"The facial region of the skull is narrow and elongate. On the outer surface of the maxillary, just above the antorbital foramen, there is a deep depression, which probably contained a gland. The usual ruminant fossa in front of the orbit appears to be wanting. The orbit is large, and completely closed behind by a strong bar of bone.

"The dentition preserved is selenodont and brachyodont, with only three premolars and three molars.¹ The first premolar is much compressed transversely, and has but a slight inner lobe. The second premolar is triangular in outline, the inner lobe being much more developed. The last premolar has this lobe expanded into a strong cusp, and the crown thus becomes broader than long. The true molars have two inner cusps, each with a basal ridge. The outer crescents have a median vertical ridge. The enamel of the molar series is more or less rugose. There was a wide diastema in front of the premolars.

"The posterior nares are situated far forward, the anterior border being opposite to the posterior cusp of the second true molar. The glenoid facet is large and convex, but the postglenoid process is quite small. The paroccipital processes were well developed, but there were apparently no auditory bullæ."

A number of other female skulls, some of them in excellent preservation, have since been obtained from the same region in which the type was found, and a study of these makes clear the main points of their structure. It is not quite certain to which of the three species of *Protoceras* now known some of these skulls should be referred, but further investigation will doubtless determine this point, as the present material in the Yale Museum is apparently sufficient for this purpose.

All the known remains of *Protoceras* are from the Upper Miocene of South Dakota. The horizon, which is a definite one, has been appropriately called by Dr. Wortman the *Protoceras* beds. They appear to be identical with the series in Oregon, which the writer had previously named the *Miohippus* beds, as that genus and several others are common to both regions.

EXPLANATION OF PLATE XIX.

Skull of the male of *Protoceras celer*, Marsh; oblique side view. Three-fourths natural size. Miocene: South Dakota, U.S.A.

II.—WILLIAM SMITH'S MANUSCRIPT MAPS.

By Professor J. W. Judd, C.B., LL.D., F.R.S., F.G.S., etc.

IT is well known to all students of the history of geology that, although the date of publication of William Smith's "Map of the Strata of England and Wales" was the year 1815, yet even before the commencement of the present century the "Father of English Geology" had not only established the principle that strata can be identified by their organic remains, but had actually applied that

¹ More perfect specimens since discovered prove that there were four premolars, the first being absent in the type.

important principle in the construction of a number of geological sections and maps. Conclusive documentary evidence of the truth of this statement is fortunately in the possession of the Geological Society. The way in which these important documents were acquired by the Society is well known to all geologists. When the Wollaston Medal was founded, it was unanimously resolved by the Council of the Geological Society (January 11, 1831)—

"That the first Wollaston Medal be given to Mr. William Smith, in consideration of his being a great original discoverer in English Geology; and especially for his having been the first, in this country, to discover and to teach the identification of strata, and to determine their succession by means of their imbedded fossils."

To the lucid historical statement in which the President of the Society—Professor Adam Sedgwick—explained and justified this award, William Smith replied in "a short and manly speech," which he concluded by presenting to the Society "some documents referred to in the President's address." These documents were as follows:—

1. A table of the Order of Strata, and their imbedded Organic Remains, in the vicinity of Bath; examined and proved prior to 1799.
2. A map of the country five miles round Bath, on the scale of one and a half inches to the mile. "Coloured geologically in 1799, by William Smith."
3. The first draft of a geological map of England and Wales, entitled "General Map of Strata found in England and Wales, by William Smith, surveyor, 1801."

The careful reader of the historical statements drawn up by Fitton,¹ Sedgwick,² and Phillips,³ will be satisfied that other and still earlier documentary evidence, in the form of manuscript sections and maps, once existed, and had been examined by those authors. But it is highly probable that by the year 1831 all such manuscripts, which could be regarded as important pieces of evidence, had been given away or lost by William Smith, with the exception of the three presented by him to the Geological Society. At all events, I fear that the chance of the recovery of any such manuscripts of William Smith, is now a remote one. Twenty-five years ago, the late Mr. W. Stephen Mitchell set himself the task of hunting for relics of the Father of English Geology in Bath and elsewhere. I was at the time in frequent communication with Mr. Mitchell, who was able to take counsel with John Phillips and other contemporaries of William Smith, then living and able to direct him in his inquiries; but I gathered that these investigations were fruitless, and that though

¹ The Edinburgh Review, February, 1818; the London and Edinburgh Philosophical Magazine, vol. i, pp. 147-60, 268-75, 442-50; and vol. ii, pp. 37-57, (1832-3).

