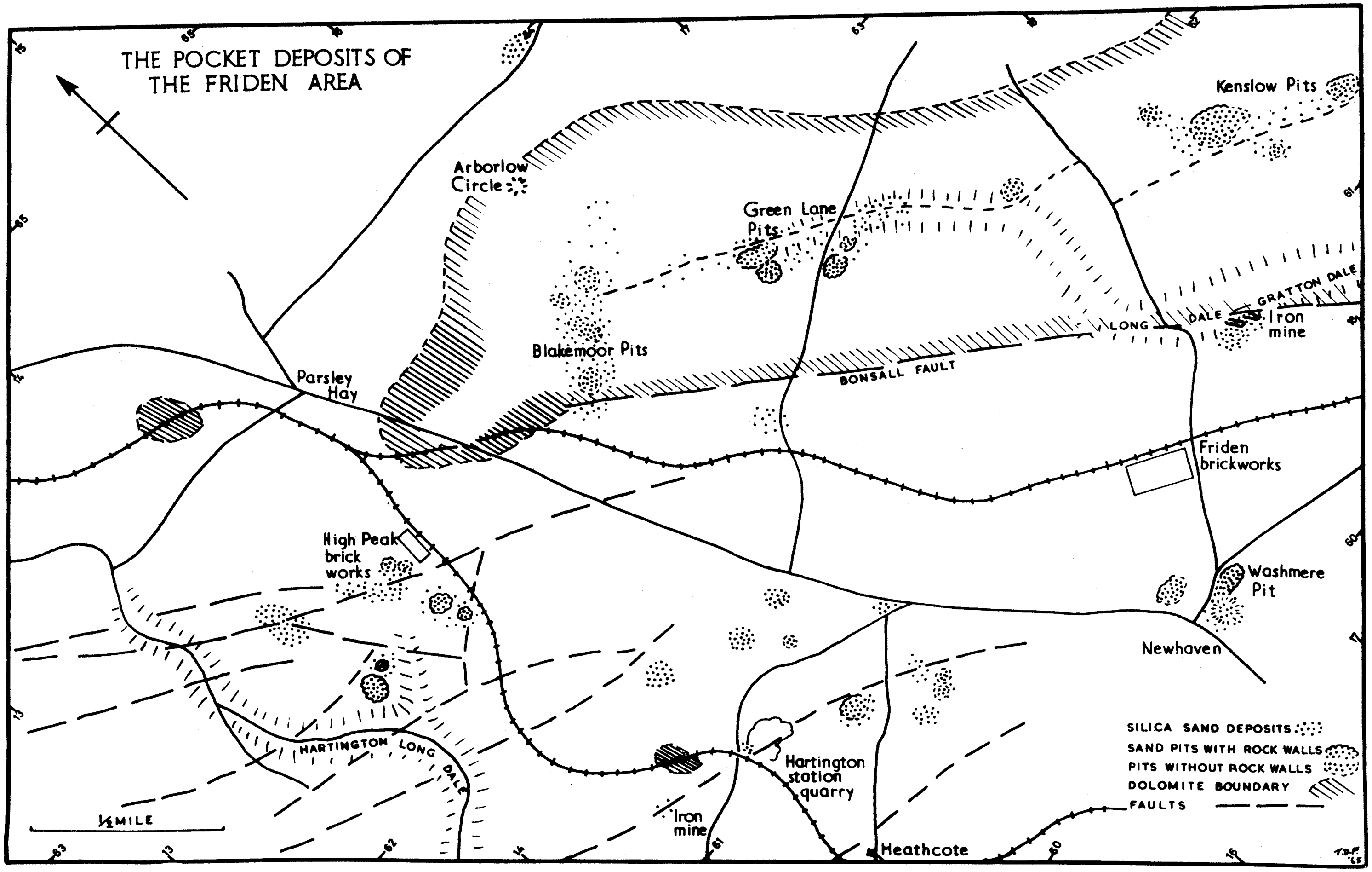
Pitty (1968) has argued that the so-called surface is not a well-preserved relict feature but an erosion surface, developed by differential solution as the cover of impermeable rocks was progressively breached. However, whilst Pitty's findings may partly explain some topographic features, his arguments do not take the full effects of the geological history into account and make little allowance for the glacial and periglacial modification of the landscape. Pitty's study did not cover the dolomitized area or the area with sand pockets.

The pockets show an apparent association, at first glance, with the dry valley system (Warwick, 1964), but closer inspection reveals that this association is fortuitous and that the pockets pre-date the dry valleys. At Long Dale, Hartington (SK/140625), a pocket on the plateau is separated by only a few yards of limestone from the dale, here incised 100 feet below the lip of the pocket. Similarly, one of the Green Lane pockets (SK/167624) has only just been by-passed by the incised dale, whilst another (SK/166626), in the floor of the dale, was only revealed by working and shows a sinuous pattern across the floor, with solid terminations both upstream and downstream. The map of the Brassington area (Text-Fig. 2) shows that some pockets occupy the floor of a shallow valley between Harborough Rocks and the hill to the west, whilst others are indiscriminately spread on hill tops or dale sides. The Low Moor pockets also occupy a valley floor (SK/188566), but working has shown that two extend into the hillsides and that, prior to working, there was no topographic expression of these.

At Blackwell (SK/2549), some 4 miles south-east of Brassington, a hill-top outlier of sand and gravel, of similar aspect to the sediments in the Pockets, was referred to by Clayton (1953) as outwash from the Berrocian (early Pleistocene) glaciation. Re-examination of the over-grown pits suggests that erratics from a veneer of drift have fallen down and contaminated the main body of sand and gravel, which is now thought to be of similar origin to the fills of the other pockets. It is here resting on Millstone Grit and no solution collapse phemomena are involved.

Dolomitization

Parsons (1922) has demonstrated that the process of dolomitization was subsequent to the deposition of the Carboniferous Limestone; from the relations of ore-bodies at Matlock and in the Golconda Mine, Brassington (Ford and King, 1965), it is seen to have been earlier than the introduction of the mineralizing solutions. Moorbath's isotopic dating of galenas from Derbyshire in 1962 suggests that the mineralization was very late Triassic or early Jurassic; and Ford (1968) has demonstrated the close relationship between some mineral deposits and the Triassic geology of the region. Thus dolomitization appears to have occurred during Permo-Triassic times, though Yorke suggested it may have been partly penecontemporaneous with limestone sedimentation.


THE POCKET DEPOSITS OF
THE FRIDEN AREA
Arborlow
Circle
Green Lane
Pits
Kenslow Pits
Blakemoor Pits
BONSALL FAULT
LONG
DALE
GRATTON DALE
Iron
mine
Parsley
Hay
Friden
brickworks
High Peak
brick
works
Washmere
Pit
Newhaven
HARTINGTON LONG DALE
Hartington
station
quarry
Iron
mine
Heathcote
½ MILE
SILICA SAND DEPOSITS
SAND PITS WITH ROCK WALLS
PITS WITHOUT ROCK WALLS
DOLOMITE BOUNDARY
FAULTS

Text-Fig. 3

Dunham (1952), Kent (1957) and Ford (1968) have suggested it was due to magnesian solutions infiltrating from a transgressive Permian Zechstein sea across the Southern Pennines, but, from the amount of dolomite in skerry-bands in the Keuper Marl, the process of dolomitization could have continued as the subsurface effect of magnesian hypersaline groundwaters beneath the Keuper evaporite lagoons.

The amount of dolomitization, i.e. the degree to which the dolomite molecule has replaced the calcite molecule, is highly variable and it appears from Parsons' figures never to have gone to completion. The dolomitized areas are mostly high ground but not necessarily the highest points (see Ford, 1963a). Dolomitization does not follow any particular stratigraphic horizons and beds from low in the D_1 subzone to high in the D_2 subzone are affected. The depth to the base of dolomitization can be plotted in a few deeper valleys, but under the plateau it is generally not known. As a result of the investigations of the area around the Golconda Mine, dolomitization is now known to penetrate to a depth of 500 feet below Harborough Rocks, i.e. down to about 700 feet O.D. The contact with unaffected limestone undulates considerably and is now known to plunge 120 feet almost vertically within the Golconda Mine. In Manystones Quarry (SK/236551) the contact is at about 1100 feet O.D.; it can be seen to undulate by as much as 60 feet. Such undulations led Parsons to map apparent faulted junctions between dolomite and limestone, but some such junctions in Manystones Quarry are clearly not along faults. "Islands" of unaltered limestone occur completely surrounded by dolomite; these are often either reef facies limestones, in which the lack of bedding has apparently excluded the magnesian solutions, or patches of bedded limestones protected by local clay beds. Dolomitization has often followed joints in the limestone downwards, with the abundance of dolomite rhombs in the limestone rapidly falling off either side (though later mineralization may obscure this.) In Manystones Quarry it may also be seen that dolomitized joints have been etched out by later groundwater movement to form small caverns.

In short, then, it may be said that the base of dolomitization is an undulating zone transgressing the strata, with downward plunges along major joints. Since the dolomite is much more porous that the unaltered limestone (Parsons gives porosities of up to 10% for the former and "negligible" for the latter), ground waters (and mineralizing solutions) can move through it much more readily; and evidence from the Golconda Mine ore-bodies shows that the base of the zone of dolomitization is a preferred path for such movement, particularly in the hollows of the undulating contact. Ground-water solution at this contact resulted in numerous small caverns prior to mineralization; since solution preferentially removed calcite from the dolomitized zone, dolomite crystal grains were released to accumulate as a sediment on the cavern floors (Ford and King, 1965).

Mineralization

The mineral-depositing solutions are generally thought to be of deep-seated hydrothermal origin (see Ford, 1961, for reviews of concepts), rising via fissures to form rake-veins and locally spreading out under impervious "Toadstones" or shales to form pipes and flats (Ford, 1968). The deposits of the Golconda Mine clearly show that the solutions also travelled outwards along the basal dolomite-limestone contact, and that, as a result, the small caverns were filled in with layers of precipitated galena, baryte and derived dolomite crystal "sand" (Ford and King, 1965). The early phases of mineralization appear to have resulted in further decalcification of the dolomitized zone, with collapse of joint blocks. This has resulted in breccias of ores and dolomite partly or completely filling small caverns. Subsequently ground-waters deposited calcite to cement some of these breccias, but later phases of decalcification have resulted in further collapse of dolomite joint blocks.

Late stages of mineralization have produced carbonates and other oxidized minerals replacing the early sulphides, thus indicating a change in the environment of the mineral solutions from reducing to oxidizing.

Hydrology

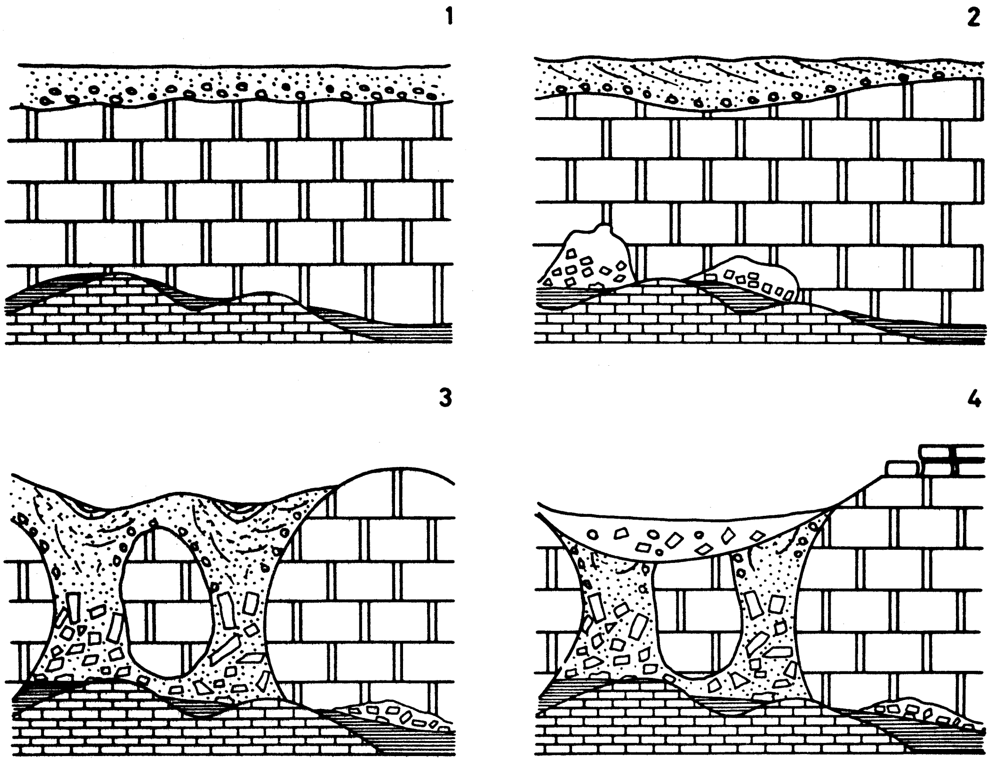
It will be evident from the above that at least three hydrological phases have already been passed through - dolomitization, local cavernization, and mineralization (with its subphases of fill, brecciation and collapse). Together these phases provided an irregular network of cavities, with or without mineral fill and collapsed joint blocks. These are clearly visible and spread throughout the area of the Golconda Mine workings (about a quarter of a square mile) and old mining records indicate that the network, though perhaps less rich in minerals, is present under much of the Brassington area. Though less obvious, the same type of network is believed to be present under much of the Gratton-Long Dale area [e.g. Mouldridge Mine (SK/194596)] and around Masson Hill at Matlock, though the presence of "toadstone" lavas at the latter has obscured the picture, and much of the evidence has been removed by mining. The hydrological relationship of the mineral deposits has been discussed by Ford (1968).

It is evident that, through the greater part of the dolomitized area, there is a network of cavities at or near the base of the dolomitized zone and thus, at any subsequent time, these must have been the preferred routes for groundwater movement. Much of such movement would no doubt have been slow, deep phreatic flow, but, with the 180 million years or so since the Triassic, this could accomplish a considerable amount of solution. Post-mineralization solution caverns up to 300 feet long are present in the Golconda Mine; and mining tradition indicates that they are widespread through the dolomitized areas. Deep solution such as this was accompanied by continued collapse - as can be seen in the Golconda Mine - and there is little doubt that some of the collapses worked their way through to the surface, to form the present sand pockets. Such collapses would of course provide the easiest routes for the percolation downwards of rainwater, with consequent modification of the pocket walls. One collapse has actually been seen in action at Spencer's Pit near Brassington. A heavy rainstorm flooded the excavation to a depth of several feet, but after a "popping noise", all the standing water and some sand drained away into a hole in the dolomite wall (which subsequently collapsed.) Hipley Dale, nearby, has traditions of a strong spring bursting forth at intervals of many years, which could come from the area of Spencer's Pit.

In view of the boulder clay cover of the sand fills and the later Pleistocene draining of the dolomitized zones by incisiion of the main Derbyshire Dales, it appears that deep phreatic solution was probably active until well into the Pleistocene Period; thus the sands must have been deposited in the pockets before the onset of Pleistocene Glaciation.

The Silica Sand Fills

The composition of the sands has been dealt with by various writers, and need only be summarized here (see Howe, 1920; Scott, 1927; Yorke, 1954-61). Some pocket fills have gravel-free sand only, some have bands of coarse gravel (up to 6 inch pebbles), whilst others have thick light grey clay beds. Rounded quartz grains are common and were probably derived from Triassic sandstones, with some additions from the Millstone Grit. The rounded pebbles include quartzites closely similar to those in the Bunter, though with the colouring bleached, and vein quartz, occasionally tourmaline-rich. Unpublished statistical work by D.B. Thompson has suggested that these could have been derived from the Lower Keuper Sandstones, as well as from the Bunter. Coal Measure sandstones and gainsters also occur as rounded pebbles; and a few Lower Carboniferous chert pebbles have been found, though these are usually less well rounded. Other pebbles include jaspers; various igneous rocks such as granites, microgranites, rhyolites; quartz conglomerates;



Text-Fig. 4

1. Triassic: Bunter Pebble Beds rest on dolomitized Carboniferous Limestone with unaltered limestone beneath. Solution cavities along the contact of dolomitized and unaltered limestone are filled with layered galena-baryte deposits.

2. Tertiary: The Bunter escarpment has receded from the Carboniferous Limestone leaving fluvial fans of Tertiary clays, sands and gravel resting on the dolomitized limestone. Increased ground-water movement has led to solution of the residual calcite in the dolomitized limestone and thus to cavern collapse in 'favourable' areas.

3. Late Tertiary: Continued collapse of the cavern roofs has allowed the Tertiary sand and gravel cover to sag into the "Pockets". Ponds in the tops of the sags receive plant debris from surrounding heath-lands in addition to aquatic vegetation.

4. Pleistocene: Glacial scour removes most of the remaining sand and gravel cover, leaving only the "Pocket Deposits", in the solution collapse hollows. Till lies across both Pockets and adjacent wall rocks. In late Pleistocene times dolomite hills are weathered into tors.

quartz vein breccias; and green and black slates.

Current-bedding and shallow channelling can be seen in some pocket-fills; their character suggests a fluvial environment of sedimentation.

A kaolinite pellicle is present round the quartz grains and serves to bind the sand in refractory brick manufacture. It may have been derived from the former cover of Triassic marls, but could also have come from the breakdown of felspar grains in the Millstone Grit. Alteration of the kaolinite pellicle has locally produced halloysite deposits (Ford, 1963b). Leaching subsequent to deposition has removed iron and manganese oxides from much of the sands; these oxides have been redeposited in some of the sand-filled caverns below or against the dolomite walls of the pockets, e.g. Kirkham's Pits, Brassington. Elsewhere baryte has been deposited at a late stage in the sands, as in Kenslow Pit at Friden; in sand-baryte rosettes associated with limonite boxstones at Spencer's Pit, Brassington; and in open cavities, as at Arborlow and Masson Hill (Ford and Sarjeant, 1964). Detrital baryte breccias occur as residual breccias or alluvial lenses at or near the base of the sand fills in the caverns of the Golconda Mine. White lead ore (cerussite) is said to have been worked from several pits (Green et al., 1887), including Green Clay Pit, Brassington; Washmere Pit, Friden; and Wester Hollow, but no evidence of this has been found in present day exposures. The cerussite probably resulted from the oxidation of galena veins in the adjacent limestones.

The sands of a few pockets are very sporadically cemented to form sandstones. One bed about a foot thick in Bees Nest Pit is a crumbly sandstone; but in Blakemore Pit, Friden, and in Low Moor Pit, scattered blocks of sandstone resembling the sarsens of Southern England may still be found.

Thus, whilst the sand fills are dominantly of Triassic material, they also include a few later contributions, and have suffered some later mineral changes. Yorke noted the absence of angular chert, limestone and dolomite gravels from the pocket-fills, in contrast to their wide distribution on the surrounding plateau and in the glacial drift cover. The early attempts to fit the sands and clays into a standard Triassic stratigraphic sequence (e.g. Boswell, 1918) cannot be upheld; a comparison with the Tertiary sands and clays of the East Dorset and West Hampshire areas, which also include derived Triassic material, seems possible. This comparison is further supported by the occurrence in Belgium of sand-and-clay filled solution pockets in the Carboniferous Limestone, clearly related to a Tertiary peneplain, and with derived Lower Cretaceous material rather than Trias in the fills (Calembert, 1954).

Since the sands can be shown to cover in part a dolomite tor landscape near Brassington, it seems that some pockets were already open to the surface when the sands were derived from surrounding Triassic outliers, whilst, elsewhere, continuing solution beneath a Tertiary sand cover has allowed collapse. Such open pockets and tors indicate a low water-table, which in turn suggests at least some incision of major valleys below the 1,000 feet erosion surface.

Some of the sand pockets have been recorded, by Yorke and others, as occurring in unaltered limestone. As many of these as are still accessible have been re-examined, and it has been found that, though the walls are dominantly limestone, the joints often show dolomitization; such pits are sometimes on or close to faults, where strong jointing may be expected. From this it may be deduced that the reason for the siting of such pits was that they represent a local downward penetration of dolomitization. This may be seen again in the Golconda Mine, where the lowest 50 feet or so of the Shaft Cavern have walls of limestone but show etched-out dolomitized joints.

The sand-fills do not generally exhibit clear bedding structures owing to their homogeneity, but, where bedding can be seen, the fill structure falls into one of three categories:

(a) undisturbed horizontal bedding, showing at the most a little sagging owing to compaction.

