THE LIFE OF HENRY CAVENDISH

1731-1810.

The Life of Henry Cavendish

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While many authors have rightly given prominence to Cavendish's researches they have invariably disregarded material whoch has deserved more recognition. This thesis seeks to overcome this deficiency.

In presenting this account of the Life of Henry Cavendish a chapter is devoted to his ancestry and early life, and another to his years of experiment.

The splendid collection of 10,000 volumes comprising his library is now brought under focus for separate treatment. In a chapter describing the disposition of his private library, a detailed analysis has been included, illustrated by Plates and Tables, of the eighteen subject classes of his catalogue. Especially noted are Cavendish's arrangement of his books, extracts from selected works, descriptions of unusual titles, publications from different periods, and in different languages, autographed copies, and his own special reference marks, with a discussion of the growth of private libraries over the centuries.

Cavendish's Journeys were prompted by a personal interest in geology which he acquired while an undergraduate at Cambridge through his friendship with the Rev. John Michell, a lecturer there at the time.

The complete texts of the journals of these tours, an index of place names, a glossary of scientific terms, and a summary account of the geology of Britain, written by Cavendish, are recorded as appendixes in Part II of this thesis. The Journeys are described in a separate chapter, and the probable routes indicated by a series of Plates.

Chapter V completes the story of the man, his characteristics, his friends, his later years, with tributes to his memory. Inserted in this chapter is a short commentary on the solid geology of England and Wales, as visualized by Cavendish, with maps to illustrate his ideas with the formations known today.

H. Cavendish

THE HONOURABLE HENRY CAVENDISH,

Born 10th October 1731 Died 24th February 1810

(From a Drawing by Alexander in the Print Room of the British Museum)

John Weale

PLATE I

THE PORTRAIT OF HENRY CAVENDISH

Cavendish was never persuaded to sit for his portrait, but a sketch was eventually obtained by William Alexander, an artist, who was invited for the purpose to dine at the Royal Society Club when Cavendish was present. Alexander was placed at a table sufficiently near to him to sketch his style of dress, and then waited for the right moment to complete the picture with a profile of his face. The likeness was immediately recognizable by members of the Society, and the sketch is now in the Department of Prints and Drawings of the British Museum.

The photograph opposite is taken from the frontispiece of Wilson's Life of Cavendish (1851).

THE LIFE

OF

HENRY CAVENDISH

1731-1810

by

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A thesis presented for the degree of
Doctor of Philosophy in the University
of Sheffield, Department of Education,
1971.

CONTENTS

ACKNOWLEDGMENTS

It would have been impossible to attempt a task of this nature without the help, given readily and generously of many individuals.

I should like first of all to thank His Grace, the Duke of Devonshire, and the Trustees of the Chatsworth Settlement for permitting me to quote from the works of Henry Cavendish. To Mr. T. S. Wragg, Librarian and Keeper of Collections at Chatsworth, I am deeply grateful for his willingness at all times to afford me access to books, documents and manuscripts, and I am particularly thankful for photographs and copies of documents he has so kindly provided. I am indebted to Professor W. H. G. Armytage of Sheffield University who originally introduced me to this subject for investigation, and to Mr. G. R. Batho, also of Sheffield University, for stimulating friendship, guidance and patient watchfulness over the years; to my friend Mr. W. F. Gosling of Market Bosworth for his abiding good will in proferring advice; to Mr. J. Hall of the Sheffield University Library for his helpful searches and useful information; to Dr. R. McCormach of the Department of History and Philosophy of Science, University of Pennsylvania, U.S.A., for details of the Royal Society Group, and for presenting me with copies of his own publications on Cavendish; to Mrs. Mary Duffy for her original drawings and key of the Solid Geology of Britain, and 'after Cavendish', with accompanying notes; to Mr. Frank Saunders of the Peak Park