² Proceedings of the Geological Society (1831), pp. 270-80.

³ Memoirs of William Smith, Author of "The Map of the Strata of England and Wales," 1844.

many biographical details of interest were collected by Mr. Mitchell, yet that no fresh manuscripts of Smith were found to reward his labours.

This being the case, the three documents in the possession of the Geological Society must be regarded of the very highest importance and of priceless value. They have been mounted on linen and framed, and have never left the custody of the officers of the Geological Society, except in the year 1876, when they were exhibited for some months at the Loan Collection of Scientific Apparatus in the South Kensington Museum.

As it appeared to me that this valuable evidence of the early work of William Smith ought to be made more accessible to the general public, while it is manifestly desirable that the precious originals themselves should never leave the custody of the Society, or be subjected to the smallest risk of loss or injury, I sought some time ago (on behalf of the Department of Science and Art) the permission of the Council of the Geological Society to have facsimile copies made of these important documents, for exhibition in the Science Museum at South Kensington, among the illustrations of British and Foreign Geological Maps.

This permission having been generously granted to me, I have taken the opportunity of making a careful and critical examination of the documents, the age and value of which are substantiated by such eminently satisfactory external and internal evidence.

It is obvious from an inspection of these manuscripts, that they have been many times folded and unfolded, and probably carried in a pocket or pocket-book, and that at the time they were mounted they were in a state of extreme dilapidation. Unfortunately, as is now only too evident, the manuscripts, after being pasted on linen mounts, were covered with a coating of varnish, which was very unevenly applied. This varnish, which has turned perfectly yellow with age, renders it very difficult to get good photographic reproductions of the documents, or to be quite certain, in some cases, as to the nature and distribution of the colours upon them. The removal of the varnish would have been attended with risk to the water-coloured maps; I therefore had to be satisfied with the best reproductions that could be obtained by the skilled photographer of the Department of Science and Art, and these were carefully coloured, after the originals, by Miss Margaret Reeks, under my superintendence. In the choice of colours we were guided to some extent by the later published maps and sections of William Smith, for it is evident that in many of his methods he was very conservative. It is hoped that these facsimiles, though they are not so good as could have been made from manuscripts in a less permanently discoloured condition, show all the important features of the documents as they originally left the hands of their author.

Four sets of these facsimile reproductions have been prepared. One set is exhibited in the rooms devoted to Geology and Mineralogy in the Science Museum at South Kensington; a second set is placed in the Library of the Geological Society; a third goes to the

Geological Department of the Natural History Museum at Cromwell Road, South Kensington; and a fourth to the Library of the British Museum at Bloomsbury.

The origin of the first of the three documents of the series has been admirably told by Phillips in his "Life of Smith" (p. 29).

"One day, after dining together at the house of the Rev. Joseph Townsend" (29, Pulteney Street, Bath), "it was proposed by one of this triumvirate" (Smith, Richardson, and Townsend) "that a tabular view of the main features of the subject, as it had been expounded by Mr. Smith, and verified and enriched by their joint labours, should be drawn up in writing. Richardson held the pen and wrote down, from Smith's dictation, the different strata according to their order of succession in descending order, commencing with the Chalk, and numbered, in continuous series, down to the Coal, below which the strata were not sufficiently determined. To this description of the strata was added, in the proper places, a list of the most remarkable fossils which had been gathered in the several layers of rock. The names of these fossils were principally supplied by Mr. Richardson, and are such as were then, and for a long time afterwards, familiarly employed in many collections near Bath. Of the document thus jointly arranged, each person present took a copy,¹ under no stipulation as to the use which should be made of it, and accordingly it was extensively distributed, and remained for a long period the type and authority for the descriptions and order of superposition of the strata near Bath."

The table in the possession of the Geological Society is in the handwriting of Richardson, but bears the following attestation written by Smith himself:

"This table of the strata, dictated by myself, is in the handwriting of the Rev. Benjamin Richardson, and was first reduced to writing at the house of the Rev. Joseph Townsend, Pulteney Street, Bath, 1799.—Wm. Smith."