(b) highly disturbed bedding due to repeated subsidence collapse, sometimes with inward dips from all sides giving a funnel-shaped appearance.

(c) disturbance in the upper parts of the sand owing to downward glacial intrusion or to cryoturbation. Slickensided masses of red clay appear in many pits, and are similar to slickensided masses in the Golconda Mine where the pressure has obviously been due to roof subsidence. In the open pits the cause is thought to be the weight of overlying ice,

A single pit may show all three of the above in different parts, or more commonly (b) and (c) only. No fans of broken-down wall dolomite have been seen in the pits showing (a) above, indicating that the pits were complete entities and were then filled. In the others detached blocks may be found at times in the sand close to the walls, due to limited subsidence as in (b) above. The sand-filled caverns in the Golconda however, frequently show alluvial dolomite and baryte breccias set in sand, apparently at the base of pocket-cum-cavern systems. Quartz pebble bands frequently show "wash-out" features in any of the above categories.

The highest sub-till fills of two pits consist of dark blue grey clay with plant remains. At both Kenslow Pit, Friden, and Bees Nest Pit, Brassington, this grey clay forms the core of a synclinal sag of the fill into the solution hollows, so that it appears to be a direct continuation of the sedimentation which covered the area. No unconformity can be detected beneath the plant-bearing clay, so that any palaeobotanical age established for the plant remains, should at least give a minimum age for the sands and almost certainly indicate the age of the sands themselves. Boulter & Chaloner (in press) have obtained remains of nearly 30 species of plants, from which they deduce a probable Pliocene age. The ecology of the plants suggests accumulation in ponds surrounded by heath land; from this it may be deduced that some sagging of the fills into the solution hollows had already started by Pliocene times, but that much of the surrounding area was covered by sandy heathland and thus little of the limestone was exposed. The plants recorded include Sequoia or Taxodium wood, sphagnum, pine, willow, heathers, Calluna, and Lycopodium. Another plant bearing clay locality was recorded by Howe (1896) at Minninglow Pit, but nothing is exposed now.

Excavations for the foundations of a magnesium factory at Hopton (Early & Dyer, 1964) have revealed a series of small clay and sand deposits, in solution cavities averaging 20 feet in diameter and up to 40 feet deep. Some of these were found to have brown plastic clays rather than the more usual white sands and clays. Similar brown clays have been seen in workings at Kirkham's Pits west of Brassington, and in the Bees Nest Pit, near Harborough Rocks. In both these cases, the brown clay appeared to lie on top of the white sands and also showed fine lamination, suggestive of rhythmic deposition in a pond overlying the sand-deposits in pre-glacial times. Glacial disturbance and compaction have allowed the brown clay to sag into the white sands.

Pressure-pitting of the under-surfaces of rounded Coal Measure sandstone pebbles (analogous to the pitting of quartzite pebbles in the Bunter) has been observed in situ in the Blackwall pits, suggesting that no great thickness of overlying sediments (and ice?) is necessary to produce this phenomenon in less indurated rocks.

The Pockets in Relation to Glacial Deposits

This topic has been covered by Yorke (1954-61) with numerous illustrations; little need therefore be said except to summarize. Many of the pockets show a cover of 10 feet or so of glacial till, composed of limestone, dolomite and chert fragments in a brownish clay matrix. A few far-travelled erratics are present, chiefly from north-west England. The till also encloses blocks up to several feet across of Namurian Shale brought from the surrounding Millstone Grit country, presumably in a hard frozen state. Patches of chert gravel are also found in the till; they are believed to be relics of a former widespread cover of chert gravel on the limestone plateau, analogous to the Clay-with-Flints of the Chalk downs. Such patches of gravel again appear to have travelled as frozen blocks. Large dolomite blocks are present in tills downstream from the tors of Harborough Rocks.

Loosely cemented limestone scree overlies the sands of one Low Moor Pocket (SK/187566), in a position comparable to the cemented screes of the Manifold Valley described by Prentice and Morris (1959). At the top of these sands at Low Moor, there are several glacial "downward intrusions" of blocks of Namurian Shale, forming the only surviving relics of a till cover high on the sides of what is now a dry valley. Otherwise no pocket in a dry valley has been seen to have a cover of till. Thus it may be deduced that most dry valley incision post-dates the last spread of glacial till. Warwick (1964) has argued that the pattern of dry valleys suggests superimposition in pre-Pleistocene times from a former Tertiary cover.

Where glacial till rests on the sands of the pockets, there are numerous erosional features attributable to ice pressure, so that wedges of till extend into the sand [the "downward intrusions" of Yorke (1954-61)] and balls of sand are enclosed in till. Once below this disturbed zone, no pocket has yet been found to show evidence of glacial action or deposits. Several tills appear to be present at Kenslow Pit (SK/182617) and Green Clay Pit (SK/240548), but the detailed history has not been studied. The brown till of the Bees Nest Pit at Brassington sometimes shows strong lamination and locally has either very sparse pebbles or none at all, suggesting that at least some of the till may have been deposited in sub-glacial waters.

The Silica Sand Pockets in Relation to Faulting

It has often been hinted that the pockets mark the position of faults; for example, Kellaway (1964) has referred to "a NW-SE trending fault and fissure belt associated with piped masses of sand silt and pebbles in .... Derbyshire ... wholly or in part of Tertiary age". An unpublished report by H. Milner has also raised the possibility of the pockets being aligned on three parallel NW-SE faults running from Friden to Brassington. Field evidence to support these hypotheses is inconclusive, however. Those pockets which have sufficient of their walls exposed have been examined thoroughly; no undoubted evidence of faulting has been seen, though the lack of stratigraphical marker horizons in the limestone makes faulting difficult to detect. Zones of fractured rock are present in the walls of several pockets (e.g. those south of the High Peak Silica works), but they suggest solution collapse rather than faulting, since the bedding appears to match on either side. Pockets now obscured, but which were shown on Yorke's photographs (e.g. the Green Lane gorge pocket, north of Friden at SK/126626) similarly show little evidence of faulting. Some pockets in the Hartington area do, however, lie close to the line of ESE-WNW faults mapped by Sadler and Wyatt (1966). Unpublished resistivity work by Dr. C.D.V. Wilson, in the area around the High Peak Silica works, supports Dr. Sadler's mapping in part by showing linear trends through some pockets, whilst others occur isolated away from these trends. A pocket at the junction of two trends has a zone of fractured rock across it but no clear evidence

Fig. 1. Three of the Pocket Deposits near the High Peak Silica Brick works, Parsley Hay, Derbyshire. (SK/145628).
The middle and further pits show a thin cover of till.

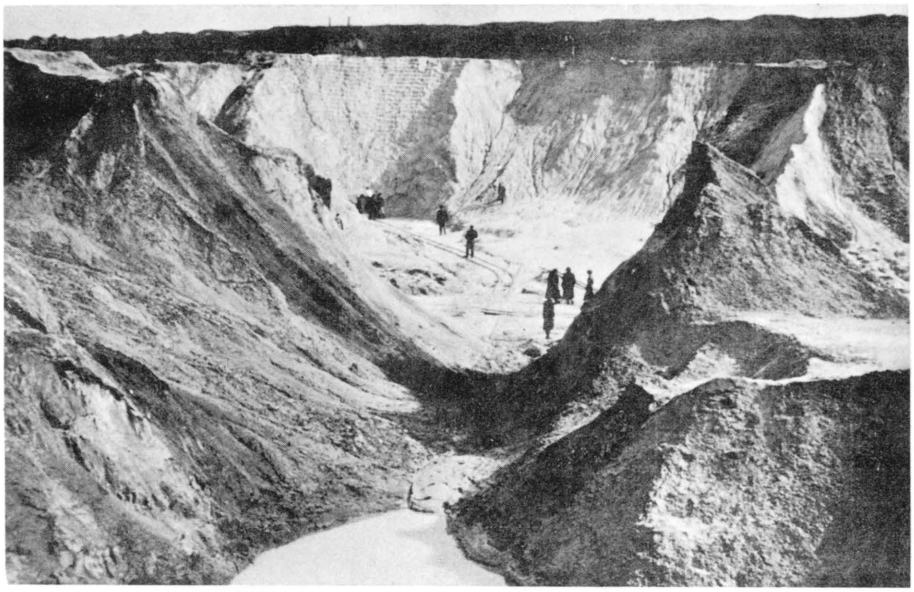


Fig. 2. The Bees Nest Pit, Harborough Rocks, Brassington (SK/241545). White sands are overlaid by till in the background. In the left centre coloured sands and clays dip steeply towards the observer, and the slumped clay in the left foreground is the plant-bearing stratum.

of faulting, though solution and collapse may have obscured this. The pockets in the Friden area lie close to the line of the NW-SE Bonsall Fault as mapped by Shirley (1958); but they are not on the line of the fault itself, though they may be on subsidiary fractures. The Kenslow Pockets unfortunately do not expose the solid walls; the Green Lane Pits, in contrast, are well exposed and show well-developed jointing but not faulting. The workings of the Mouldridge Mine (SK/194595), close to the line of the Bonsall Fault, show some small sand-filled solution cavities comparable with those of the Golconda Mine, in an area of mineralized solution cavities and flats close to the base of the dolomitized zone; but no faulting has been recognized in the mine itself.

The pockets in the Brassington area are not on any recognized faults, though the Harborough deposits are elongate in a NW-SE direction parallel to the main jointing of the area and to the many small mineral veins. The sand-filled caverns of the Golconda Mine similarly show a NW-SE trend, but this is clearly related to the effect of jointing on the undulations in the base of the dolomitized zone.

At Ribden, Staffordshire, some of the pockets are close to, but not on, faults (see Ludford's map, 1951).

A number of apparent sand deposits, inadequately exposed through not having been worked, are well away from the alleged NW-SE trend of faultings. These include Calling Low near Middleton-by-Youlgreave (SK/182646), Hubberdale Mines near Flagg (SK/1469) and Alsop Moor limeworks (SK/158564).

Both the Bonsall fault and the faults near the High Peak Silica works are post-mineralization fractures; Shirley (1958) noted that the topographic expression of some of these indicates that the faults are "geologically recent". Most writers have assigned them to the Alpine earth movements in early-to-mid-Tertiary times; since none of the pockets or their fills show any signs of having been fractured, it can be deduced that the pockets are post-faulting and thus probably mid to late Tertiary age. Thus they are also younger than the faulting in the Cheshire Basin, often assigned to Jurassic or Cretaceous times.

Comparisons with Similar Deposits Elsewhere

As the Derbyshire pocket-deposits have been referred to both Triassic and Tertiary ages, usually without too close a lithological and structural analysis, it seems desirable now to offer comparisons with similar deposits elsewhere.

Firstly, comparisons must be made with undoubted basal Triassic deposits where they rest on Carboniferous Limestone at other localities in the Midlands. At Breedon, Leicestershire, Keuper Marl rests on dolomitized Carboniferous Limestone, with but a thin and well-cemented breccia between. This thickens locally as fillings of pre-Triassic wadis. Exactly comparable associations of Marl and thin basal breccia are seen resting on the Precambrian rocks of Charnwood Forest in Leicestershire. No solution collapse phenomena are visible at Breedon; and none would be expected in Charnwood. Along the southern margin of the Weaver Hills in Staffordshire, Keuper Marls and S^ndstones rest on both unaltered and on dolomitized Carboniferous Limestone. The sands and conglomerates are red-coloured and loosely consolidated, in contrast to the bleached and completely unconsolidated sands of the Ribden Pockets only 1½ miles away. The latter obviously include derived Triassic material, but they have been leached of their iron oxides and disaggregated at some later date by solution, and they have collapsed into a pocket.

At the Snelston inlier (5 miles south of Ashbourne (SK/154403), silica-cemented sands formed quartzite dykes where the Keuper Sandstone rested unconformably on the Carboniferous

Limestone (Bemrose, 1904).

In North Wales, Maw (1865) described two pockets filled with sands and gravels and white clays near Llandudno. One of these, at Nant-y-Gamer (SH/801816), is still visible and is clearly a solution cavity in dolomitized Carboniferous Limestone which was once filled with unconsolidated red sands, with lenses and bands of chert gravel. Patches of these, and of kaolinite clay like the halloysite of the Brassington pockets (Ford, 1963b), are still to be seen adhering to the walls. The lithology of these sands in quite unlike that of the Trias of the nearest outcrops in the Vale of Clwyd and in Cheshire. Maw (1867) also described a series of similar pocket deposits in Flintshire; the sites of most of these have been visited, only to find that the pockets have long been abandoned and are now overgrown or filled in. One, at Ffrith-Garreg-Waen (SJ/131750), yielded small exposures of unconsolidated white and yellow sandy chert gravel and one patch of blue clay with gastropod shells. This is probably the clay referred to by Maw as lignitic, but it is close to a present day pond and may represent no more than an earlier stage of the same pond. The inference is that these pockets too are Tertiary rather than Triassic. The fills may even be Pleistocene outwash. Green et al. (1887) commented that the Derbyshire deposits were probably of the same age as those in North Wales.

A solitary clay, sand and gravel filled pocket at Flimston, south Pembrokeshire (SR/928953) forms a hollow in a Tertiary peneplain cut across Carboniferous Limestone. Within a mile or so are Triassic "gash" breccias of quite different lithology, though apparently of similar origin by solution collapse, as indicated by stalagmitic layers and fragments among the red marl matrix. Dixon (1921) referred this deposit to the early Tertiary on grounds of lithological resemblance to the Bovey Tracey Beds; he also noted comparisons with the Derbyshire and North Wales deposits.

Permian sandstone "dykes" fill solution cavities in the Devonian limestone of Berry Head, Brixham (SX/937568). Fully cemented, these sandstones enwrap recrystallized stalactitic calcite bands, but no large collapse phenomena have been seen (Richter, 1966).

The sandy marginal facies of the Oligocene lake basin at Bovey Tracey, Devon, are very similar in appearance to the Derbyshire pocket deposits. These sands and clays have long been regarded as filling a fault-bounded trough, but it is possible that solution of Devonian limestones (or back-reef evaporites?) has had some effect at depth.

The iron-ore filled "sops" in the Carboniferous Limestone of Cumberland and Furness (Smith, 1924) are partly metasomatic replacements of the limestone by haematite and quartz, with a little fluorite and baryte, and partly Trias-filled solution collapses with cavities lined with crystalline haematite and quartz. The sops and their fills are of probable Triassic origin· the degree of lithification of the sands and the haematization make them quite unlike the Derbyshire pocket deposits. Iron-ore filled cavities and replacements like those of Cumberland occur in the Forest of Dean and South Wales (Sibly, 1919) and are also of Triassic age.

Near Killarney in Eire, Walsh (1960) described a mass of Cretaceous chalk, 150 miles from the nearest outcrop, which has subsided into the Millstone Grit apparently owing to solution of the Carboniferous Limestone beneath. Subsidence was intermittent during deposition of the Chalk, as shown by spreads of shale fragments within the Chalk. Since the Chalk is a marine sediment, this implies that the solution leading to collapse may have taken place beneath the sea floor. Also in Eire, Maw (1867) described some sand-filled pockets near Caher in Tipperary, which appear to be comparable to the pockets of North Wales and Derbyshire. No Trias is known anywhere near Caher; and, as the fills contain lignitic clays, they again appear to be late Tertiary or Pleistocene in age.

Fig. 3. One of the Green Lane Pits, Friden (SK/167624), after excavation of almost all the sand-fill.

In South Wales, Thomas (1954a & b, 1959, 1963) has described solution subsidence collapses which have let down masses of Millstone Grit into the limestone beneath by as much as 800 feet. These are thought to have been in action from Triassic times onwards, though most of what is visible today is thought to be of Tertiary age. No Triassic or Tertiary sediments have been recognized in any of the pockets of derived Millstone Grit.

In Belgium, a number of large pockets of sand and clay are found filling hollows cut in the Tertiary peneplains across the folded Carboniferous and Devonian Limestones. One visited east of Dinant was very similar to the Derbyshire pocket deposits. Belgian geologists such as Calembert (1954) have long assigned these pockets to the Tertiary, since no Triassic is known to have been deposited across the area and because the feather-edge of the Tertiary beds is only a few miles to the north, where the latter show a similar lithology. The sands are thought to have been derived from Lower Cretaceous deposits nearby. A well-known but incompletely studied example is the "Iguanodon Mine" of Bernissart, where solution of the Carboniferous Limestone allowed a cover of some hundreds of feet of Coal Measures to collapse, leaving an open pothole into which some 20 large reptiles and numerous smaller animals fell to their death during Wealden times. Later Cretaceous and younger sediments subsequently filled this pocket.

Finally, it must be noted that pockets of Tertiary beds filling solution collapses in the Chalk of southeast England are quite common, though few approach the size of the Derbyshire pockets (see Kirkaldy, 1950).

Conclusions

It is concluded that the silica sand pockets are due to the collapse of solution caverns beneath, as has long been suggested, but several modifications to the hypothesis seem necessary. The controlling factor in distribution is the form and position of the base of the dolomitized zone of the Carboniferous Limestone. This is now shown to have large solution collapse caverns, as at the Golcona Mine; also to have downward projections along major joints, e.g. Manystones Quarry, some of which have been so etched out as to leave pockets with apparently unaltered walls of limestone. Faulting in itself is inadequate to explain the distribution, but joints and minor fractures, opened by faulting and which have been dolomitized, appear to have been important in places.

Intermittent solution collapse under varying hydrological conditions has led to a variety of features, including (a) caverns with or without a partial sand fill, sometimes overlying breccias of dolomite or mineral fragments; (b) caverns which have had their collapses work right through to the surface either before sands were available to fill them, or, more often, after the sand cover had been laid down; (c) collapses which have worked through to the surface sufficiently long before the arrival of the sand fill for subaerial erosion to modify their forms, giving buried dolomite tors and buried former surface watercourse-gorges, e.g. the "gorge Pit" of Yorke (1961, p. 19) at Friden (N.G.R. SK/166626) and the great Harborough Rocks gorge embracing the Bees Nest Pit, Green Clay Pit and two old pits. No evidence can be found to support Yorke's early concept of a great river course from the Trent to Cheshire, running through these pits.

The age of the pockets and their fills is now clearly established as not only post-mineralization, i.e. post-Triassic, but also post-faulting and of probable late Tertiary date. Solution collapse was probably acting intermittently beneath the surface through Mesozoic times, reaching a culmination of topographic effect in the late Tertiary. The fills themselves are at least partly of Tertiary age, with a high proportion of redistributed Triassic material from a former Triassic cover. There seems to be no need to invoke swallow holes at the edge of a retreating

Namurian shale cover to explain the pockets as was suggested by Kent (1957); indeed, the pockets bear little resemblance to the swallow holes at the present Namurian shale margin west of Castleton.

The total lack of flint pebbles in the fills suggests that the Chalk (or at least the flint-bearing Chalk) may not have been laid down across the Peak District.

The distribution of the pockets along a NW-SE line through Friden and Brassington is misleading in view of the occurrence of sands well outside this, including some as yet untested deposits near Flagg and the long-abandoned pits at Ribden. The apparent association with the 1,000 foot erosion surface is also misleading, though probably partly correct. Sand pits occur in Wester Hollow at Brassington at only 900 feet O.D. and the sand filled caverns of the Golconda descend to 700 feet O.D. It seems that, in places, the existence of a sand-filled pocket has been exploited as a weakness in later Pleistocene valley cutting, whilst elsewhere the pockets have been by-passed, e.g. the Kenslow Pit at Friden and the pocket above Long Dale, Hartington. More accurate plotting of the distribution of sand deposits by shallow drilling is needed to complete the picture.

The Blackwall outlier indicates a former extent of the sands and gravels on to the Millstone Grit country around the limestone massif.

The fills thus demonstrate the existence, in late Tertiary times, of a widespread fluvial sand and gravel fan over the South Pennines, with local ponds carrying aqueous vegetation and receiving transported heath vegetable remains from the surrounding area. The fluvial nature of this fan and the high proportion of derived Triassic material indicate that it was probably derived largely from the retreating Triassic escarpment, after the final mid-Tertiary uplift. The pockets and fills thus provide evidence of a former sheet of Tertiary sediments on the South Pennines; and it is of interest to speculate on the possible former extent further afield. Hey (verbal communication) has found evidence of early Pleistocene gravels in East Anglia, carying bleached "Bunter" pebbles closely similar to those of the Pocket Deposits, which occur in fluvial deposits apparently derived from the west. It thus becomes possible that the Pocket Deposits are not only the relics of a South Pennine Tertiary Sheet, but that the sheet spread as far east as East Anglia, or, alternatively, that the East Anglian gravels were derived from the South Pennines by meanders of a river flowing eastwards in early Pleistocene times.

Acknowledgements

Thanks are due to Mr. D.B. Thompson, for fruitful discussions in the field and for his critical reading of the manuscript; to Drs. Richard Hey and R.J. Rice, for discussion in the field; to Mr. M.C. Boulter, for discussion of the significance of his findings concerning the plant fossils and for permission to use these in the text; to Dr. C.D.V. Wilson, for geophysical data; and to Dr. G.T. Warwick for general discussion. We are also grateful to the Derbyshire Silica Firebrick Co. Ltd., to Messrs. Kirkhams', Messrs. Spencer and to the Steetley Refractories Co. Ltd. for permission to visit their pits on numerous occasions; and to Hopton Mining Co. for permission to visit the workings of the Golconda Mine. Thanks are also due to Dr. Courtenay Yorke for supplying us with copies of his private publications.

T.D. Ford, B.Sc., Ph.D.,
R.J. King,
Department of Geology,
The University,
Leicester

REFERENCES

BEMROSE, H.H.A. 1904. On some quartzite dykes in the Mountain Limestone near Snelston, Derbyshire. Quart. J. Geol. Soc. Lond. Vol. 60. pp.364-371.

BOSWELL, P.G.H. 1918. A Memoir on the British Resources of Refractory Sands. Taylor and Francis, London, pp. 127-9.

BOULTER, M.G. & W.G. CHALONER
Neogene microfossil plants from Derbyshire, England. Rev. Palaeobot. Palynol. (in press).

CALEMBERT, L. 1954. Les formations tertiaires de la haute Belgique. IN P. FOURMARIER's Prodrome d'un description de la Géologie de la Belgique. Liège. 826 p. pp. 737-9 Les puits naturels.

DIXON, E.E.L. 1921. The country around Pembroke and Tenby. Part XIII of the Geology of the South Wales Coalfield. Mem. Geol. Surv. E & W. 220 p.

DUNHAM, K.C. 1952. Age relations of the epigenetic mineral deposits of Britain. Trans. Geol. Soc. Glasgow. Vol. 21. pp. 395-429.

EARLY, K.R. and K.R. DYER
1964. The use of a resistivity survey on a foundation site underlain by karst dolomite. Géotechnique. Vol. XIV. pp. 341-348.

FORD, T.D. 1961. Recent studies of mineral distribution in Derbyshire and their significance. Bull. Peak Dist. Mines Hist. Soc. Vol. 1 No. 5. pp. 3-9

1963a. The Dolomite Tors of Derbyshire. East Midland Geographer. Vol. 3. No. 19. pp. 148-153.

1963b. The occurrence of Halloysite in Derbyshire. Clay Minerals Bulletin. Vol. 5. No. 30. pp. 302-307.

1968. The stratiform ore deposits of Derbyshire. IN PROC. XV Inter-University Geological Congress, Leicester. pp. 73-96.

FORD, T.D. and R.J. KING
1965. Epigenetic layered galena-baryte deposits in the Golconda Mine, Brassington, Derbyshire. Econ. Geol. Vol. 60. pp. 1686-1702.

1966. The Golconda Caverns, Brassington, Derbyshire. Trans. Cave Res. Gp. G.B. Vol. 7. No. 2. pp. 91-114.

FORD, T.D. and W.A.S. SARJEANT
1964. The stalactitic barytes of Arborlow, Derbyshire. Proc. Yorks. Geol. Soc. Vol. 34. pp. 371-386.

GREEN, A.H. et al. 1887. The Carboniferous Limestone, Yoredales and Millstone Grit of North Derbyshire. Mem. Geol. Surv. E & W. 2nd edn. 212 p.

GREENWOOD, H.W. 1918. The Trias of the Macclesfield District with notes on its relation to the adjacent Carboniferous Rocks and to the Trias of the Midlands. Proc. Liverpool Geol. Soc. Vol. 12. pp. 325-338.

HOWE, J.A. 1896. Notes on the Pockets of clay and sand in the Limestone of Staffordshire and Derbyshire. Trans. North Staffs. Field Club. Vol. 31. pp. 143-9.

1920. Refractory materials - fireclays. Geol. Surv. Spec. Rep. Min. Res. Vol. XIV. 243 p.

HULL, E. 1864. On the copper-bearing rocks of Alderley Edge. Geol. Mag. Vol. 1. pp. 65-69.

KELLAWAY, G.A. 1964. Structural rings and fissure systems in relation to river development. Proc. Geol. Soc. Lond. No. 1617. pp. 100-104.

KENT, P.E. 1957. Triassic relics and the 1000 ft. surface in the Southern Pennines. East Midland Geog. Vol. 1. No. 8. pp. 3-10.

KIRKALDY, J.F. 1950. Solution of the Chalk in the Mimms Valley, Herts. Proc. Geol. Assoc. Lond. Vol. 61. pp. 219-223.

LUDFORD, A. 1951. The stratigraphy of the Carboniferous Rocks of the Weaver Hills district, North Staffs. Quart. J. Geol. Soc. Lond. Vol. 106. pp. 211-230.

MAW, G. 1865. On some deposits of chert, white clay and white sand in the neighbourhood of Llandudno. Geol. Mag. Vol. 2. pp. 200-204.

1867. On the distribution beyond the Tertiary districts of white clays and sands subjacent to the Boulder Clay. Geol. Mag. Vol. 4. pp. 241-251 and 299-307.

MOORBATH, S. 1961. Lead isotope abundance studies on minerals in the British Isles and their geological significance. Phil. Trans. Roy. Soc. (Ser. A), Vol. 254, pp. 295-360.

PARSONS, L.M. 1922. Dolomitization in the Carboniferous Limestone of the Midlands. Geol. Mag. Vol. 59. pp. 51-63 and 104-117.

PILKINGTON, J. 1789. A view of the present state of Derbyshire. J. Drewry, Derby. 2 Vols. 469 and 464 p.

PITTY, A.F. 1968. The scale and significance of solutional loss from the limestone tract of the Southern Pennines. Proc. Geol. Assoc. Lond. Vol. 79. pp. 153-177.

PRENTICE, J.E. and P.G. MORRIS 1959. Cemented screes in the Manifold Valley, North Staffordshire. East Midland Geog. Vol. 2. No. 11. pp. 16-19.

RICHTER, D. 1966. On the New Red Sandstone neptunian dykes of the Tor Bay area, Devonshire. Proc. Geol. Assoc. Lond. Vol. 77. pp. 173-186.

SADLER, H.E. and R.J. WYATT
1966. An S_2 subzone inlier in the Lower Carboniferous at Hartington, Derbyshire. Proc. Geol. Assoc. Lond. Vol. 77. pp. 55-64.

SCOTT, A. 1927. The origin of the High Peak Sand and Clay deposits. Trans. Ceramic Soc. N. Staffs. Vol. 26. pp. 255-260.

SHIRLEY, J. 1958. The Carboniferous Limestone of the Monyash-Wirksworth area, Derbyshire. Quart. J. Geol. Soc. Lond. Vol. 114, pp. 411-429.

SIBLY, T.F. 1919. The Haematites of the Forest of Dean and South Wales. Geol. Surv. Spec. Rep. Min. Res. Vol. X.

SMITH, B. 1924. The Haematites of West Cumberland, Lancashire and the Lake District. Geol. Surv. Spec. Rep. Min. Res. Vol. VIII. 2nd edn.

SYLVESTER-BRADLEY, P.G. and T.D. FORD (eds.)
1968. The Geology of the East Midlands. Univ. Leicester Press. 400 p.

THOMAS, T.M. 1954a. Solution subsidence outliers of Millstone Grit on the Carboniferous Limestone of the North Crop of the South Wales Coalfield. Geol. Mag. Vol. 91. p. 220.

1954b. Swallow holes on the Millstone Grit and Carboniferous Limestone of the South Wales Coalfield. Geogr. J. Vol. 120. pp. 468 -

1959. The geomorphology of Brecknock. Brycheiniog. Vol.3. pp.55-156.

1963. Solution subsidence in south-east Carmarthenshire and South-west Breconshire. Trans. Inst. Brit. Geog. Pub. No. 33. pp. 45-60.

WALSH, P.T. 1966. Cretaceous outliers in south-west Ireland and their implications for Cretaceous palaeogeography. Quart. J. Geol. Soc. Lond. Vol. 122. pp. 63-84.

WARWICK, G.T. 1964. Dry valleys of the Southern Pennines. Erdkunde. Bd. XVIII. Heft 2. pp. 116-123.

YORKE, G. 1961. The Pocket Deposits of Derbyshire. Private publication, Birkenhead. 86 pp. (revision of 1954 edition plus supplements).

CORRELATION OF CHESHIRE PLAIN AND DERBYSHIRE DOME GLACIAL DEPOSITS

by

Peter C.D. Cazalet

Summary

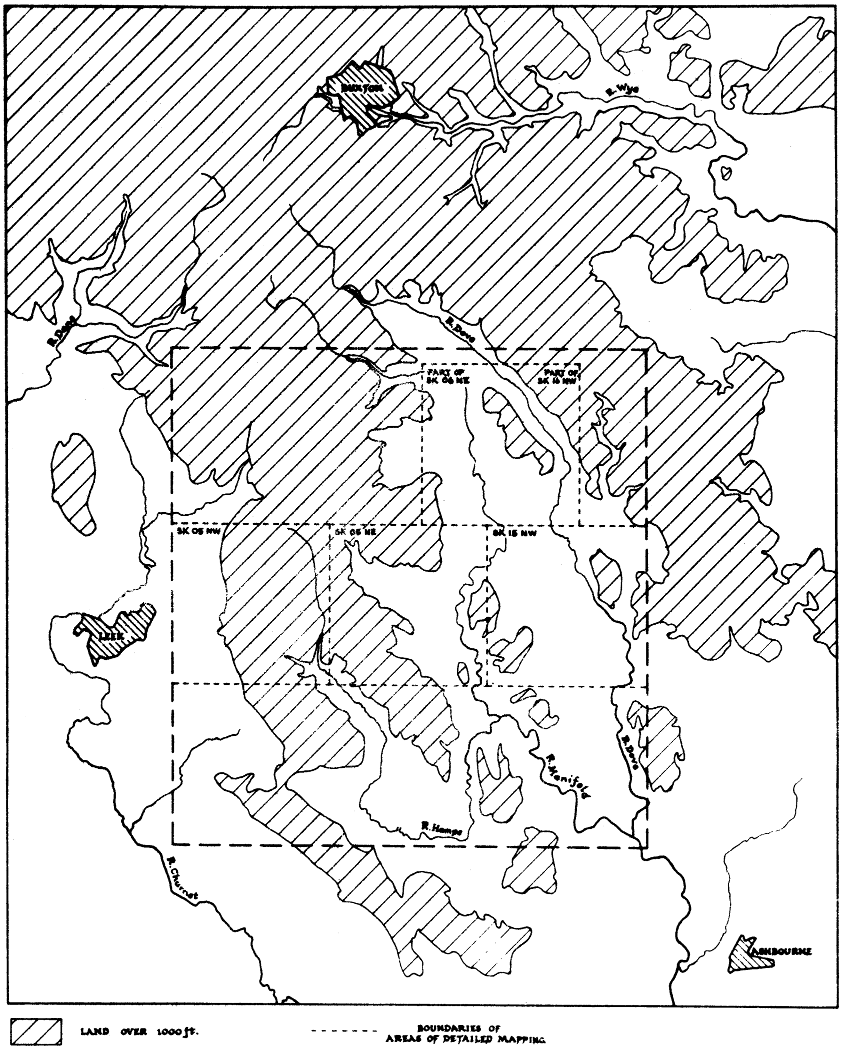
Two boulder clays are present in the Cheshire Plain. On the Derbyshire Dome there is a single boulder clay which underlies loess. There is evidence in the soils on the Derbyshire Dome of two phases of post-loess clay translocation, separated by an interval of soil erosion. The amount of translocated clay in profiles affected by both clay translocation episodes is about twice that found in profiles only influenced by the later phase. This is analogous to differences in depth of decalcification reported by Boulton and Worsley (1965), in glacial deposits on each side of the Late Weichselian moraine in the Cheshire Plain.

It is suggested that the till and loess on the Derbyshire Dome and the earlier till in the Cheshire Plain are of the same age and were deposited no earlier than the Early Weichselian (Warthe) stadial; that the two phases of clay translocation represent soil formation during the Warthe - Late Weichselian interstadial and Postglacial respectively; and that the soil erosion episode occurred during the Late Weichselian stadial.

Introduction

Investigations of the extensive glacial deposits in the Cheshire Plain have revealed at least two depositional episodes. Boulton and Worsley (1965) have dated at about 20,000 years B.P. the most recent of these, represented by deposits north of the Wrexham - Whitchurch - Bar Hill moraine. Deposits to the south of the moraine are of uncertain age but, according to Holmes (1965, p.690, fig. 519), may be equivalent to the Early Weichselian Warthe moraines in Europe.

Glacial deposits on the central part of the Derbyshire Dome have received little attention.



Text-Fig. 1. Location of the study area. The general area of study is bounded by the thick broken line. Thin broken lines, which are the boundaries of 6" Ordnance Survey quarter-sheets, outline the areas in which detailed soil studies were carried out.

Their distribution is not fully known, neither is it certain when they were deposited. In particular, the relationship between these deposits and those in the Cheshire Plain is obscure. Jowett and Charlesworth (1929) postulated an 'Older Drift' glaciation of both areas, followed by a 'Newer Drift' glaciation largely confined to the Cheshire Plain. Charlesworth (1957, p.776) suggested that the Pennine till was deposited during his Second Welsh glaciation (Riss, Saale) but also mentions an Early Pennine glaciation during the Mindel/Elster glacial episode (1957, p.1016). Pigott (1962) found evidence of loess on the Derbyshire Dome, overlying till and limestone residues with evidence of interglacial weathering.

During studies of soil development in the areas shown in Text-figs. 1 and 2, the present author (1968) has obtained information on the glacial deposits on the Derbyshire Dome which suggests correlations with glacial events in the Cheshire Plain.

Definition of terms

Clay translocation. A soil-forming process involving the movement of clay minerals and other colloidal materials. In profiles where this process has operated, the upper soil layers (horizons) are depleted and the lower enriched in clay-size particles.

The process is thought to take place under slightly acid conditions and in an environment where soil organisms rapidly decompose plant debris. Organic decomposition products are thought to be involved in the mobilization and transport of clay, and the size and distribution of soil pores to be an important factor influencing clay deposition (Dalrymple, 1967).

Translocated clay is detectable in the field by estimates of clay content and by the presence of wax-like coatings on structure faces, stones or the walls of soil pores.

In the laboratory, translocated clay may be confirmed from thin soil sections and should typically have the following properties:

i) The material should be quite distinct from residual materials in the horizon of deposition.

ii) The material should show strong birefringence under crossed polarizers.

iii) The material should be finely laminated.

iv) The material should be associated with water-movement pathways, such as structure faces, soil pores, etc.

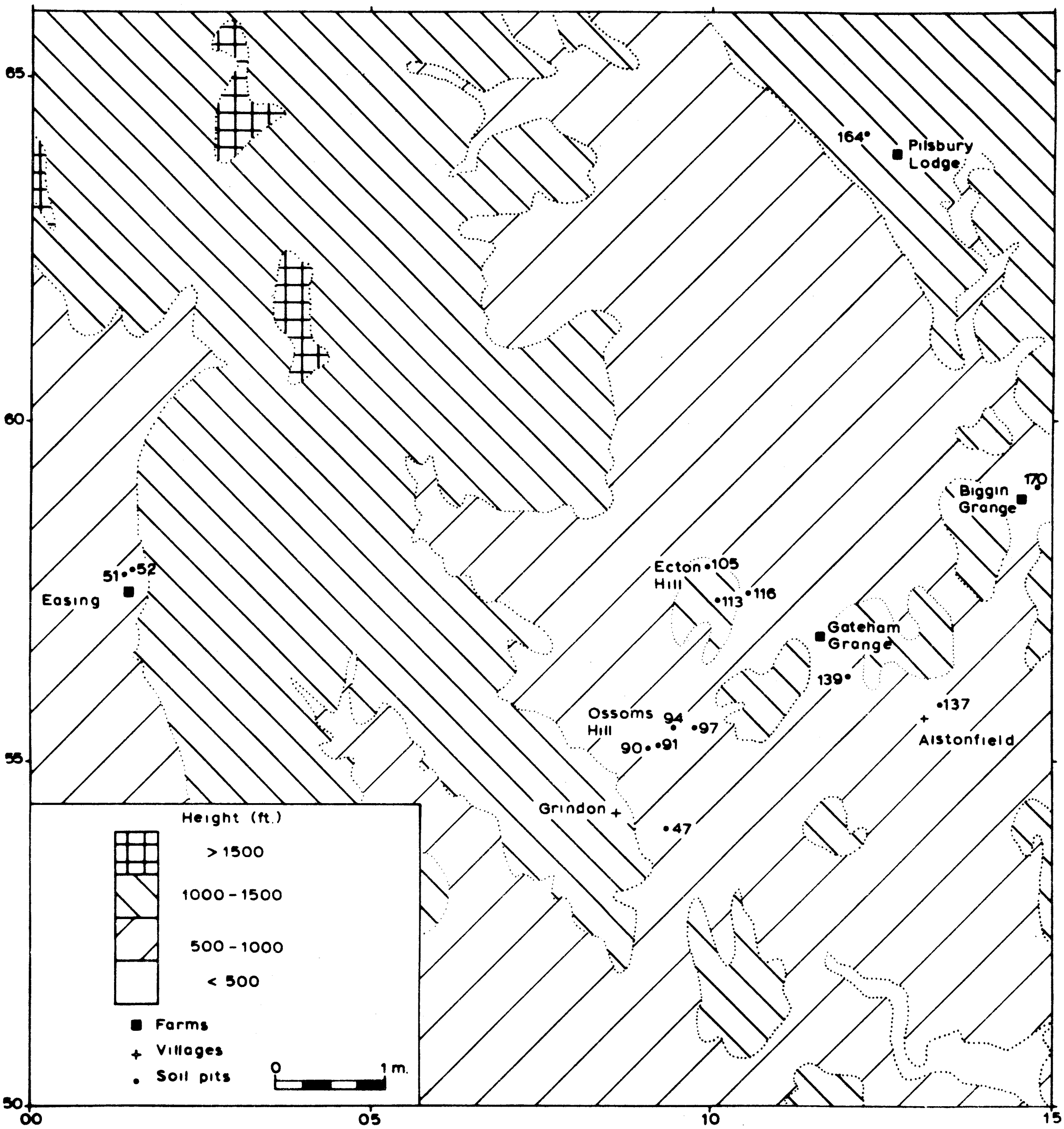
Brewer and Haldane (1957) have demonstrated that artificially produced clay translocates have such characteristics.

Other terms relating to clay translocation in the text are:

Matrix. Residual material in a horizon of clay deposition.

Non-matrix clay. Birefringent clay-size material distinguishable from the matrix.

Laminated clay. Non-matrix clay with all the features of typical translocated clay listed above.



Text-Fig.2. Location of soil pits mentioned in the text. The area shown in an enlargement of the area bounded by thick broken lines in Text-fig.1.

Unlaminated clay. Non-matrix clay distinguished from laminated clay by weaker birefringence and less obvious lamination or association with soil pores etc., sometimes with an eroded appearance.

Methods of Study

Samples were collected from the different soil horizons exposed in pits dug for the examination and description of soil profiles. The location of the soil pits referred to in the text is shown in Text-fig. 2. After drying, part of each sample was lightly crushed in order to disintegrate the soil structures. The material coarser than 2 mm. was then removed by sieving and discarded.

The complete particle size distribution of the less than 2 mm. fraction of each sample was determined using the method described in Cazalet (1968). Three grades, covering the range 75 - 2000 μ, were separated by sieving and weighed. Weight data for 12 grades, covering the range 75 - 4 μ, were obtained by Coulter Counter analysis, which measures particle size distributions electronically. After plotting the combined data as cumulative weight per cent. (of the less than 2mm. fraction), the graph was interpolated to 2 μ in order to determine the amount of less than 2 μ clay.