"This very curious and important document," as Sedgwick pointed out, "was the first tabular sketch of our formations, drawn up before William Smith had, in conjunction with Mr. Richardson, finally decided upon the names by which they ought to be designated; and the successive groups, from the Coal-measures to the Chalk inclusive, are represented by a series of numbers, accompanied with explanatory notes, but without any proper names affixed to them."²

As full transcripts of this table have been published by both Fitton³ and Phillips,⁴ it will be sufficient here to indicate the several divisions then recognized by Smith with the names by which they were subsequently known.

¹ According to a written statement of William Smith, published by Fitton, a copy of the document was, at the time it was drawn up, given to William James, Esq.

² Proc. Geol. Soc., vol. i (1831), p. 276.

³ Phil. Mag., vol. ii (1833), pp. 46, 47.

⁴ "Life of William Smith," p. 30.

1. Chalk, 300 feet (Chalk, Upper and Lower).
 2. Sand, 70 feet (Firestone, Upper Greensand).
 3. Clay, 30 feet (Gault).
 4. Sand and Stone, 30 feet (Portlandian or Cornbrash?).
 5. Clay, 15 feet (Bradford Clay?).
 6. Forest Marble, 10 feet (Forest Marble).
 7. Freestone, 60 feet (Great or Bath Oolite).
 8. Blue Clay, 6 feet
 9. Yellow Clay, 8 feet
 10. Fuller's Earth, 6 feet
 11. Bastard ditto and sundries
 12. Freestone, 30 feet (Inferior Oolite).
 13. Sand, 30 feet (Midford Sand).
 14. Marle Blue, 40 feet
 15. Lias Blue, 25 feet
 16. Lias White, 15 feet
 17. Marlestone Indigo and Black Marle, 15 feet
 18. Red-ground, 180 feet (Trias).
 19. Milstone
 20. Pennant Stone
 21. Grays
 22. Cliff
 23. Coal
- Fuller's Earth Series.
 Lias.
 Rhætic.
 Carboniferous.

The absence of distinctive names to the strata, with the inadequate thicknesses assigned to some of them, and some minor errors as to the order of succession, afford sufficient evidence, if this were needed, that the document is really of the early date which it bears.

The second document in this series is even more interesting, as it may be justly regarded as the oldest *geological* map in existence, if we distinguish geological from agricultural or soil maps. We cannot do better than tell its history in Smith's own words—

"During my five years' close confinement" (1794–99) "to practical engineering on the Coal Canal, my much-wished-for opportunity of collecting observations enough from the ranges of the different strata to make an accurate delineation of the stratification throughout England were suspended."

But after his connection with the Coal-Canal works had ceased, Smith adds—

"I drew in colours, on a map of the vicinity of Bath and on Day and Masters' County Survey, all very accurately to a certain extent, which embraced an interesting but intricate variety of strata in hills around Bath."¹

The geologically coloured copy of Day and Masters' Map of Somersetshire (on the scale of one inch to a mile) was publicly exhibited and explained by Smith at an annual Agricultural Meeting at Bath in the year 1799. This map unfortunately has been lost, but the Map of the Vicinity of Bath is one of the documents

¹ Phillips' "Life of William Smith," p. 27.

preserved by the Geological Society. It bears the inscription in Smith's handwriting :

"Presented to the Geological Society, Feb. 18th, 1831.

Wm. Smith.

Coloured Geologically in 1799."

The basis of this geological map is of circular form and 15 inches in diameter. It is entitled : "A Map of Five Miles round the City of Bath, on a scale of one inch and a half to a mile, from an Actual Survey, including all the New Roads, with Alterations and Improvements to the present time, 1799." "Printed for and sold by A. Taylor and W. Moyler, Booksellers, Bath."

Although this map includes only a very small area, it presents many features of great interest. In the first place, it shows that William Smith was aware of the importance of representing upon maps the actual limits between the outcrops of different strata. Though no lines are drawn, Smith's well-known method of colouring the base of a formation with a deep tint, and shading this upwards towards the outcrop of the next overlying stratum, enables us to see how carefully he had mapped all the geological lines around Bath. There are only three colours employed on the map and no index ; but it is evident that the yellow tint represents the Bath Oolite, the base of the freestones being very accurately mapped, so that even the smallest outliers can be made out agreeing most closely with the map of the Geological Survey ; a blue tint is drawn at the base of the Lias, and a red one at the base of the Trias, the inliers of Carboniferous being left blank. How far William Smith was in advance of his contemporaries, is shown by a comparison of this map of William Smith, showing carefully indicated lines of outcrop, with the excellent map of the Environs of Paris by Cuvier and Brongniart (1809), in which colour is spread over the areas occupied by the several formations, without any clear and definite indications of the actual limits of the outcrops. The colours used by Smith in this map were the same as those employed by him in the later maps of 1801 and 1815, and thus we have in it the first indication of a scheme of colour now very generally adopted by geologists.