Although the size distribution of the whole less than 2 mm. fraction was determined, the only data quoted here are for the 'loess' (10 - 70 μ) and clay (less than 2 μ) grades. At the 95% confidence level, the precision of the method is better than 6% of stated value for both fractions (see Text-figs. 4 and 5).

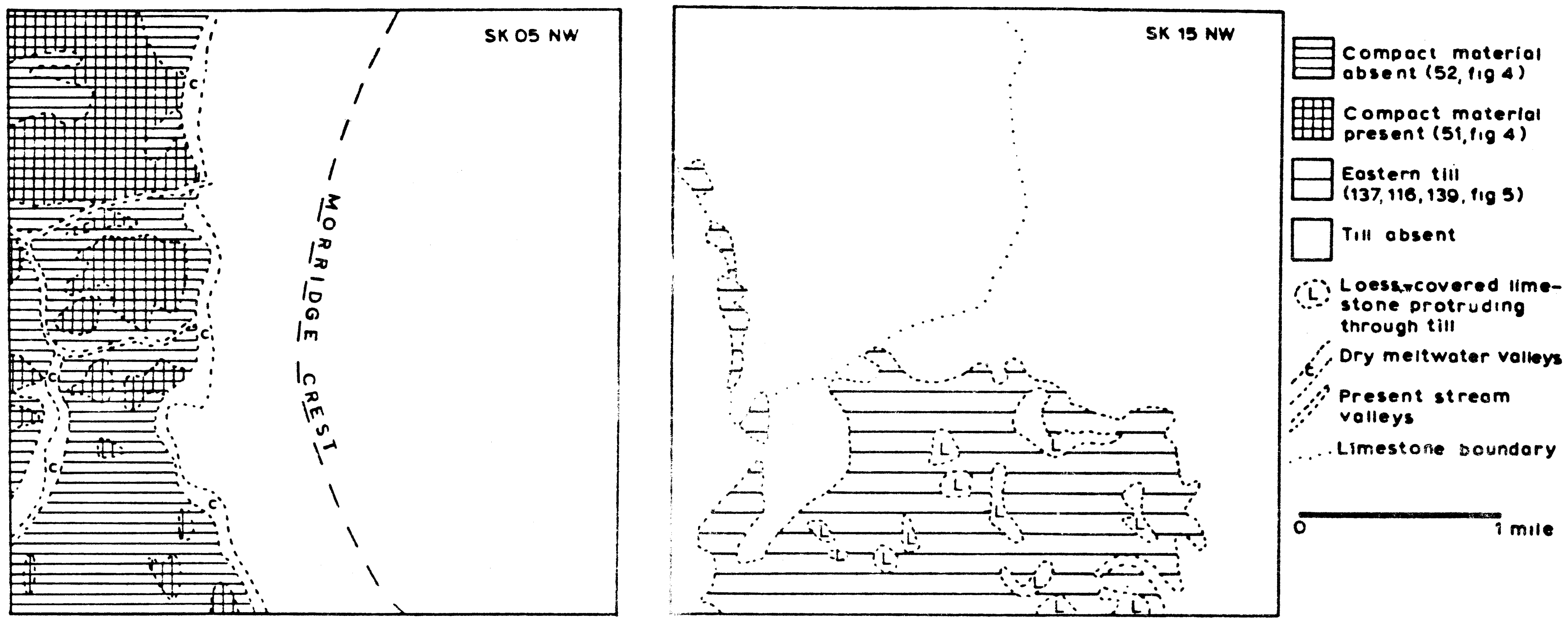
The particle size information suggested that, in the lower horizons of some profiles, there were accumulations of translocated clay. Thin sections of uncrushed material from these horizons were therefore prepared to confirm this, using the Dammar Gum-Lakeside resin impregnation procedure described by Dalrymple (1957). Two or three sections were prepared of material from each horizon. The relative amounts of laminated and unlaminated clay and of matrix were determined by point count and the results expressed as a percentage of total points counted, usually based on a total of 200 - 300 points.

Western deposits

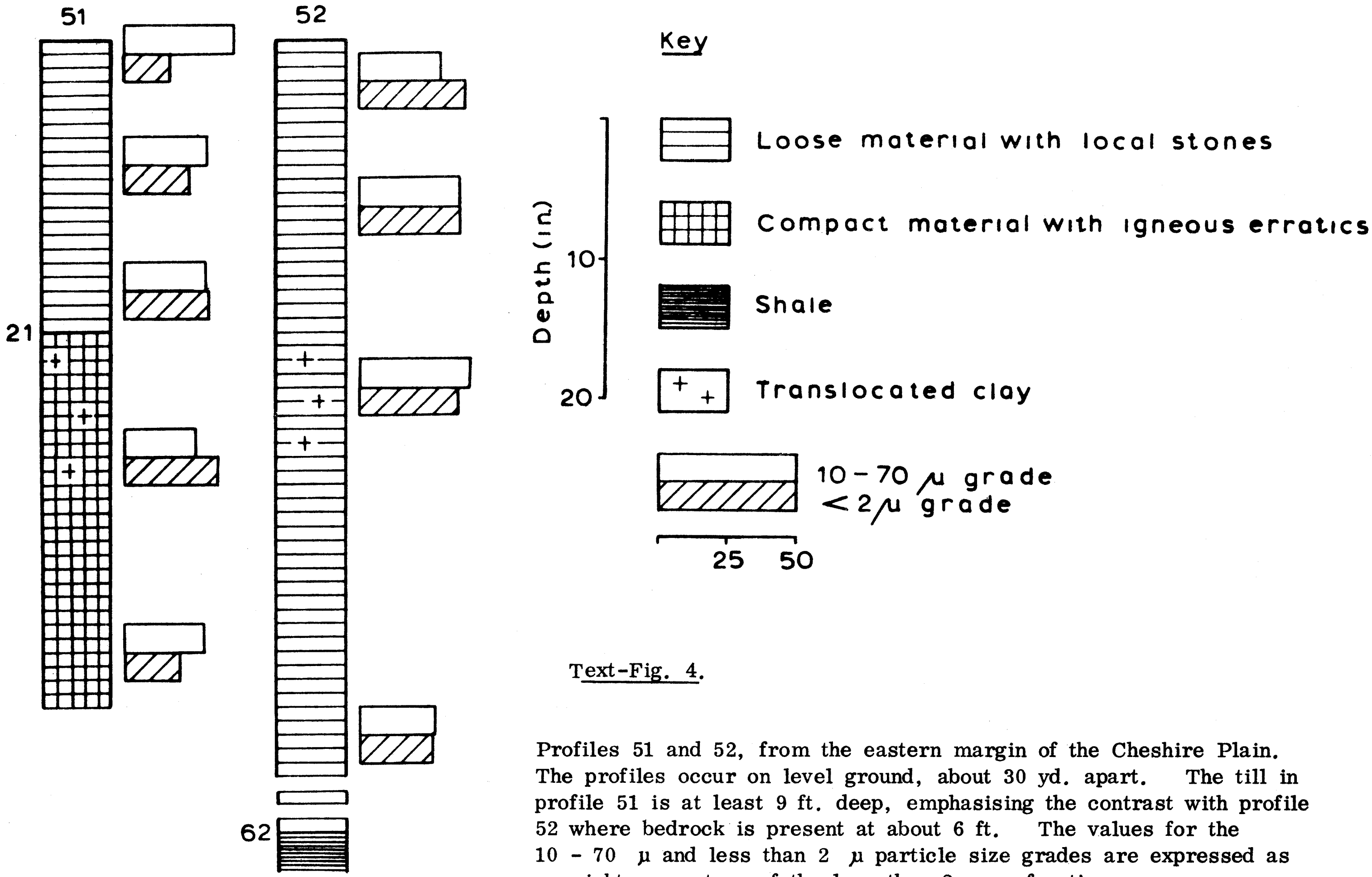
Till is present in the study area at altitudes below 1000 ft. to the west of Morridge (Text-fig. 3). This till therefore lies on the eastern margin of the Cheshire Plain. The Late Weichselian moraine lies to the north of the study area, so the till is pre-Late Weichselian in age. According to Boulton and Worsley (1965), it is thinner and more dissected than the Late Weichselian till. Furthermore, it is decalcified to about twice the depth found in Late Weichselian deposits. Both these observations suggest deposition some time before the Late Weichselian glacial episode.

The two profiles examined (profiles 51, 52 at 014578*) occur on level ground and are developed in deposits of two types. The first type is a compact, red-brown material containing numerous quartz and igneous pebbles. It has polygonal cracks resembling those in North Welsh till of Riss age, ascribed to periglacial freeze-drying by Stewart (1961). The second material is a looser,

* All map references are on Sheet 111, O.S. 7th Edition.
These are only quoted for the more important sites mentioned in the text.



Text Fig. 3. Distribution of till in the western and central parts of the study area. In the western sector, the distribution of locally-derived material is included in order to demonstrate the relationships between this deposit and the pre-Late Weichselian till.



Text-Fig. 4.

Profiles 51 and 52, from the eastern margin of the Cheshire Plain. The profiles occur on level ground, about 30 yd. apart. The till in profile 51 is at least 9 ft. deep, emphasising the contrast with profile 52 where bedrock is present at about 6 ft. The values for the 10 - 70 μ and less than 2 μ particle size grades are expressed as a weight percentage of the less than 2 mm. fraction.

yellow-brown deposit containing mainly local stones with rare quartz and igneous pebbles. In some places it overlies red-brown till, and in others, bedrock (Text-figs. 3, 4). Both deposits are poorly sorted. The red-brown material is clearly pre-Late Weichselian till. The yellow-brown material is probably a locally-derived Late Weichselian sludge deposit.

Evidence for the presence of loess in these profiles is inconclusive. Although the typical loess particle size grade is moderately well represented (Text-fig.3) the local rocks all contain considerable amounts of silt, which in particle size analysis is indistinguishable from loessial material.

Particle size evidence suggests the presence of a weak clay peak at the junction of yellow-brown and red-brown materials in profile 51 (Text-fig.4). This is confirmed by thin section evidence which shows that mainly unlaminated clay (8%) is present in the horizon with the highest clay content (Tab. 1; Plate 6, Figs. A, B).

Particle size evidence also shows a very weak clay peak in profile 52; and this is also confirmed from thin sections which show about 6% of unlaminated clay. By analogy with some of the Derbyshire Dome soils described below, the translocated clay shows evidence of disturbance and clay translocation seems to have ceased.

If the material west of Morridge was not stabilised until the Postglacial, the small amount of translocated clay represents Postglacial clay movement. The values of 6 - 8% are of the same order as those found in Postglacial soils developed in Wisconsin till (Buol and Hole, 1961).

Central Pennine deposits

There are three deposits overlying the limestones of the gently undulating central plateau (Derbyshire Dome) at altitudes between 900 and 1100 ft. - silt, residual clay and till.

The silt, by far the most extensively distributed material, has he following properties:

i) More than 50% of the particle size distribution lies between 10 and 70 μ.

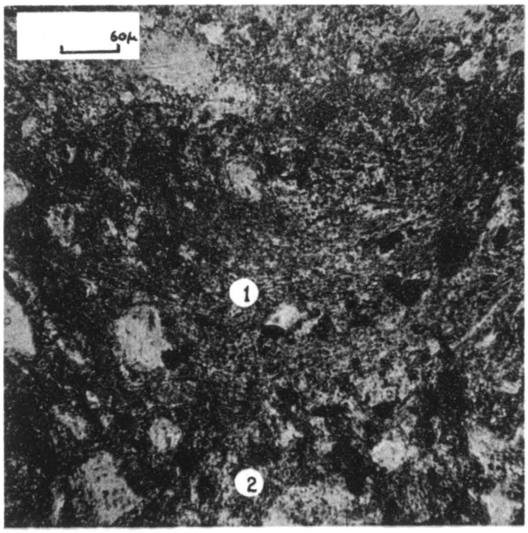
ii) The clay content is less than 25%.

iii) The silt is much better sorted than any other parent material in the area. Of the 41 silt samples analysed, the 10 - 70 μ grade medians of 30 (75%) lie between 26 and 30 μ

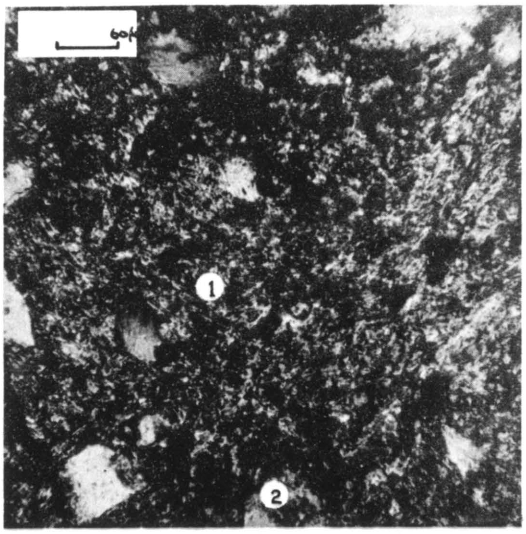
iv) Silt with these characteristics is detectable at least in the upper horizons of all soils on the limestone and also on other parent materials which weather to produce mainly clay-size residues.

This combination of properties is characteristic of loess (Bagnold, 1941, pp. 88-92; Cailleux, 1953; Swineford and Frye, 1945). The deposit will therefore be subsequently referred to as loess.

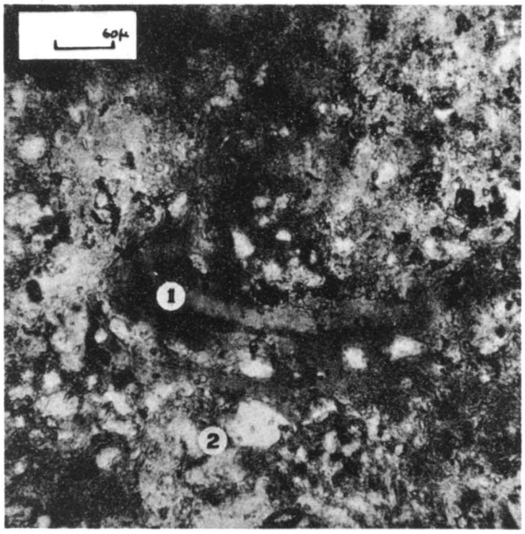
The loessial soils form a morphological sequence in which the depth of the deposit is closely correlated with slopes of different intensity. The soils are associated with pure limestones contain-



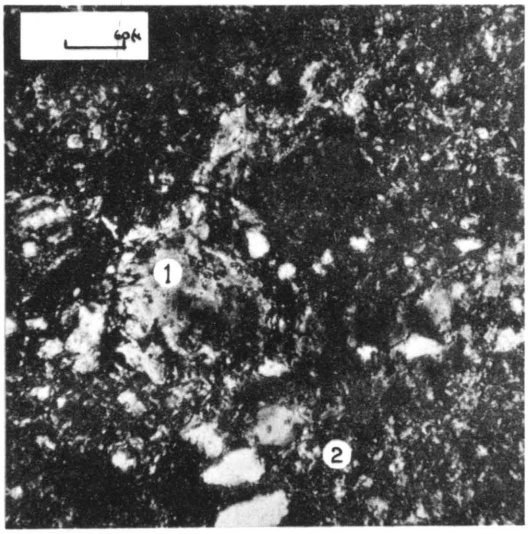
A



B



C

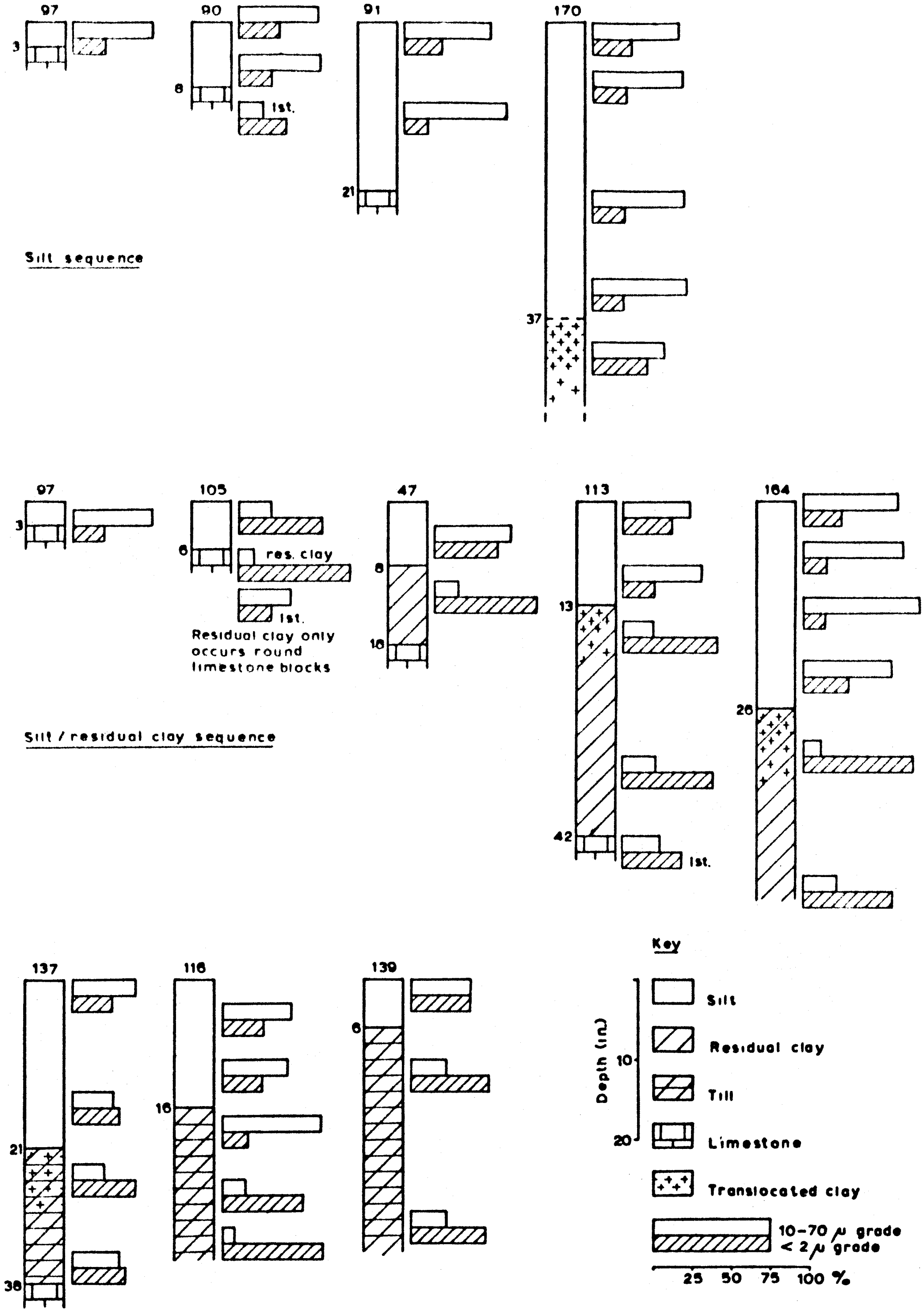


D

Plate 6 figs. A, B. Part of the clay accumulation horizon of profile 51. Note the very weak lamination and birefringence of the non-matrix clay and the absence of an associated conducting channel.

figs. C, D. Part of the clay accumulation horizon of profile 170. Although the clay is more strongly birefringent, lamination is weak and there is no conducting channel present.

1, non-matrix clay; 2, matrix.
A, C, plain polarized light; B, D, crossed polarizers.



Silt/till sequence

Text-Fig. 5. Soil sequences in the central part of the study area. Considerable amount of translocated clay are only found in the deepest soils of each sequence. Profile 97 is considered to be the shallowest member of both silt and residual clay sequences since it consists of a mixture or organic matter, limestone fragments and loess. The particle size data are as in Text-fig. 4.

ing more than 95% carbonates. Only on nearly level sites where the deepest soils occur is non-matrix clay present in the lower horizons (Text-fig. 5). In other profiles on moderate or steep slopes, the absence of clay accumulation may well be explained by solifluction. Point count data of a representative deep profile (profile 170 at 148591) establish that the clay accumulation horizon contains 14% of unlaminated clay (Tab. 1; Plate 6, Figs. C, D).

Stoneless clay overlying less pure limestones (average carbonate content about 80%) is interpreted as limestone weathering product and is referred to as residual clay. The shallowest profile (97) consists of organic matter mixed with limestone fragments and loess. In the deeper profiles, the horizons directly overlying the limestone are formed in residual clay alone, but the upper horizons contain loess. The loess is mixed with residual clay in the profiles of intermediate depth (105, 47) and is only present as a distinct deposit in the deepest soils (113 at 101574; 164 at 123642).

The soils containing residual clay form a morphological sequence in which thickening loess/ loess-residual clay/residual clay horizons are related to slope intensity. Only in the deepest soils on nearly level sites are there indications of substantial clay translocation (Text-fig. 5). In the shallower soils, the absence of translocated clay is probably the result of solifluction. These soils have relatively high clay contents throughout the profile, however, and this is thought to inhibit clay movement (Hallsworth, 1963). Point count data (Tab. 1) establish that the mainly laminated non-matrix clay in profile 113 totals 21.5%. The mainly unlaminated clay in profile 164 amounts to 17.5% (Pl. 7, Figs. A, B, C, D. respectively).

Also present in this group of soils are occasional profiles on nearly level ground in which more weakly developed zones of clay accumulation occur. An example of this situation is profile 94 at 094556, in which the volume of non-matrix clay, all unlaminated, totals only 6%.

The central till deposit is confined to a single area between the River Manifold and the River Dove near Alstonfield (Text-fig. 3). Quartz and igneous erratic pebbles are abundant.

All three profiles in this material occur on gentle slopes. The profiles form a morphological sequence in which increasingly poor soil profile drainage is jointly controlled by depth of loess and depth of till. Thus profile 137, at 134559, is well drained, 116 is poorly drained and 139 is very poorly drained (Text-fig. 5). Significant clay translocation is only found in the well drained stage (profile 137), where laminated clay totals 22% (Tab. 1). The absence of clay movement in profiles 116 and 139 is probably due to a combination of low soil porosity and high clay content.

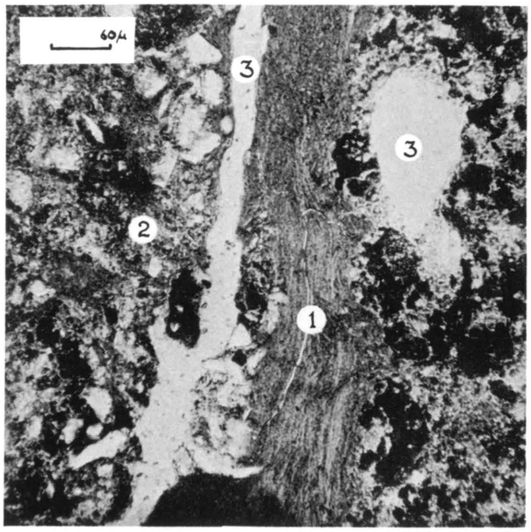
The accumulation zones of profiles 113 and 137 contain about 22% of laminated clay, but in profiles 164 and 170 non-matrix clay totals only 17.5% and 14% respectively and is mainly unlaminated. In these four profiles the total clay content is comparable. The slightly lower values in profiles 164 and 170, however, the lack of lamination and the absence of associated conducting channels are together consistent with disturbance of the clay and suggest that clay translocation is no longer taking place.

It will be noted that significant amounts of non-matrix clay (more than 14%) are only found on well drained, level sites. Occasionally on such sites, as in profile 94, much less clay is evident (6%). Examination of all the soils described from the area suggests very strongly that the distribution of clay translocation values is distinctly bimodal, with a group of values greater than 14% and another group lower than 8%. This bimodal grouping indicates that clay translocation may have taken place in two stages, with profiles 113, 137, 164, and 170 participating in both stages and profile 94 only in the later one. The observation that even on some level sites only the later stage is represented suggests that a phase of parent material redistribution or soil erosion separated the two episodes of clay translocation.

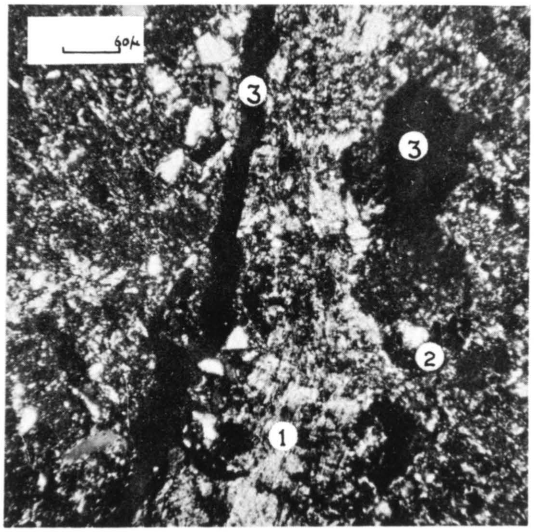
TABLE 1

Fabric feature	Profiles with laminated birefringent clay		Profiles with unlaminated birefringent clay		Profiles with small amounts of birefringent unlaminated clay	
	137/25-28"	113/15-18"	170/40-45"	164/30-32"	94/22-26"	51/30-33"
Matrix (+ voids)	78.5	77.5	86.0	82.5	94.0	92.0
Laminated clay	20.0	22.0	0.5	1.5	-	2.0
Unlaminated clay	1.5	0.5	13.5	16.0	6.0	6.0
Total clay	21.5	22.5	14.0	17.5	6.0	8.0
Total points counted	276	254	276	139	228	221

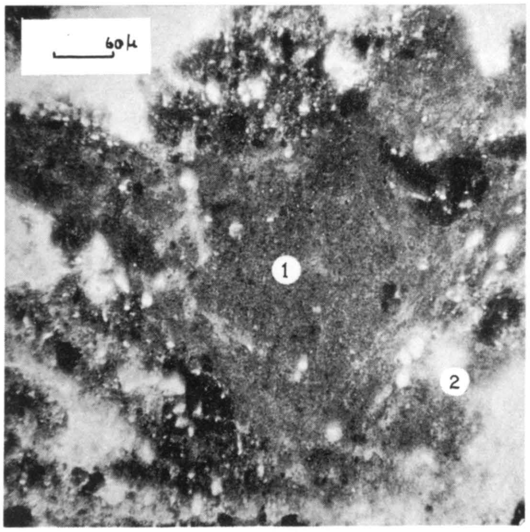
Point count data for the horizons of clay accumulation, suggested by particle size data, of the profiles discussed in the text. The results are expressed as a percentage of the total number of points counted.



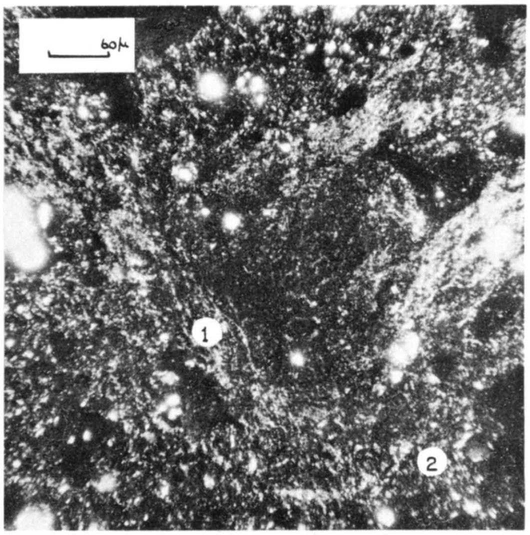
A



B



C



D

Plate 7 figs. A, B. Part of the clay accumulation horizon of profile 113. Note the strong lamination and birefringence of the non-matrix clay and its association with a conducting channel.

figs. C, D. Part of the clay accumulation horizon of profile 164. Note the weak lamination and birefringence of the non-matrix clay and the absence of an associated conducting channel.

1, non-matrix clay; 2, matrix; 3, conducting channel.
A, C, plain polarized light; B, D, crossed polarizers.

The loess covers all other deposits; its deposition must therefore post-date deposition of the till. The presence of loess also seems to have been a prerequisite of clay movement, for there is no evidence of clay movement either in the shallower residual clay soils or in the deeper till profiles. In profile 170, furthermore, translocated clay has been deposited in a horizon with clear loessial characteristics. Clay translocation must therefore post-date loess deposition.

This evidence, together with the above interpretation of the clay translocation data, seems to establish that six events have influenced the formation of the present-day soils on the Derbyshire Dome:

i) Deposition of till.

ii) Deposition of loess.

iii) Clay translocation, initial phase, in profiles 113, 137, 164 and 170.

iv) Soil erosion (but not in the above profiles)

v) Clay translocation, second phase, in profiles 113, 137, 164 and 170; the only phase in profile 94.

vi) Disturbance of translocated clay in profiles 94, 164 and 170 but not in profiles 113 and 137.

Conclusions

Boulder clays of two glacial episodes are known to be present in the Cheshire Plain. In the central Pennine area there is evidence of only one boulder clay, but this underlies a silt deposit with the particle size attributes of loess. It is therefore tempting to equate the deposition of till in the central area with that of the earlier Cheshire Plain till, and the deposition of loess in the central area with the deposition of Late Weichselian till in the west.

Although these correlations cannot be completely ruled out, they are inconsistent with the evidence presented here, which suggests a rather more complex situation.

In both western and central parts of the study area there is evidence of a phase of soil erosion. In the western sector this is indicated by the dissection of the earlier till, followed by deposition of colluvial material; in the central sector there is no conclusive evidence of till dissection, but the loess has clearly been redistributed and some of the soils eroded. Differences in the amount of translocated clay between profiles 113, 137, 164 and 170, and profile 94 (all on level sites) substantiate this view.

It seems, therefore, that the phase of soil erosion post-dates deposition of the earlier western till and the central till and loess.

Neither area was apparently over-ridden by Late Weichselian ice, so it seems reasonable to suggest that at least part of the soil erosion/redistribution phase occurred during the Late Weichselian.

This suggestion receives support from the clay translocation data. On level sites in the western and locally in the central area, comparable but small amounts of clay translocation (6 - 8%) have been observed.

TABLE 2

Period	Western area and Cheshire Plain	Derbyshire Dome
Warthe stadial (Early Weichselian glaciation)	Deposition of till (and loess?).	Deposition of till and loess.
Interstadial	Initiation of decalcification of till. Dissection of till ?	Initiation of clay translocation in profiles 113, 137, 164 and 170. Dissection of till?
Late Weichselian stadial	Deposition of till. Dissection of Warthe till Deposition of local material on Warthe till and bedrock.	Soil erosion.
Postglacial	Decalcification of Warthe and Late Weichselian tills. Disturbance of translocated clay in profiles 51 and 52.	Resumption of clay translocation in profiles 113, 137, 164 and 170. Initiation of clay translocation in profile 94. Disturbance of translocated clay in profiles 94, 164 and 170 but not in profiles 113 and 137

Summary of the suggested correlations of the Cheshire Plain and Derbyshire Dome glacial deposits.

The fact that, on other level sites in the central area, much larger amounts of translocated clay are present (14 - 22%), together with the evidence that all clay translocation post-dates loess deposition, indicates that the loess was probably deposited some time before the Late Weichselian glacial. So far as is known, clay translocation only takes place in a temperate environment in which organic matter is readily decomposed. Therefore, if 6 - 8% of translocated clay represents the amount of Postglacial clay movement, 14 - 22% is likely to represent this amount plus an increment translocated during a pre-Late Weichselian phase of climatic amelioration. Deposition of loess and till in the central area must therefore pre-date this phase; the loess is consequently unlikely to be a Late Weichselian deposit.

It seems that either the Warthe or Saale glacial episodes would probably have been sufficiently extensive to have deposited till in the central area. Of the two, the Warthe stadial seems the more likely. The reason for this is that, if the till and loess were deposited during the earlier Saale glacial, it is difficult to envisage why the subsequent, apparently almost as extensive, Warthe glacial episode could have left no trace in the central area. At least two loess deposits should be present, and for this there is no evidence.

Although the actual glacial episode in which central till and loess were deposited is uncertain, it seems that the central and earlier western tills may well have been deposited by the same ice-sheet. Boulton and Worsley (1965) have established that glacial deposits south of the Late Weichselian moraine are decalcified to nearly twice the depth found in materials to the north of the moraine. In the present study, the point count estimates of clay translocation fall into two equally distinct groups, with the values in the higher group being almost twice those in the lower. Given that factors other than time may influence rates of decalcification and clay translocation, the analogy nevertheless seems significant.

It therefore seems likely that the central and earlier western tills were deposited during the same glacial episode, and that this episode was probably the Early Weichselian Warthe stadial.

The chronology thus tentatively established is summarised in Tab. 2.

Acknowledgement

I thank Dr. J.B. Dalrymple for instruction in the preparation of thin soil sections.

P.C.D. Cazalet, B.A., Ph.D.,
Geography Department,
Bedford College,
University of London,
Regents Park,
London, N.W.1.

References

BAGNOLD, R.A. 1941. The physics of blown sand and desert dunes. London; Methuen. 265 pp.

BOULTON, G.S., AND WORSLEY, P. 1965. Late Weichselian glaciation in the Cheshire-Shropshire basin. Nature, Lond., Vol. 207, pp. 704-706.

BREWER, R., AND HALDANE, A.D. 1957. Preliminary experiments in the development of clay orientation in soils. Soil Sci., Vol. 84, pp. 301-309.

BUOL, S.W., AND HOLE, F.D. 1961. Clay skin genesis in Wisconsin soils. Soil Sci. Soc. Amer. Proc., Vol. 25, pp. 377-379.

CAILLEUX, A. 1953. Les loess et limons eoliens de France. Bull. Serv. Carte Géol. Fr., Vol. 51, pp. 437-459.

CHARLESWORTH, J.K. 1957. The Quaternary Era. Vol. 2, London; Arnold. 1700 pp.

DALRYMPLE, J.B. 1957. Preparation of thin sections of soils. J. Soil Sci., Vol.8, pp. 161-165.

1967. A micromorphological study of soil porosity and the translocation of clay-sized material from certain Grey-brown Podzolic soils in Great Britain and New Zealand. Trans. 8th Int. Cong. Soil Sci., Bucharest, Roumania, (1964), pp. 1175-1181.

HALLSWORTH, E.G. 1963. An examination of some factors affecting the movement of clay in an artificial soil. J. Soil Sci., Vol. 14, pp. 360-371.

HOLMES, A. 1965. Principles of physical geology. London; Nelson. 1288 pp.

JOWETT, A., AND CHARLESWORTH, J.K. 1929. The glacial geology of the Derbyshire Dome and the western slopes of the southern Pennine upland. Quart. J. Geol. Soc. Lond., Vol. 85, p. 307.

PIGOTT, C.D. 1962. Soil formation and development on the Carboniferous Limestone of Derbyshire. I. Parent materials. J. Ecol., Vol.50, pp. 145-155.

STEWART, V.I. 1961. A permafrost horizon in the soils of Cardiganshire. Welsh Soils Discussion Group Report No. 2., pp. 19-22.

SWINEFORD, A., AND FRYE, J.C. 1945. A mechanical analysis of wind blown dust compared with analyses of loess. Am. J. Sci., Vol. 243, pp. 249-255.

Manuscript received 28 October 1968.

EAST MIDLANDS GEOLOGICAL SOCIETY

EXCURSION REPORTS, 1968

MINERAL LOCALITIES AT THE BASE OF THE TRIAS IN LEICESTERSHIRE AND DERBYSHIRE

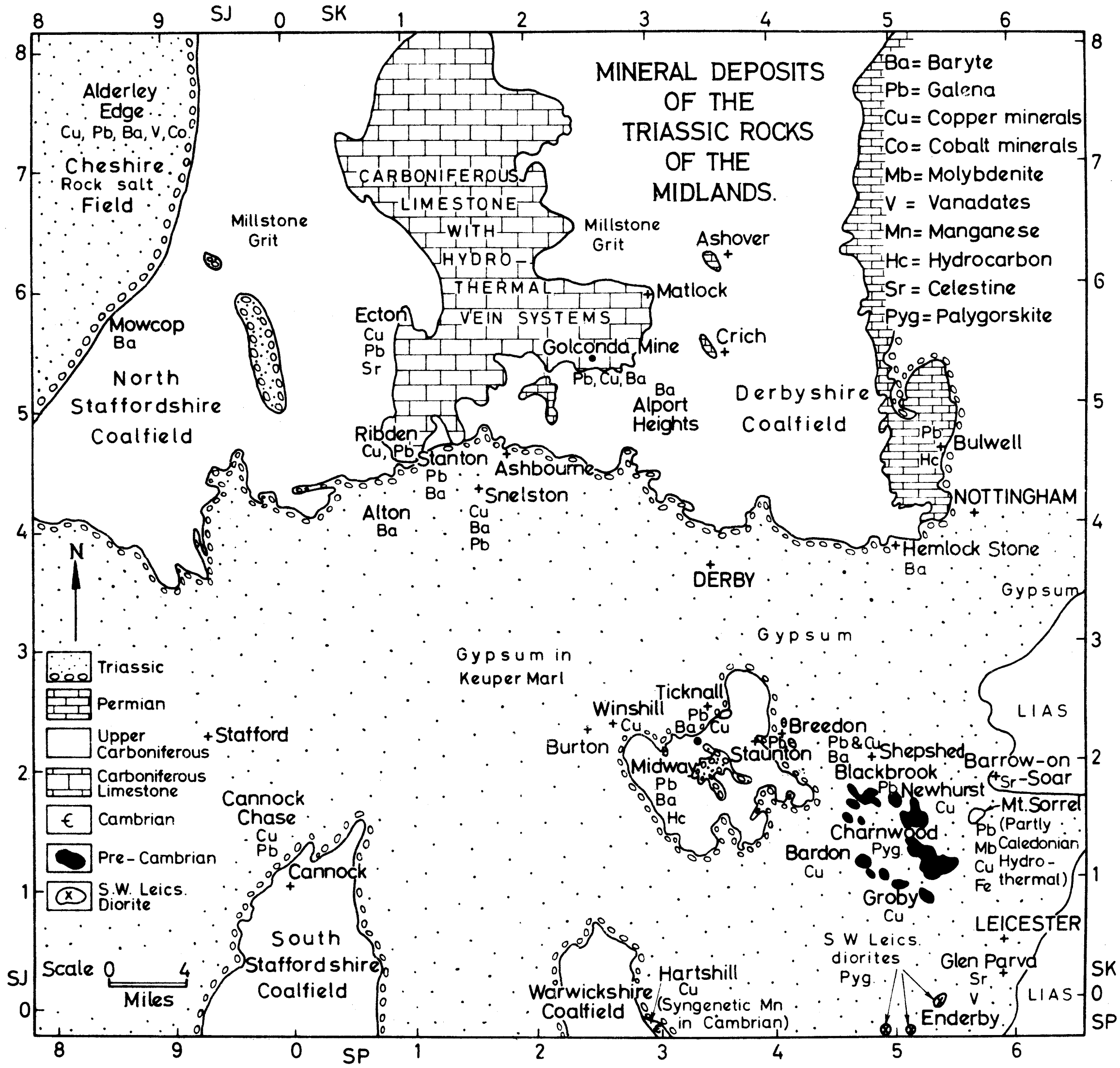
Leaders : R.J. King and T.D. Ford | Saturday, 4th May 1968

The theme of the excursion, which was attended by some 60 persons, was to demonstrate the varied nature of the "hydrothermal" mineral associations at the base of the Trias and to show that the associations were at least partly controlled by the nature of the underlying rock.

The first stop was made at Enderby Warren quarry (SK/538001), by kind permission of Redland Roadstone Limited. Here Keuper Marl is seen to rest unconformably on one of the South Leicestershire diorite masses, believed to be of Caledonian date (Le Bas, 1968). The diorite has a dark banded appearance due to analcitization associated with late Caledonian metasomatic effects. In the north-east corner of the quarry, the contact with the Keuper Marl is easily accessible. The Red Marl has patchy development of basal breccia in hollows in the diorite surface, and the spaces between the boulders are seen to be filled with a white clay mineral, palygorskite (Evans and King, 1962). This magnesium-bearing chain silicate is widely dispersed throughout the Keuper Marl on a microscopic scale, but has been concentrated here. It is seen to penetrate joints in the diorite, but gradually dies out downwards, thus demonstrating its origin in the Triassic groundwater circulation.

After crossing Charnwood Forest by the M1 (with some interesting hitch-hiking for half the party!), the next stop was at Newhurst Quarry, Shepshed (SK/486180), by kind permission of Groby and Charnwood Granite Company Limited. Here the basal Trias has been exposed recently in a new cutting. Some 20 feet of gritty sandstones alternate with bands of ripple-marked and mud-cracked marl and with lenses of a fine breccia, formed of chips of the nearby Blackbrook Series of the Charnian and its intrusive diorite. About 3 feet from the base one band of sandstone, some 4 inches thick, carries disseminated galena in crystals up to about 2 mm. in diameter. The sandstone can be followed for about 30 feet and carries galena throughout, but little sign of it is seen in beds above or below at this point, though galena has been found in the basal breccia elsewhere in the quarry.