The third and most important of these documents is a copy of Carey's Index to the Map of England, coloured geologically. The map is eleven inches high by nine inches in breadth, and has the manuscript title, "General Map of Strata found in England and Wales, by Wm. Smith, Surveyor, 1801." On the side of the map is written, "Wm. Smith, Milford, near Bath," and at the bottom, "Presented to the Geological Society by Wm. Smith, Feb. 21, 1831," all the inscriptions being in Smith's own handwriting.

Before considering the geological information which is furnished by this map, it will be interesting to recall the opportunities which Smith really had of making himself acquainted with the positions of the outcrops of the English strata. When between 12 and 13 years of age (in 1781), Smith paid a visit to London, and appears

to have been greatly struck by an exposure of the Chalk in a road-cutting at Henley. In 1787, when 18 years of age, he was apprenticed to Edward Webb, and, as he himself says, "was employed in the survey of estates and the inclosure of extensive commons and open fields in the counties of Oxford, Warwick, Worcester, Gloucester, Wilts, Hants, and Somerset, which embraced all the strata, from the red marl at Inkborough and Rugby, near Alcester, to the sand and gravel over chalk at Dibden, between the New Forest and Southampton."

When Smith settled in Somersetshire in 1791, he was familiar with "the surface of the country from London to Bath, and from Warwick to Southampton"; and during his surveys at Stowey and the High Littleton Collieries (1791-2) he not only found fresh evidence of his views about the superposition and continuity of the several strata, but detected the unconformity between the Secondary strata and the underlying Carboniferous rocks. In 1793, while taking levels for the Somersetshire Coal Canal, he "proved the red marl, lias, blue marl, and inferior oolite on the tops of the highest hills to be generally inclined towards the east; and this notion of a general declination appeared to hold through all the varieties of strata in the considerable extent of country before noticed; and other levels down two parallel valleys in the same strata seemed further to confirm the same notion." In 1794 Smith made a post-chaise journey of 900 miles—from Bath to Newcastle-on-Tyne by one route, and back again by another—and was able to satisfy himself that the order of succession which he had made out in the south-west of England could be applied to the whole of the country. During the period that Smith was resident engineer to the Somersetshire Coal Canal (1793-9), he not only worked out the minute details of the order of succession of the Jurassic rocks in the district, but finding difficulty in identifying the several Jurassic strata—owing to the resemblances between the several clays and oolitic limestones on different geological horizons—he was led to the great discovery with which his name will ever be associated. In Smith's own words: "Doubts were at length removed by a more particular attention to the site of the organized fossils, which I had long collected. This discovery of a mode of identifying the strata by the organized fossils respectively imbedded therein—the sharpness of those in their primitive sites, contrasted with the same fossils rounded and water-worn in gravel—led to the most important distinctions, which at once seemed to clear away the rubbish and common stumbling-blocks in geology."

It will thus be seen that at the date when Smith prepared the manuscript geological map of England, he had minutely surveyed the Jurassic strata and Carboniferous rocks of Somersetshire, and gained a wide but much more general knowledge of all the strata, from the Chalk to the Coal-measures inclusive, over an area extending from Warwickshire and the Bristol Channel on the west to London and Southampton on the east. Outside this area, Smith's knowledge of the country was derived from his post-chaise journey

to the north, supplemented by persevering inquiries in every quarter where he could hope to glean information.

The idea of a general geological map of England appears to have been generated in the mind of William Smith upon the occasion of the famous post-chaise journey in 1794; but during his five years' close confinement to practical engineering on the Coal Canal, his much-wished-for opportunities of collecting observations enough from the ranges of the different strata to make an accurate delineation of the stratification throughout England were, as we have already seen, suspended.

The leisure which followed his resignation of the post of Resident Engineer to the Coal Canal was spent by Smith in endeavouring to carry out his great scheme. He says that he "wasted much time in poring over maps, in contriving how the ranging edges and planes of the different strata could best be rendered intelligible; models were thought of, and one small map was cut along the edges of some of the strata with a view of defining their extent, and of showing how one stratum was successively covered by another." He adds that "some small maps of England were spoiled by speculating on the ranges of stratification without sufficient data. The intricacies in their marginal edges were such that I found, to mark point by point, as the facts were ascertained, was the only way in which I could safely proceed."

The result of Smith's speculations as to the best way of representing the outcropping strata upon maps is seen in the method which he finally adopted, and which was first illustrated in the manuscript maps of 1799 and 1801. The *base* of each formation is shown by a band of colour which is shaded upwards towards the next succeeding formation. The colours adopted in the manuscript geological map of England and Wales of 1801 appear to have been very similar to those used in Smith's later engraved maps.

There is nothing in the way of an index of colours attached to this first geological map of England and Wales, but, by reference to the author's later publications, it is not difficult to determine what the several bands of colour are intended to indicate. The formations of which the outcrops are represented range from the Chalk to the Old Red Sandstone, the colours employed being eight in number, though a number of other signs, indicating collieries, mines, and slate-quarries, adds much to the valuable information supplied by this remarkable map.

The strata represented are, in descending order, as follows:—

1. Chalk (*green*).
2. "Sand of the Portland Rock," with which is confounded (as in later maps) the Carstone of Norfolk (*purple*).
3. Oxford Clay ("Church Clay" of Smith) (*grey*).
4. Oolite. The outcrop represented is that of the Great Oolite of the Bath area, and of the Inferior Oolite both south and north of that area (*yellow*).
5. Lias (*dull blue*).
6. Trias and Permian ("Red Marl" of Smith) (*light red*).

7. Carboniferous Limestone, with which is confounded the Mag-
nesian Limestone (*bright blue*).
8. Old Red Sandstone (*reddish-brown*).

The distribution of the Coal-measures is indicated by the crowding together of the crosses representing collieries; the position of the slaty rocks by marks standing for slate-quarries; while a few mines are represented in the North of England, Wales, and Derbyshire, but none in Cornwall!

The east coast of Great Britain has been roughly continued by a manuscript line as far as Forfarshire, the name "Redhead" being written nearly in the position of Arbroath. Collieries are represented near Edinburgh, a colliery and limestone, with the words "Coal 9 yards thick," in the South of Fife, and limestone in Forfarshire. Where the west coast of Scotland would appear we have in Smith's handwriting "Slate, etc., Eysdale Island, Isle of Bute." In the Isle of Man patches of colour indicate the limestones of Castletown and the red sandstones of Peel.

While this first sketch of a geological map is remarkable for the accuracy with which the main outlines of the geological structure of the country are represented, certain omissions and errors are noteworthy as affording the clearest evidence that the map was actually constructed at the date written upon it (1801), and that it had no additions made to it at a later date.

The absence of any colouring for the Tertiary strata of East Anglia and the London and Hampshire Basins, for the Wealden area, and for the Jurassic district of the Eastern Moorlands of Yorkshire, are especially striking in this connection. It can be shown that in the years immediately following 1801, Smith had opportunities, which he utilized with more or less success, in obtaining information concerning these three districts, but no trace of knowledge concerning them appears on the map. Yet of his industry and ingenuity in bringing together every fact which could aid him in the construction of the map of 1801 we have abundant proofs. The Yorkshire Wolds were only seen by him from the top of York Minster and recognized by their contour, yet the range of the Chalk is well represented in Yorkshire and Lincolnshire, as well as in the North and South Downs, and in Dorsetshire and the Isle of Wight. Accurate information was obtained by Smith, as we have seen, concerning Scotland and the Isle of Man, which he had never visited, and it may be added, as further evidence of his painstaking inquiries, that a colliery is represented at Bovey Tracey and another in the Eastern Moorlands of Yorkshire.

Alike, then, from its excellence and its defects, this map appeals to British Geologists as being the first sketch—an imperfect one it is true, but far in advance of any earlier or contemporary work—of that remarkable "Map of the Strata of England and Wales" which was published by William Smith in 1815, and which will ever remain the most striking monument of his genius.