Down in the main quarry, copper mineralization has been known for many years. A sheet of native copper, 10 feet across and 1/8 inch thick, was found in a joint in the diorite many years ago (King, 1967). Recently a number of veins of quartz with chalcopyrite have been found in the lower level of the quarry. They are rarely more than an inch thick and can be seen to be cut through by later veins of calcite and dolomite, which carry oxidized copper minerals such as chalcocite, azurite, malachite and, rarely, native copper. Some of these are in veins which can be traced as gradually widening joints up to the base of the Trias; and there can be little doubt that the copper in the primary quartz veins has been redistributed by Triassic groundwater circulation. Chalcocite and malachite have been found amongst the boulders in the basal Triassic breccia elsewhere in the quarry; also a few small patches of a white clay mineral, possibly palygorskite, have been found in the breccia.



Text. Fig. 1. Sketch-map of the Mineral Deposits of the Triassic rocks of the Midlands, showing localities visited, and their relationship to the regional geology (after Ford, 1968).

The next locality, some 2 miles to the west, is beneath the Shepshed-Blackbrook road bridge over the abandoned Loughborough-Coalville railway (SK/463186). The railway was built in 1883 and abandoned in 1963; over this section its route was made by partly infilling a canal dug in the 1780s and abandoned in 1802. At some unknown date, galena was found in the cutting; and in 1865 a small mine trial was opened and driven in for a few yards. The entrance was subsequently filled in and the locality was lost and completely forgotten, until Moorbath (1962) applied isotope dating methods to British galenas. One of his specimens was obtained from the Geological Survey collections, but was only vaguely labelled "Blackrook, Garendon Park, Charnwood", although in a Triassic matrix. No more precise locality could be determined. (Blackrook is a mistaken spelling of Blackbrook). The chance discovery by Dr. W.A.S. Sarjeant of a brief note concerning galena - bearing pebbles in the Trias by the Nottingham geologist, James Shipman (1882), enabled the Directors to tie this 'Blackrook' specimen to the old canal-railway cutting; a series of trial excavations since the Field Excursion has revealed the lost mine near the old railway bridge. Specimens of galena in Triassic breccia were found in the spoil outside the lost mine and thin layers of galena have been found interbedded with the Keuper Sandstone inside the adit. A full account of this geological detective story is in press (King and Ludlam). The discovery is of particular significance in demonstrating the distribution of galena in the basal Trias, which is rarely exposed owing to the cover of boulder clay and pre-glacial gravels; the latter were also visible beneath the bridge.

It was not possible to visit Breedon Cloud Quarry (SK/413216) on this excursion, but the leaders explained the nature of the chalcocite and malachite occurrences in the basal Keuper breccia there and reminded members of the sand-filled fissures, with galena and malachite impregnations, described in the "Mercian Geologist" (King, 1966).

The Carboniferous Limestone inlier at Ticknall (SK/362238) was next visited. Some 40 feet of beds are visible, lying nearly horizontal. The former Triassic cover has been mostly eroded away but was once visible above the roof of the "caves", underground workings in the far south-east corner of the quarries. Projection of the Triassic cover from this point shows that it must have once been no more than a few feet above the present exposure. The topmost bed of limestone has been dolomitized, probably by penetration of magnesian fluids from the former cover of Trias, but several shaly horizons have dolomitization limited to a few joints in the lower beds. One such joint complex is present in a wall of rock left standing between two of the old quarries; members were able to see the small solution cavities at the dolomite-limestone contact, lined with galena and barytes and forming, in some respects, a miniature development of the mineralization story at the Golconda Mine, Brassington (Ford and King, 1965).

After driving across the Trent Valley to the Derbyshire limestone massif, the final call of the day was made at Manystones Quarry, near Brassington (SK/235551). This disused quarry was worked for the pure Hoptonwood Limestones beneath a thin cover of dolomitized limestone, and the contact is well displayed in the quarry walls. At the contact, solution cavities developed in the relatively porous dolomite above the impervious limestone, some of the cavities being at the basal limit of dolomitization down joints. The dolomitization is almost certainly of Permian age (King and Ford, 1968; Ford, 1968). The subsequent mineralization of the Triassic period resulted in a precipitate of bedded galena and baryte in the bottoms of the solution cavities, similar to those seen in the Golconda Mine, the cavities being finally infilled with calcite scalenohedra. The details of some faces were figured by King (1966). The evidence for the former cover of Triassic sediments was outlined before making a hasty retreat for the bus as rain set in. The rain and the lateness of the hour prevented the final scheduled stop in the Masson Hill opencast fluorspar workings (SK/284591), where it would have been again possible to demonstrate that downward penetration of dolomitizing fluids preceded the development of solution cavities in the joints of the limestones between two toadstones and that the cavities were subsequently infilled with fluorspar.

In the final discussions, it was pointed out that the study of basal Triassic mineralization has so far been pursued from an academic point of view, but that there might well be some economic significance, since all the points with such mineralization represent former "highs" in the Triassic landscape, and the "lows" are as yet unknown and unexplored. If any form of gravitational separation of minerals in the lows had taken place, there might be ore-deposits hidden beneath the Triassic rocks of the Trent valley.

R.J.K. and T.D.F.

REFERENCES

EVANS, A.M. and KING, R.J. 1962. Palygorskite in Leicestershire, Nature, Vol. 194, No.4831, p. 860.

FORD, T.D. 1968. The stratiform ore-deposits of Derbyshire. Proc. 15th Inter-Univ. Geol. Cong., Leicester (in press).

FORD, T.D. and KING, R.J. 1965. Epigenetic bedded galena-baryte deposits in the Golconda Mine, Brassington, Derbyshire. Econ. Geol., Vol. 60, pp. 1686-1702.

KING, R.J. 1966. Episyngenetic mineralization in the English Midlands. Mercian Geol., Vol. 1, pp. 291-302.

1967. The minerals of Leicestershire. Part I: Elements. Trans. Leic. Lit. and Phil. Soc., Vol. 61. pp. 55-64.

KING, R.J. and FORD T.D. 1968. Mineralization. Chapter 7 in P.C. SYLVESTER-BRADLEY and T.D. FORD (Eds.), Geology of the East Midlands. Leicester; Univ. Press, 400 pp.

KING, R.J. and B. LUDLAM. The quest for a lost lead mine in Leicestershire. Bull. Peak Dist. Mines Hist. Soc., Vol. 4, No. 1 (in press).

LE BAS, M.J. 1968. Caledonian Igneous Rocks. Chapter 3 in P.C. SYLVESTER-BRADLEY and T.D. FORD (Eds.) Geology of the East Midlands. Leicester; Univ. Press, 400 pp.

MOORBATH, S. 1962. Lead isotope abundance studies. Phil. Trans. Roy. Soc., Ser. A, Vol. 254, pp. 295-360.

SHIPMAN, J. 1882. Galena in the Lower Keuper Sandstone. Midland Naturalist, Vol. 5, p. 280.

SYLVESTER-BRADLEY, P.C. and FORD, T.D. 1968. The Geology of the East Midlands. Leicester; Univ. Press, 400 pp.

EXCURSION TO THE NUNEATON AREA, WARWICKSHIRE

Leader : W.A. Cummins — Saturday, 15th June 1968

The object of the excursion was to examine the Pre-Cambrian and Cambrian rocks of the Nuneaton area and to consider their relationships with the adjacent outcrops of Carboniferous and Triassic strata. A party of about 40 members and friends assembled for the beginning of the excursion at the entrance to Judkin's Quarry (SP 346929). Most had travelled by coach from Nottingham and Derby: some had arrived by car. The Quarry Manager greeted the party and then guided the coach along the quarry road, down through a narrow cutting, and onto the quarry floor. Here the leader of the excursion gave an outline of the stratigraphy and structure of the area and an account of the history of its geological investigation. The sequence of strata is set out below:-

TREMADOCIAN	Merevale Shales
UPPER CAMBRIAN	Monk's Park Shales Moor Wood Flags Outwoods Shales
MIDDLE CAMBRIAN	Abbey Shales Upper Purley Shales
LOWER CAMBRIAN	Lower Purley Shales Camp Hill Quartzite Tuttle Hill Quartzite Park Hill Quartzite
PRE-CAMBRIAN	Caldecote Volcanic Series

The Nuneaton Inlier of Pre-Cambrian and Cambrian rocks appears as a narrow strip, nowhere much more than a mile wide, along the north-eastern margin of the Warwickshire Coalfield. The Pre-Cambrian volcanic rocks dip to the south-west at angles ranging from 20° to 40°. To the south-west, these are unconformably overlain by the more steeply dipping Cambrian strata (dips up to 60°). The Cambrian rocks are intruded by frequent sills of microdiorite. The ancient rocks of the inlier are flanked to the south-west by the unconformable Middle Coal Measures, which dip gently away in that direction, and to the north-east by the relatively flat-lying Keuper Marl. A strip of Upper Old Red Sandstone has recently been identified, separating the Coal Measures from the Cambrian shales in the northern part of the area (Kellaway et al., 1966, p.47). The basal conglomerate and sandstones of the Keuper rest unconformably on the Pre-Cambrian, Cambrian and Carboniferous rocks, but the north-eastern boundary of the inlier is in part controlled by a post-Keuper fault with a throw of several hundred feet to the north-east.

The history of investigation of the Cambrian rocks (Eastwood et al., 1923, p.22) is interesting. In 1822, the Cambrian quartzite and shales were referred to by W.D. Conybeare and W. Phillips as Millstone Grit and Coal Shale. J. Yates, in 1829, considered that the intrusive sills indicated a Lower Palaeozoic age for these rocks. But thirty years later they were still retained in the Carboniferous System by the Geological Survey: the junction with the overlying Productive Coal

Measures was apparently conformable and there were no fossils. The first Cambrian fossils were found by Professor C. Lapworth in 1882. A few years later, detailed mapping of the Cambrian shales by Dr. (later Sir) A. Strahan revealed the unconformable overstep at the base of the Carboniferous strata.

After this introductory talk, the excursion proceeded as recorded below.

1. Judkin's Quarry (entrance at SP 346929) extends for nearly half a mile along the strike in a north-west - south-east direction. Quarrying has been considerably extended since the area was mapped by J.R.L. Allen (1957, Plate 1; 1968, Figure 3) : Pre-Cambrian rocks are now exposed along the whole length of the north-eastern face. The party proceeded along the north-eastern face of the quarry on the upper level of working. Here the Welded Tuff division of the Caldecote Volcanic Series is exposed. The rock is a massive, unstratified, coarse crystal lithic tuff. The crystals are mainly of feldspar and the rock fragments of fine green volcanic material, often flattened so as to give the rock a streaky appearance and its only indication of stratification. Members who had been on the previous Society excursion commented on the occurrence of small blobs and veins of malachite in these tuffs.

Towards the northern end of the quarry an intrusion of markfieldite is exposed. A few years ago the basal Cambrian conglomerate, with large rounded boulders, was to be seen resting on a smooth surface of this markfieldite; but this contact has since been quarried away. The importance of this contact, first recorded by Wills and Shotton (1934), was that the Pre-Cambrian age thus demonstrated might also apply for the similar intrusive markfieldites of Charnwood Forest, whose age was not obvious from stratigraphical evidence. Time did not permit a detailed examination of the contacts between the markfieldite and the surrounding tuffs.

The base of the Cambrian is exposed in the short north-western face of the quarry. The contact with the underlying tuffs is disturbed by faulting, running mainly parallel to the Cambrian bedding. Some stratification was seen in the tuffs just below the Cambrian, and the angular discordance between these and the overlying quartzites was noted. The quartzites in this part of the quarry, the Park Hill Quartzite, contain much volcanic detritus eroded from the underlying Pre-Cambrian volcanic rocks.

Two shale partings, each several feet thick, can be seen in the quartzites of the north-western face of the quarry. A quartzite bed in the lower shale parting displayed a very fine drag fold. The upper shale parting was intensely brecciated. These observations show how, in a succession of competent strata, movements may be concentrated in a few relatively incompetent layers. The faulting along the junction between the Cambrian quartzites and the Pre-Cambrian volcanics is probably another example of the same phenomenon.

The quartzites above the upper shale parting, the Tuttle Hill Quartzite, can be seen along the length of the south-western face of the quarry. The party proceeded quickly along this face, noting ripple marks on the bedding planes and thin sills of microdiorite intruded into the quartzites.

The party then visited the lower level of the quarry at the south-eastern end, overshadowed by the large spoil heap. Here the base of the Cambrian was again examined. The angular discordance between the Cambrian and Pre-Cambrian is very clear, as bedding is well displayed in the fine laminated tuffs of the Pre-Cambrian; but the actual junction is occupied by a post-Cambrian intrusion of microdiorite.

Beneath the Cambrian at this lower level, the Bedded Tuff division of the Caldecote Volcanic Series was examined. The beds varied in thickness from a few inches to several feet and the lithology from fine laminated tuff to crystal tuff and coarse lithic tuff with few crystals. To see such a variety of Pre-Cambrian volcanic rock types freshly exposed by quarrying is a treat not often enjoyed by geologists in the East Midlands.

The party then gathered in the cutting at the eastern end of the quarry, where the road leads down onto the working levels. Here, on both sides of the cutting, the cross-bedded Keuper Sandstone is exposed, with a basal conglomerate unconformably resting on the Pre-Cambrian volcanic rocks. The pebbles in the conglomerate, of various shape and sizes, are of quartzite and volcanic and intrusive igneous rock types, such as the party had been examining in the quarry.

Some members of the party examined the base of the Cambrian at the north-western end of the lower level of the quarry, where quarrying is being extended northwards into the older higher level floor. Here the unconformity is unmarred by faulting or intrusion; the quartz has a basal conglomerate with large rounded boulders up to 18 inches across resting directly on the underlying Pre-Cambrian volcanic rocks.

By this time, thirst and hunger were making themselves felt and the party left Judkin's Quarry with regret, mingled with some anxiety about closing time at the next stop. Three Cambrian - Pre-Cambrian contacts had been examined, one faulted, one intruded and one unconformable; also the unconformity at the base of the Trias.

2. The Stag and Pheasant (SP 324927) has spacious accommodation inside and also seats outside facing onto the green at Hartshill. The party stopped here for lunch and, when suitably refreshed, left the coach and proceeded on foot for the second half of the excursion, which consisted of a traverse across part of the Cambrian succession.

3. Woodlands Quarry (SP 324948) is a small quarry in the upper part of the Cambrian quartzite, the Camp Hill Quartzite. It was still being worked in 1923 (Eastwood *et al*. 1923, p.26) but has not been used for a long time now. It is filled with water, surrounded by a new barbed wire fence and watched over by a spirited lady in a bungalow which overlooks it. Conditions were not ideal, but some members of the party went in at the top end of the quarry (north-east) to examine the shale and limestone parting near the base of the quartzites in this quarry. The limestone beds are each less than a foot thick and the rock is purple and, in places, sandy and micaceous. This is the lowest fossiliferous horizon in the local Cambrian succession; members were pleased to find abundant specimens of the pteropod *Hyolithes* and one example of the brachiopod *Kutorgina*. Although the quartzites overlying the Hyolithes Limestone are glauconitic, they are purple-coloured as a result of the abundance of small grains of purple shale in them.

Above the Camp Hill Quartzite, and well exposed along the south-western edge of the quarry, are the Purley Shales. These shales are bright red or maroon and have the green spots so often found in sediments of this colour. The question of the primary or secondary origin of the red colour was discussed, the primary origin being favoured because of the abundance of grey and black shales higher in the succession which should have been equally susceptible to reddening.

4. Hartshill Hayes (SP 323942), just to the west of the remains of the Abbey and Castle of Hartshill, is the site of Illing's (1915) excavations in the Abbey Shales. The party marched through dense undergrowth and woodland and some time later arrived, in varying stages of exhaustion, streaming with sweat and covered in spiders and insects, at the remains of Illing's trenches. Some members expressed surprise that they had apparently reached their intended destination. After recovering, the party settled down to look for fossils, but without much success - a few unidentifiable inarticulate brachiopods and a few trace fossils, but not a sign of a trilobite. Five weeks previously a student on a University excursion from Nottingham collected a perfect and complete specimen of the Middle Cambrian trilobite *Agnostus rex* here.

5. Moor Wood (SP 317939) is the site of old quarries, extending for nearly a quarter of a mile along the strike, in a microdiorite sill intruded into the Outwoods Shales. The intrusive rock is leucocratic, relatively coarse in the middle and distinctly finer towards the upper contact (the lower contact is not visible). The shales away from the intrusion are soft and black, but near the contact they are bleached and baked, spotted slate being produced as a result of contact metamorphism. No fossils were found at this quarry.

6. A small cutting (SP 317940) a little higher up in Moor Wood, crosses the outcrop of a lower sill in the Outwoods Shales. Here the sill is seen in its weathered state and shows well-developed spheroidal weathering.

Just south of Moor Wood, the Middle Coal Measures rest on the Outwoods Shales. Further to the north-west, progressively younger shales in the Cambrian succession appear beneath the overlying Coal Measures.

7. The Stag and Pheasant (SP 324927) was open again by the time the party returned to the coach after a long afternoon in the hot sun and marching through the local jungle. We refreshed ourselves once again and set off for home.

Acknowledgement

I am grateful to Mr. G. Walton for drawing my attention to the presence of the Upper Old Red Sandstone in the Nuneaton area.

W.A.C.

REFERENCES

ALLEN, J.R.L. 1957. The Pre-Cambrian geology of Caldecote and Hartshill, Warwickshire. Trans. Leics. Lit. Phil. Soc. Vol.51, pp.16 - 31.

1968. The Nuneaton District in P.C. Sylvester-Bradley and T.D. FORD, 1968, pp.15 - 19.

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

ILLING, V.C. 1915. The Paradoxidian fauna of the Stockingford Shales. Quart. Journ. Geol. Soc. Lond. Vol.71, pp.386 - 450.

KELLAWAY, G.A. et al. 1966. Atherstone (155) and adjacent Sheets. Inst. Geol. Sci. Ann. Rept. for 1965, p.47.

SYLVESTER-BRADLEY, P.C. and FORD, T.D. 1968. The Geology of the East Midlands. Leicester University Press, 400 pp.

WILLS, L.J. and SHOTTON, F.W. 1934. New sections showing the junction of the Cambrian and Pre-Cambrian at Nuneaton. Geol. Mag. Vol.71 pp.512 - 521.

THE UPPER PERMIAN OF YORKSHIRE

Leader: D.B. Smith — Friday, July 5th - Sunday, July 7th, 1968

Report prepared by Dorothy M. Morrow, in association with Denys B. Smith

This joint meeting, arranged by the Yorkshire Geological Society, was attended by a party of members of both Societies and also by others who were members of either one or the other Society. The party assembled at York for the weekend excursion, in which it was planned to visit Upper Permian beds between Ripon and Doncaster. On the Friday evening, the Leader showed slides describing the palaeogeography of the area and the localities to be visited.

The Table below summarizes the rocks investigated:-

Bunter Sandstone	Evenly bedded fine grained brick red silty sandstone with thin beds of dark red mudstone. The lower beds grade into:
Permian Upper Marl	Dull dark red silty mudstones with thin beds of fine grained brick red sandstones. Contains the Upper Anhydrite, 20 - 50 feet above the base.
Upper Magnesian Limestone	Mainly thin bedded hard silt - and fine-sand grade sub-littoral carbonate with thin beds of green, grey, red, lilac and purple mudstone. Generally sparsely fossiliferous but locally composed almost entirely of the alga *Tubulites permianus* and the lamellibranchs *Liebea squamosa* and *Schizodus schlotheimi.* Plants are locally abundant. The rock is partly oolitic around Ripon and Sherburn-in-Elmet and partly oncolitic further south. It is widely finely cross-laminated and channelled and locally partly de-dolomitised. There are extensive collapse structures, due to solution of sulphate in underlying strata.
Permian Middle Marl	Dull dark red and grey silty mudstones with interbedded sulphates (anhydrite at depth passing into gypsum towards the outcrop) and subordinate thin dolomites. The marls are widely contorted due to solution and mobility of the sulphate beds. The deposit is interpreted as a playa type deposit of a wide backreef lagoonal zone.
Middle Magnesian Limestone	Mainly oolitic, soft white dolomite. Rare beds of soft green mudstone present, with two thin parallel mudstone beds at the base (Hampole Beds). Interpreted as a shallow water shelf/ lagoon deposit grading eastwards into an off-shore subaqueous bar facies.
Lower Magnesian Limestone	Composed mainly of algal-ooliths, oncolites and stromatolites in the upper part, and of granular non-oolitic carbonates in the lower part. Patch-reefs common at all levels in shoal areas, rare or absent elsewhere. The lower part locally contains many mudstone partings. Abundant lamellibranchs in shoal areas.

Older Permian beds including the Permian Lower Marl, the Marl Slate, Basal Permian Sands and Basal Permian Breccia were not seen on the excursion.

Saturday, 6th July

The party, travelling by coach, first visited Wetherby Station (SE 398483). The Station is now disused and the cutting shows an exposure of the first carbonate phase of the English Zechstein. This consists of 45 ft. of level bedded, finely oolitic dolomite, a further 20 ft. of which is hidden beneath the floor of the cutting. The bedding of these carbonates is parallel, an almost invariable characteristic of the Lower Magnesian Limestone. The exposure shows fine details of channel bedding, ripple marks, small burrows and other indications of shallow water intertidal conditions, in rocks made up of fine ooliths composed of pure dolomite with a little interstitial calcite. This is the standard facies, containing no reefs. These beds thin north-westwards against a rising land surface.

Further along the cutting, north of the A 659 road bridge (398485), about 30 ft. of the upper beds of the Lower Magnesian Limestone are exposed. These beds, still remarkably horizontal, were stated to be predominately algal stromatolites, pisolites and oncolites.

Newsome Bridge Quarry, North Deighton (SE 379515) This pretty, disused quarry displays the unconformity between the underlying Plumpton Grit (Namurian) and the upper (algal) beds of the Lower Magnesian Limestone. The lower oolitic beds (and the rest of the older Upper Permian beds) of the Lower Magnesian Limestone are missing. The surface of the Plumpton Grit was said to be part of a pre-Upper Permian peneplain, which has an irregular surface here but has a more regular surface to the west nearer the Permian shoreline. Scattered purple-stained quartz pebbles are found in places above the unconformity and large blocks of Carboniferous sandstone are incorporated into the lowest Permian beds, indicating a turbulent environment.

The main features of this exposure is a medium-sized patch reef, which caps a small hill (probably formerly an island), on the surface of the unconformity. The reef has a small polyzoonal core but is mainly composed of algal stromatolites. It passes laterally into and is overlain by level-bedded oncolitic dolomite.

Grimbald's Crag, Knaresborough (SE 362558) The party first descended to the bed of the River Nidd near the weir (SE 364558). At this point, due to progressive overlap, the whole of the first cycle carbonate is absent and the Namurian sandstones are overlain directly by the Middle Magnesian Limestone. At the base of the Permian beds lie 10 to 15 ft. of well bedded oolitic dolomite and this is overlain by the wedge-bedded oolite, of a type generally characteristic of the middle Magnesian Limestone in central Yorkshire. Lamellibranchs were collected from near the river level, but they are rare in the overlying beds.

In the crag itself, the unconformity was pointed out beneath thick wedge-bedded dolomite. Fossils are rare at this point. The oolite is believed to have accumulated in the form of elongate sub-aqueous dunes, as much as 30 ft. high. The rock has many interesting petrographical features. It appears as a good oolite in thin section, but this detail is not apparent in hand specimen. It contains as much as 10% of quartz, which has selectively replaced some of the dolomite and also forms authigenic overgrowths. Some felspar and detrital calcite are also present. All these crystals show as dark spots in the dolomite.

Immediately above the unconformity are some interesting dome-like structures, still being investigated. The leader suggested that these structures may be injection complexes formed over springs, sand volcanoes, or, possibly, stromotolite structures.

The Nidd Gorge, Knaresborough (SE 346566) At the bottom of the gorge, in the Castle Grounds, another exposure of the Middle Magnesian Limestone was seen resting unconformably on the Plumpton Grit. Here again, above the unconformity lies a oolite-sand bar facies, with wedge bedding units 20 - 30 ft. thick. Immediately above the unconformity there is a reddish bed, 6 - 8 inches deep, of detritus from the Namurian beds below.

On the route to the next locality, the leader described the geology of the area through which the coach travelled. Around Burton Leonard, dune bedded Middle Magnesian Limestone is 150 ft. thick, giving rise to a rolling topography not unlike the Chalk country.

Monkton Moor Quarry, Wormald Green (SE 307653) This enormous quarry is exploiting the Middle and Lower Magnesian Limestones. The party first walked over the undulating limestone pavement veined with gypsum (the top surface of the Middle Magnesian Limestone) to see the Permian Middle Marl, at a bank at the S.E. corner of the quarry.

In the quarry, the Middle Magnesian Limestone is only 18 ft thick. The dune bedding is absent and there is only a little wedge bedding. The dolomite is more or less entirely oolitic, with a few thin clay beds and a few poorly preserved fossils.

Beneath the Middle Magnesian Limestone, and separating it from the Lower Magnesian Limestone at the base of the quarry, lie the Hampole Beds. Only a few inches of these beds are present here, but the typical 'sponge-cake' or 'birds-eye' structure could be seen. These beds were said to mark the top edge of intertidal flats, the two mudstones indicating the beginning of subsequent reinudation. Mudcracks indicated periodic dessication.

From Wormald Green to Ripon, further features of the geology were pointed out. These included sink-holes through the Bunter Sandstone, near Ripon.

Quarry Moor, Ripon (SE 308692) The excellence of this exposure compensated for the fact that it was situated at the far side of an evil-smelling corporation rubbish tip. The party were eventually rewarded by seeing the fine section at the top of the Middle Magnesian Limestone, capped by Permian Middle Marls. In these beds, solution of sulphates has led to great irregularities in the bedding; and to a large extent the upper beds are now dedolomitized and contorted, whereas the beds below are regular. There are also sags in the bedding where the evaporites have been dissolved out.

The upper beds of the dolomite showed wonderful algal laminations.

Ripon Parks, Ripon (SE 313739) At this locality, the party saw a newish exposure of part of the Upper Magnesian Limestone in the roadside. These beds displayed the characteristic shallow water sedimentary structures. Here and in other localities, a unique fossil assemblage comprising the alga Tubulites permianus and the lamellibranchs Liebea squamose and Schizodus schlotheimi is found. This area is subject to subsidence as a result of solution of the evaporites in the Permian Middle Marls below. The leader read out an interesting contemporary account of the initiation of a sink-hole and then led the party to see an excellent example in a nearby field. The day was completed by a visit to Fountains Abbey, after which the party returned to York.

Sunday, 7th July

Copley Lane Quarry, Sherburn-in-Elmet (SE 481348) In this large quarry, in the Upper Magnesian Limestone, there is also a few feet of the Permian Upper Marl. The Billingham Main Anhydrite is missing and it was thought that it had been dissolved out.

A huge collapse structure, which stops at the level of the base of the drift could be seen in the quarry face. The limestone beds are broken and the cavity filled by the Permian Upper Marls. The structure was described as a 'fossil' sink hole, since it must have developed prior to the deposition of the drift.

The main mass of the Upper Limestone, over 40 feet thick, is almost a pure white dolomite containing ooliths and shells, with ripple marks and other evidence indicating shallow water conditions. Above the white beds are a few feet of brownish-grey thin-bedded and flaggy dolomites. Above these again are thin beds of purple or green quartz-rich mudstones, overlain in turn by dolomite with a concretionary appearance. At the top, there are three or four feet of lilac and grey dolomitic mudstones which are capped by the Permian Upper Marls. At the base of these marls there is striking evidence of cryoturbation.

New Micklefield (SE 445325) The arrival of 33 cars amongst the backyards of this Yorkshire mining village resulted in a turn-out of the entire population in considerable excitement, and an interested outer circle of spectators watched the examination of the exposure. The old quarry face is cut in wedge-bedded Middle Magnesian Limestone and there is an excellent section of the Hampole Beds, with its characteristic structures. The Hampole Beds overlie a slight discontinuity which may indicate a period of erosion.

The Wentbridge Cutting and Quarry (SE 487178) The exposures here consist of Lower Magnesian Limestone resting uncomfortably on Westphalian sandstones, about 250 ft. above the Top Marine Band of the Coal Measures. The Limestone, mainly dolomitic, is generally oolitic and locally, near the base, extremely shelly. In the quarry the Permian rocks include a large polyzoan reef, with bedded limestones beneath it. The latter contain the lamellibranchs Schizodus and Bakevellia, usually as external or internal molds. Higher beds could be seen to pass into the reefs or over the top, with characteristic primary dip.

South Elmsall (SE 483115) An old quarry close to the village exposes the higher part of the Lower Magnesian Limestone. The quarry face sections a reef consisting of polyzoa and bivalves at the base and stromatolites at the top. Good specimens of weathered oncolites could be collected from the side of this quarry.

Because some members of the party were leaving the excursion at this point, the President of the East Midlands Geological Society moved a vote of thanks to the leader and to the Secretary of the Yorkshire Geological Society for the arrangements. The majority of the party continued to the next exposure near Cadeby.

Cadeby Quarry (SE 5200) The Steetley Company's quarry exposes nearly the whole of the Lower and Middle Magnesian Limestones, with the well-marked Hampole Beds in between. In the Lower Magnesian Limestone there are patch reefs all round the quarry. As at South Elmsall, polyzoan-bivalve assemblages in the core of each mass are surrounded and overlain by algal stromatolites. Above the Hampole Beds are buff coloured wedge-bedded dolomites. The Hampole Beds exhibit their characteristics structures. Plant remains were found in some beds.

Sprotbrough (SE 534015) This quarry also showed the junction between the Lower and Middle Magnesian Limestone but here, as opposed to the last exposure, it was possible to examine the Hampole Beds at the junction 'in situ'. The Hampole Beds were much thinner here than in the Steetley Quarry, only a short distance to the west. A feature of the exposure is the squeezing up of the Hampole clays into the overlying beds, in places filling joints and vertical cracks, in places producing dome-like structures.

It was generally agreed that this should be the last exposure and, after congratulating the leader, Mr. D.B. Smith, the party made their way home individually.

D.M.M. and D.B.S.

REFERENCE

SMITH, D.B. 1968. The Hampole Beds etc., Procs. Yorkshire Geol. Soc., Vol. 36. pp. 463 - 467, text-figs. 1 - 2, Plate 18.

Because of pressure on space in this issue of the "Mercian Geologist", publication of the reports on the two latter field excursions of 1968 (to Bedfordshire and to the Lake District) has been delayed. Reports on these excursions will appear in Vol. 3 no. 2 (publication planned for July, 1969).

REVIEWS

N. Kirkham 1968. Derbyshire lead mining through the centuries. Truro: D. Bradford Barton. 132 pp., 12 pls. 30s.

Miss Nellie Kirkham (Mrs. J.H.D. Myatt) is, beyond all question, the greatest authority on the lead mines of the Peak District. Her personal knowledge of the mines is immense; she has visited and studied most mines that have been accessible within the last thirty years and has examined a great deal of the available documentation - mine plans and records, manuscripts in public and private collections, and published histories. Her many friendships among Derbyshire mineral miners and speleologists have been a further fruitful source of data. The product of her researches has been an impressive sequence of papers describing the mines, soughs, and mining history of the Peak : she has also written two books, one of which, "Unrest of their time" (London: Cresset Press, 1938), is a fascinating and unusual novel of Derbyshire lead mining life, now regrettably difficult to obtain. (Her second, "The Pilgrim's Way", is an account of travels in south east England). For many years, Miss Kirkham carried a lone torch in her researches; it is only within the last decade that industrial archaeology has become a fashionable study. Beyond question, her work has saved for posterity much information that would otherwise have been lost; her endeavours merit the highest praise.

The publication of her book on Derbyshire lead mining has long been eagerly awaited; and it has been well worth waiting for. This is a sound, balanced and extremely readable general treatment, which can be enjoyed equally by the newcomer to the field and by the specialist. It is divided into eight sections ("The lead miner"; "Laws and customs"; "Minerals"; "The mines"; "Ore dressing"; "Drainage"; "History"; "Finance, production and closure"), prefaced by an introduction which includes a fine verbal evocation of the Derbyshire landscape. There is a fascinating section on terminology and a useful, if perhaps over-brief, bibliography. The illustrations are well chosen and excellently reproduced. (The dust-jacket picture of the magnificent Water Grove Mine Chimney caused the reviewer certain pangs of regret, for he was one of those who fought a losing battle, some years ago, to save it from being destroyed).

Some points merit criticism. On page 22, the terms "tut" and "tutwork" are discussed: their Cornish definition is given, but the Derbyshire meaning is not made clear. On page 120, "£9.11" should presumably read "£9-11-0". At several points, the text is rather unspecific and it would have been more interesting if a mine name or locality had been quoted. For example, the last paragraph of p.91 quotes atmospheric engines as being "erected in the Winster district"; at which mines? - there are many in this area. Two underground installations are mentioned : the mine names are again not quoted. Similarly (p.87) : "It has been stated in print more than once that soughs were useless . . . ."; the quotation of a specific instance would have been helpful. A brief list of Derbyshire lead mines and soughs is given as an appendix; this is useful, but a more comprehensive list would have been even more so, and one giving the grid references of the mines would have been of immense value. The text contains a general map of the lead-mining area and detailed maps of the Eyam mines and Watergrove Sough; but the reader unfamiliar with Derbyshire has no means of locating most of the mines mentioned, for very few are named even on Ordnance Survey maps.

In general, though, this is a first-class account and one that is unique in its subject-matter : the only other work currently available dealing, in part, with the Derbyshire mines, Raistrick and Jennings' "History of lead mining in the Pennines" (1965. London: Longmans, 347 pp.) is almost exclusively historical and is oriented more towards the Yorkshire lead mines. Perhaps we may hope eventually for a much larger and more detailed work on this area from Miss Kirkham; but, as a general account of the Derbyshire mines, the work here reviewed is unlikely to be surpassed.

William A.S. Sarjeant

P.C. Sylvester-Bradley & T.D. Ford (editors) 1968. The geology of the East Midlands. Leicester: Leicester University Press. 400 pp., 7 pls., 57 text-figs., 19 tabs. 84s.

Although geological accounts of parts of the East Midlands area had appeared much earlier (for example, Henry Porter's "Geology of Peterborough and its vicinity", 1861, and J.W. Carr's "Contribution to the geology and natural history of Nottinghamshire", 1893), the first attempt at a general geological account of the whole of this region was made in 1948, when a "Guide to the geology of the East Midlands" was published by Nottingham University, under the Editorship of Professor C.E. Marshall. This comprises a series of papers, each treating a particular part of the geological column, variously written by J. Shirley, W.W. Black, W. Edwards, H.H. Swinnerton, K.C. Edwards, P.E. Kent, F.A. Henson and the editor: the papers are contained within a total compass of 111 pages, so that they are of necessity both brief and generalised: there was not room for detail and the value of the book to the geologist in the field is inevitably reduced, as a consequence.

Perceiving that there was room for more comprehensive and up-to-date work, Professor P.C. Sylvester-Bradley began the preparation of the present volume around 1961, when contributions were solicited, and received, from a number of authors. At the time of formation of the East Midlands Geological Society in 1964, the book had not appeared; and during the following year, Dr. F.M. Taylor and the reviewer paid a visit to Professor Sylvester-Bradley, to enquire regarding its progress, specifically as to whether there was any prospect of its appearing in time for the Nottingham meeting of the British Association in 1966. Possibly under the stimulus of this visit, active work on the production of this volume recommenced, under the joint editorship of Dr. T.D. Ford; but, as a result of unforeseen delays, the book did not finally appear until September 1968.

Once again, this work consists of a collaboration by a number of different contributors, each dealing with a particular area and/or a particular district. In the 1948 volume, the area considered to comprise the East Midlands was centred on Nottinghamshire and included parts of Derbyshire, Staffordshire, Warwickshire, Leicestershire, Northamptonshire, Lincolnshire and Yorkshire, with the River Humber taken as northern boundary; the exact limits were thus somewhat nebulous. The limits imposed by Professor Sylvester-Bradley are much more clearly defined: they are illustrated in Text-fig.1 of the volume and are based on National Grid lines (though the sketch map leaves one wondering whether the area hidden by the key is included!) One feels, however, that the limits chosen are both arbitrary and surprising, for whereas the northern parts of Derbyshire, Nottinghamshire, Staffordshire and Lincolnshire and southern Yorkshire are excluded and the area nowhere intersects the North Sea coast, it does include points as far south as Banbury and even Luton.

The account provided of the geology of the East Midlands, as thus delimited, is well-planned and comprehensive. The style of presentation is sufficiently closely controlled to produce the necessary degree of standardisation between sections, but there is necessarily some variation in quality between chapters, according to their authorship. The format is sufficiently luxurious to justify the high price; the text, plates and figures are clear and attractive (though Fig.57 was inserted upside-down in the reviewer's copy!)

Of the nineteen contributors, six are members of this Society - Dr. T.D. Ford, Dr. M.J. LeBas and Dr. R.J. Rice (Leicester); Mr. K. Spink and Dr. F.M. Taylor (Nottingham); and Dr. P.E. Kent (British Petroleum.) Dr. Ford deals with the Precambrian of Charnwood Forest, the Carboniferous Limestone and the Millstone Grit; he is co-author, with Mr. Spink, of the Section on the Coal Measures and, with Mr. R.J. King, of the chapter on "Outliers of possible Tertiary age" and he contributes to Mr. King's chapter on "Mineralisation" and Dr. Rice's treatment of the Quaternary. Dr. LeBas deals with Caledonian igneous rocks: Dr. Taylor with the Permian and Triassic formations: and Dr. Kent is responsible for the chapters dealing with the Rhaetic beds and with the buried floor of eastern England.

An adequate review of a volume of so wide a scope is impossible in the space available - and would, in any case, require the services of a team of reviewers! In brief, Professor Sylvester-Bradley, Dr. Ford and their team of contributors are to be congratulated on having produced a work of profound importance, which merits a place on the shelf of every geologist interested in the East Midlands.

William A.S. Sarjeant.

R.G. West 1968. Pleistocene geology and biology, with especial reference to the British Isles. London : Longmans. 377 pp., 16 pls., many text-figs. 63s.

The Quaternary is the period of the Earth's history whose events have most immediately determined our present landscape; its deposits, albeit often thin, are more widespread than those of any earlier period, even if one excepts soils from inclusion in this category. Yet somehow it occupies a surprisingly small part of the attention of most British geologists, whether professional or amateur; and it is accorded scant treatment in the stratigraphy courses of many Universities and colleges. The reasons for this are twofold. First of all, it lacks the glamour of ancientry and its faunas and floras, with only a few exceptions, are available for study in the living version: their fossil remains are thus of reduced interest. Secondly, and most importantly, its study involves quite different techniques from those applied to the earlier geological systems. Quaternary sediments are thus dismissed as "drift" - a tiresome blanket hiding the real geology. . . . and so their study has progressively come to be taken over, in Britain (though this is not the case elsewhere in Europe and in America), by the botanist and the geographer.

Since the nineteenth century, there has been a great gulf in Quaternary literature between the two extremes of scientific papers, only accessible to and digestible by specialists, and solid reference works on the scale of Charlesworth's expensive, two-volume "The Quaternary Era". The relatively few works on an intermediate scale have either been specialist in scope or else American in origin and orientation: these latter have, in many instances, been scarcely less restricted in coverage and none has provided anything approaching a satisfactory introduction to all aspects of post-Tertiary geology and biology. The work here reviewed (written, be it noted, by a botanist !) is the first to attempt the formidable task of being comprehensive in coverage : it thus fills a real gap in scientific literature.

The plan of the book is admirable. The term "Pleistocene", in West's usage, includes the Holocene and thus covers the period right up to the present day; it is equivalent in scope to "Quaternary". This is essentially a glacial episode in the earth's history and, as West emphasises, we are probably now living in an interglacial : we cannot assume the episode is over.

Appropriately, therefore, the character of glaciations occupies prime attention, after which the nature of landscape - forming processes in glaciated and non-glaciated regions are successively considered. Excellent sections on the techniques of stratigraphical and biological investigation follow : then the questions of land/sea level changes, the problems of chronology and dating, and the topic of climatic change successively receive attention. A general discussion of the Pleistocene and its subdivisions prefaces the final section, in which the Pleistocene of the British Isles, its flora and its fauna, are given special attention. Two appendices (on techniques) and an index complete the text, which is illustrated by a group of plates and an excellent series of text figures.

The wide scope of this work, combined with its compression into the comparatively brief span of 377 pages, necessitates a high density of facts per paragraph. This is very definitely a textbook : information is packed too closely for it to be easy reading. A detailed and adequate index to the very many technical terms used is thus an essential; and, unfortunately, the index falls far short of being satisfactory. Many terms are not indexed at all : for example, "limnic", "telmatic", "autochthonous", "allochthonous", "sags", "calcareousness", "turfa", "talik", "crysturbation" "cryohydric", "cryoxerotic", "hydrosere". Other terms are mentioned on more pages than the index indicates : for example, "ruderals" appears on p.132, as well as on p.323; "Deckenschotter" on p.218, as well as p.163; "cryostatic effects" on p.70, as well as p.78; and the discussion of "humification" is not confined to p.54, but extends onto p.55.

The author is careful to define most terms quite clearly, but a handful entirely escape definition (e.g. "swalls", "ruderals", "Deckenschotter") and several are used, either in text-figures or in the text itself, ahead of their definition. Examples : "till" used p.10, defined pp.20-25; "urstromtaler" used p.67, defined p.88; "positive economy" used p.11, defined p.13. The text-figures in general are clear and helpful, but there are a few points of difficulty here also; for example Text-fig. 5.9 is most difficult to understand and the shading in Text-fig.7.10 is not adequately explained.

Errors in punctuation occur : and a few sentences fail to convey their meaning or make incomplete sense, e.g. p.10 "Ablation results in melting . . . ." : p.9 "Two characters in banding appear less important. . . . " (it is not clear to what their importance is relative). Such slight errors would be less serious in a work with a lower concentration of data per paragraph : but, as it is, they can produce serious confusion.

The author has also not been particularly well served by his publishers. The dust jacket picture of Britain under ice is excellent and evocative but, whilst a contraction of the title on the spine was inevitable, surely the full title, with its exact indication of the scope of this work, should have appeared on the front cover of both book and dust-jacket. (The contracted title, "Pleistocene geology and biology", is misleading in that it suggests a world coverage.) The plates are well chosen and informative; but they are poorly reproduced. Their concentration into one section must have reduced production costs and is forgivable; still, their placement, where relevant, in the text would have been helpful.

The good things in this book, however, far outweigh the faults. The excellent exposition on techniques is invaluable : the section on geomorphology is refreshingly comprehensive and up-to-date; and the clarity of conception and execution evinced by the text-figures merits especial praise (the key to sediment symbols, Text-fig. 4.2; the series of figures illustrating structures in the sediments of the periglacial zone; and the series of pollen diagrams are noteworthy). The excellent summary of current information on British Pleistocene palaeogeography is particularly useful. All in all, the author is to be congratuated on having tackled a formidable task with outstanding success.

William A.S. Sarjeant.

"Studies in Speleology" Vol.1, No.4, December 1966. London : Association of the Pengelly Cave Research Centre. 25s. (free to members of the Association).

The scope of this journal is adequately indicated by its title : geology is one of several concerns and the journal is of more direct interest to speleologists than to geologists. Of nine papers in the issue in question, only one (A. Droppa : The correlation of some horizontal caves with river terraces) is of direct geological relevance : another (T. Harrisson: William Pengelly, 1864 and the Niah Caves, 1965) is an interesting sidelight on the work on an early geologist. One paper on archaeology, two on speleological techniques, and four on biological topics complete the issue; their scope is world-wide. The format is attractive, the illustration (text-figures and well-produced plates) excellent.

William A.S. Sarjeant.

R. Neves and C. Downie 1967 : Geological excursions in the Sheffield Region. Sheffield: University of Sheffield. xlv + 163 pp., 48 figs., 5 pl. 16/-. Available from Messrs. Hartley Seed Ltd., University Booksellers, Glossop Road, Sheffield 1.

This book was published in time for the 6th International Congress of Carboniferous Stratigraphy and Geology, which was held in Sheffield in September 1967. Many of the itineraries listed were used for the congress excursions. However, it was thought by the publishers that the book would have a wide appeal for students of geology and the general public in Sheffield, Yorkshire, Nottinghamshire and Derbyshire and elsewhere, who wished to visit the area. Thus the book covers a wider spectrum of the geological column than that of the conference, extending upwards and including the Cretaceous System.

The publication of the book was made possible by financial assistance from the Peak Park Planning Board, the University of Sheffield, the Department of Geology at Sheffield University and the International Congress of Carboniferous Stratigraphy and Geology.

In all, there are some 24 separate excursions listed, extending from the Wye Valley and Earl Sterndale, Derbyshire, in the west to Nettleton, Lincolnshire, in the east. The southernmost localities include Crich, Ambergate and Wirksworth.

A map (Fig. 1) illustrates the geology of the area but embraces a region somewhat in excess of that covered by the excursions.

The book commences with an introduction summarising the geology of the area, with up-to-date tables on the Carboniferous Stratigraphy.

Each excursion has an introduction giving details of the sequence present in the area, often illustrated by a text-figure. The itinerary given (complete with National Grid references) allows the excursionist to follow a route without difficulty but not necessarily in the numerical order shown on the maps, which would sometimes cause unnecessary detours.

On the Ashover excursion, for example (Fig. 61 p. 38), visits to localities three and four would entail a diversion of several miles, if visited after locality two and before locality five. It would perhaps be better to start at locality four and omit locality three altogether or call there on the return journey.

Such difficulties are fortunately few and this book will be a welcome guide for the many teachers, students and schoolchildren, who are now beginning to realise that there are things to be seen in the Peak District National Park and the Sheffield region of considerable geological interest. With the book 'Geology of the East Midlands' (edited by P.C.S. Bradley and T.D. Ford, 1967 and here reviewed) a very large area of Eastern England is now served with modern geological excursion itineraries and literature.

Frank M. Taylor.

D. Rayner 1967. The Stratigraphy of the British Isles. Cambridge: University Press. 453 pp., 80 text-figs., 8 pls., index. 70s.

For many years students of British stratigraphy have been asking for a course book on the subject that is detailed and up-to-date enough to make it largely unnecessary to delve into scattered literature, unless a research topic is contemplated. Dr. Rayner's book admirably fills this need, which had existed for far too long.

Dr. Rayner is a Senior Lecturer at the University of Leeds and has specialised in stratigraphy and palaeontology. She is thus well qualified to write a book of this type; and no doubt its content has been tried out on a number of generations of undergraduates ! Dr. Rayner is especially to be congratulated on producing a book of such scope written entirely by herself, ensuring continuity of style and presentation.

The book commences with an introduction which is concerned with the general principles of stratigraphy, including the time factor, and the use of sedimentary structures and fossils in correlation. Reference is also made to the general tectonic setting of the British Isles. Some readers may prefer to continue reading these general topics by moving from this point to the end of the book, where a chapter includes such topics as palaeogeography, the effect of continental drift and the origin and development of British seas.

The detailed stratigraphy is described, using the major divisions of the geological column for chapter headings. The way in which this is done must always be a personal choice and no doubt the need to conserve space may also have an influence on the actual division decided upon: the result, however, provides some anomalies which everybody will not be willing to accept. Thus the Pre-Cambrian rocks are condensed into a single chapter, only 23 pages in length; this has been achieved by including the Dalradian Series at the end of the Cambrian chapter, which is 24 pages long. The Carboniferous System, on the other hand, is divided into two chapters, 34 and 36 pages in length respectively. This difference in length and detail no doubt reflects the interest of the author; but students of Pre-Cambrian geology will find their chapter too brief, whilst the two chapters on the Carboniferous will be too detailed for them.

The description of Ordovician rocks is one of the best accounts so far available of a very difficult succession of sediments and volcanic rocks. Not everyone will like the inclusion of Silurian rocks in the same chapter, if they are interested only in the Ordovician.

In dealing with the time between the end of the Carboniferous Period and that of the Jurassic. Dr. Rayner is faced with the difficulty of describing one System, the New Red Sandstone, or two, the Permian and Triassic Systems. In the main Sherlock (1911) is followed for the East Midlands by the use of the term Permo-Triassic System and Wills (1948) for the West Midlands. The main difficulty apparently occurs in the East Midlands; Dr. Rayner, following Sherlock, believes that the Bunter Sandstones of that area are equivalent to the Magnesian Limestone (p.238, p.249) and overlain by the Keuper Group (Upper Triassic). The Institute of Geological Sciences, in recently published maps and the Ollerton Memoir (1961), clearly include the Bunter Sandstone facies in the Lower Trias. Thus the Lower Trias is either present in the East Midlands, or not, depending upon the authority consulted. At the present time this problem has still to be clarified, but this is not the impression given by Dr. Rayner. If one accepts either one view or the other, then reasons should be given in support of one and rejection of the other. No new evidence is available in Dr. Rayner's book to support a Zechstein age for the Bunter Sandstone. Where can one see the lateral passage of Bunter Sandstone into Upper Magnesian Limestone? Sherlock's work applied particularly to Southern Nottinghamshire, where a sandy facies similar to the lowest Bunter Sandstone (Lower Mottled Sandstone) was seen adjacent to parts of the Middle Permian Marl; but Lower

Mottled Sandstone and higher Pebble Beds also overly the Upper Permian deposits in south Notts. The same situation applies in Yorkshire; and the Beds are thinning in Durham. Are there no Triassic beds above the Middlesbrough beds in Co. Durham?

The author's somewhat dogmatic approach to the subject no doubt results from the need for brevity arising from shortage of space. The lack of explanation is encountered in other places too. In the chapter devoted to the Jurassic, the word Kimmeridge(ian) is spelt with a single 'm' throughout, except for the heading to p.303 (which is presumably an error.) However the British Mesozic Committee have recommended that D'Orbigny's original spelling (Kimmeridgian) be adopted, even though this was probably an error: and this recommendation was accepted by both the International Colloquia on the Jurassic (1962, 1967).

The factual evidence given is generally of a high standard, but there appears to be at least one important slip; surely ammonites have been collected from the German Muschelkalk (p.237) ?

The book is printed in very clear type and the many original illustrations are valuable additions to the work. Some of the figures (e.g. Fig.63, p.318) look a bit crowded, however, with sections and diagrams filling all the available space. The reviewer's copy (purchased) was badly trimmed, with corners of pages folded in and other pages not cut.

The reviewer has enjoyed, and been stimulated by, reading this book and found it an excellent summary for his students.

Frank M. Taylor.

W. Youngquist 1966. Over the hill and down the creek. Caldwell, Idaho: Caxton Printers. 322 pp., 15 text-figs. $5. (Available directly from The Caxton Printers, Ltd., CALDWELL, Idaho, U.S.A; currency transfer can be arranged on basis of invoice).

In the late nineteenth century, the death of a scientist of any eminence was inevitably followed by the production of a biography (or sometimes of several), usually in two or more volumes and containing transcripts of all his letters that could be found and which were considered worthy, or fit, for publication. (One suspects that the letters of such turbulent and warm-hearted figures as Hugh Miller were drastically censored!) The reading of these tomes is often a long process, but it is a fascinating and rewarding one; and they are in valuable source - works in the history of science.

Regrettably, the changing winds of the twentieth century have blighted this particular branch of literature. Even the adventurous life of such an eminent figure as J.W. Gregory has gone unchronicled; and it is regrettable that Sir Edward Bailey was too occupied, in the latter part of his life, in writing the biographies of others to set forth his own.

It is thus good to find at least one truly contemporary geological biography, written, not in the sternly respectable vein appropriate to our Victorian and Edwardian forebears, but in a much more lighthearted vein appropriate to our present age. It is studded with the sorts of anecdotes which geologists delightedly treasure - anecdotes which, nonetheless, give a perfectly accurate impression of the bizarre range of chance happenings to which the geologist's activities inevitably subject him.

Dr. Youngquist is primarily a palaeontologist, though his commercial work involved a wider concern. He worked first of all at the University of Idaho; then in South America with Standard Oil (New Jersey); and finally he returned to work successively at the Universities of Kansas and Oregon. His biography frequently disappears from sight among the anecdotes and there is little said about the two latter stages of his career: but the concerns he expresses and the problems he encountered are quite typical ones and the whole gives a very true-to-life impression of the activities of a geologist of today. As well as being entertaining reading, this is an excellent historical document!

One small correction; the geologist rebuffed by the postmaster (p.56) was surely Patrick, not Robert, Sutherland ?

William A.S. Sarjeant.

Secretary's Report, February 1968 - August 1968

Introduction

The Society's activities during the first part of 1968 followed the plan now becoming familiar as the Society continues to develop. The outstanding event of the period happened not to the Society but to a member, the then Professor W.D. Evans. It was possible to include in the last issue of the journal an announcement of the gift of a Life Peerage, together with a short appreciation, as a frontispiece. Members will now know that Professor Evans chose the title of Lord Energlyn, of Caerphilly, in the county of Glamorgan.

The Annual General Meeting, 1968

At this meeting, the Trust Deed establishing the Society's Trust Fund was formally approved by members and, later that evening, signed by the Trustees, Professor W.D. Evans, Dr. P.E. Kent and Dr. F.M. Taylor. The establishment of the Trust Fund necessitated a large number of changes to the Constitution. These and others, intended to tidy up the Constitution a little, were agreed to and a copy of the revised Constitution was sent out to all members with Circular No. 48.

Following upon the closure of the business meeting, the President then gave his first Presidential Address on "A description of Productive Coal Measures in the East Midlands". This address was published in the "Mercian Geologist" Vol. 2, No. 4.

The evening was concluded by a tour of the new Department of Geology, University of Nottingham, made at the invitation of Professor Evans, who then generously entertained members to supper at the conclusion of the tour.

The Lecture Programme

The 1967-68 lecture programme was concluded by the talk given by Dr. E.L.G. Bowell, on "The Identification of Lunar Surface Materials"; the Nottingham Astronomical Society were invited to participate in this joint meeting. An audience of 80 heard a profress report on lunar surface exploration.

The Collectors Evening

On the 6th April 1968, a large gathering of members and friends spent a profitable evening examining some 30 exhibits provided by 28 exhibitors. The Secretary apologises for any misrepresentation or omissions in the following list:-

I.C. Starmer	Pegmatite and apatite veins from Norway
S. Henley	Cornish Minerals (2nd collection)
A.J. Rundle & C.H. Rochester	Fossils from Holwell, Leics.
A.J. Rundle	Minerals and rocks from Italy and Morocco. Recent Brachiopods and Molluscs.
A.J. Rundle & W.A. Cummins	Cropston Reservoir fauna.
C.H. Rochester	British Fossils.
R.E. Elliott	Facies in Productive Coal Measures.

R.A. Naylor	British granites.
J.H. Sykes	Rhaetic rocks and fossils.
K. Spink	Canadian geology - Book and pamphlets Commentary with Canadian geological slides.
I. Horne	Selection from his collection.
P. Spencer	Coal Measure fossils.
A.E.G. Allsop	Jurassic fossils.
R.W. Morrell	Fossils and mineral specimens. Geological prints and books.
R.B. Elliott	Rocks from Skye.
N. Leiter	Mineral specimens collected from Ceylon and India.
J.R. Fletcher	British minerals.
C.N. Cooper	Chalk fossil sponges and others.
Miss E.M. Palmer	Shipman's sections and Lincolnshire photographs.
Miss E. Ramsell	Jurassic fossils.
Mrs. D.M. Morrow	Rocks from the Scottish Highlands.
S.R. Elliott	Common and unusual minerals.
H. Fox	Collection of Univalves.
Dept. of Geology University of Nottingham	Ammonoids. Selected mineral specimens.
East Midlands Geological Society	Publications.

The 1968 Excursion Programme commenced with a demonstration of the North Leicestershire and South Derbyshire mineralisation, conducted by Mr. R.J. King and Dr. T.D. Ford. For the first time it was found necessary to hire two coaches, to take over sixty people around the exposures. One of these coaches subsequently broke down on the motorway and had to be replaced, but, as the occupants of this coach hitched a lift on another to the next exposure, not too much time was lost. This excursion, demonstrating the ideas of Messrs. King and Ford on mineralisation in the area, was well received.

In June, the Society visited Nuneaton to see, for the first time, Cambrian rocks. Led by Dr. W.A. Cummins, the excursion illustrated, amongst other things, the variable contact of the Cambrian with the Pre-Cambrian within the space of one quarry.

A joint excursion with the Yorkshire Geological Society was arranged for July. The excursion was originally intended to visit ironstones in the south-east Midlands; unfortunately, the untimely death of Professor J.H. Taylor necessitated a change and the excursion visited the Permian rocks of Yorkshire. The Society is grateful to Mr. D.B. Smith of the Institute of Geological Sciences for leading this excursion.

"The Mercian Geologist" Vol. 2. No. 4.

Printing this number of the journal was unfortunately delayed and it was not possible to issue the journal to members until the beginning of August. The number brought to a close Volume Two, which has turned out to be a little thicker than Volume One. Dr. W.A. Cummins acted as Editor from August 1967 through to October 1968, in the absence of Dr. W.A.S. Sarjeant, who spent the year as Visiting Professor at the University of Oklahoma: Dr. Sarjeant has now resumed his duties as Editor. The editorial board are now looking forward to the appearance of the first part of Volume Three.

Financial Affairs

The Society's audited accounts and balance sheet were presented to members at the Annual General Meeting and also distributed with the circular following the meeting. The Treasurer would like to remind members that prompt payments of subscriptions, due on February 1st., by cheque or bankers order, saves a great deal of work on his part and also the anxiety of council members when the financial position of the Society is discussed from time to time!

Membership

The state of membership on the 30th July 1968 was as follows:-

Ordinary Members	180
Joint Members	54
Junior Members	9
Honorary Members	2
Institutional Members and subscribers	103
TOTAL	348

Conclusions

The executive officers of the Society have been helped increasingly during the year by individual members of the Society. Some of the tasks performed are becoming rather routine and our requests for their services may appear to be a little brusque and our thanks a little too casual. If this is the case, we apologise and extend herewith our grateful thanks to all those who have provided assistance, in whatever way, to the organisation and smooth operation of the Society.

F.M. Taylor

THE MERCIAN GEOLOGIST

Journal of the East Midlands Geological Society

The journal first appeared in December, 1964. The following numbers have since been published:-

Vol. 1	No. 1	December 1964
Vol. 1	No. 2	June 1965
Vol. 1	No. 3	January 1966
Vol. 1	No. 4	September 1966
Vol. 2	No. 1	January 1967
Vol. 2	No. 2	January 1967
Vol. 2	No. 3	December 1967
Vol. 2	No. 4	August 1968

The journal deals especially with the Geology of the Midlands of England, but other articles have been accepted which are of current interest to geology generally. Manuscripts should follow the format of papers included in this number of the Journal and be sent to 'The Editor', Mercian Geologist, at the address below.

In Vol. 1, there are 25 original articles, 5 general papers, 2 Presidential addresses, 10 excursion reports and a number of book reviews. It comprises 383 pages, 24 plates, numerous text figures, an index, title page and cumulative contents page.

Vol. 2 has a similar content, but the second number of this volume was devoted to a 'bibliography of the geology of the Peak District of Derbyshire' compiled by Dr. T.D. Ford and Dr. M.H. Mason. It comprises 450 pages, 25 plates, numerous text figures, an index, title page and cumulative contents page.

All parts of the journal, which is issued bi-annually, are available. It may be obtained by membership of the Society and by subscription as indicated below:-

Ordinary Membership	25/- annually
Institutional Membership	25/- annually
Joint Membership (Husband & Wife)	30/- annually

Single copies are supplied at 15/- (12/6d to members). Multiple copies at 12/6d each. (Vol. 1 is priced at £3 2s. 6d. complete).

Librarians in overseas institutions may care to take advantage of exchange agreements, whereby the Mercian Geologist is exchanged for other original geological journals. This exchange scheme is organised through the Department of Geology, University of Nottingham, England, and not through the Society.

All enquiries for current subscription rates, details of back numbers, and exchanges should be addressed to:-

Dr. F.M. Taylor,
Department of Geology, The University,
Nottingham, NG7 2RD., England

Overseas subscribers may care to use facilities offered by B.H. Blackwell, Broad Street, Oxford, England, or through booksellers and agents in their own country.

CONTENTS