Planning Board for reproducing the Geological Drawings, the Library Analysis, and the key to the figures represented in the Royal Society Group; to Miss S. Ottewell, and Mr. C. Jones, Cartographers of the Department of Geography, of Sheffield University for genealogical tables and the maps of the Journeys; to Mr. R. A. Dudley of Lady Manners School, Bakewell, for his geographical help; to Mmme. A Coatval of Rennes and Professor Crépillon, E.N.P. Caen for their trouble in obtaining useful information for the Dramatis Personae; to Mr. T. R. Harris of Camborne, Cornwall, as also the Camborne School of Metalliferous Mining for information; to Miss D. Greene, for kind permission to quote from her work, 'The Glass Works', Rotherham, (1751-1783); to Mr. P. B. Littlewood, Assistant Director of Libraries Museum and Arts, Rotherham, for confirming various place-names; to the County Records Office, Gloucester, also for locating place-names; to the Chief Librarian, Merthyr Tydfil; the Librarian of the Sheffied University Library; to the City Librarian, Birmingham Public Libraries; to the London Library; to the County Librarian, Newport, Mon.; to the Librarian, University of London; to Mr. J. P. Heathcote, of Birchover, Derbyshire; to Mr. D. Mather of Bakewell for photographs; to the Clerk of the Borough of Banbury; to the Rev. P. F. Johnson of St. Mary's Parish Church, Banbury; to Mr. P. W. Hett, Mining Records Officer, National Coal Board, Eastwood, Nottingham; to the Mayor of Calais; to the University of Lille; to my typist Mrs. Margeret Hill whose careful and conscientious work has considerably eased the strain of production; and lastly to my wife and son who, without demur, have accepted long absences from their company.

LIST OF BRIEF REFERENCES

ARMYTAGE	W. H. G. Armytage, *A Social History of Engineering*, (1961).
AYKROYD	W. R. Aykroyd, *Three Philosophers*, (1935).
BERRY	A. J. Berry, *Henry Cavendish*, (1960).
BICKLEY	G. Bickley, *The Cavendish Family*, (1911).
BORLASE	W. Borlase, *Natural History of Cornwall*, (1758).
BRADLEY	E. T. Bradley, *Life of the Lady Arabella Stuart*, (1889, 2 Vols.).
BRADNEY	J. A. Bradney, *History of Monmouthshire, Hundred of Trelech*, Vol. 2, Part 2, (1904-1933).
DICKINSON	H. W. Dickinson and R. Jenkins, *James Watt and the Steam-Engine*, (1927).
D.N.B.	*Dictionary of National Biography* ed. Sidney Lee (1885-1900, 63 Vols.).
ENTWISTLE	J. Entwistle, *Memoir by His Son: Fifty Four Years a Wesleyan Minister*, (9th Edition, 1867).
FITZPATRICK	T. C. Fitzpatrick, A. Schuster, *et. al.*, *A History of the Cavendish Laboratory, (1871-1910)*, (1910).
FRANCIS	W. Francis, *Gwennap, A descriptive poem in Seven Cantos*, (1845).
GREEN	J. R. Green, *A Short History of the English People*,(1874) Rev. and Enl. 1919.
GREENE	D. Greene, *The Glass-Works, Rotherham (1751-1951)*,(1952).

HANDOVER	P. M. Handover, Arbella Stuart, (1957).
HARRIS	T. R. Harris, 'John Edwards (1731-1807), Cornish Industrialist', Transactions of the Newcomen Society, Vol. XXIII, (1942-1943), (1948).
H.C.C.	The Henry Cavendish Catalogue, Chatsworth MSS.
IRWIN, Heritage	R. Irwin, The Heritage of the English Library, (1964).
IRWIN, Origins	R. Irwin, The Origins of the English Library, (1958).
JOHN	A. H. John, The Industrial Development of South Wales 1750-1850, (1950).
LARSEN	E. Larsen, The Cavendish Laboratory, (1962).
LEICESTER and KLICKSTEIN	H. M. Leicester and H. S. Klickstein, A source Book in Chemistry, 1400-1900, (1952).
MANTOUX	P. Mantoux, Industrial Revolution in the Eighteenth Century, (1961).
McCORMACH (J.M. and H.C.)	R. McCormach, 'John Michell and Henry Cavendish: Weighing the Stars', The British Journal for the History of Science, Vol. 4, No. 14, (1968), pp.126-155.
McCORMACH (H.C.)	R. McCormach, 'Henry Cavendish: A Study of Rational Empiricism in Eighteenth Century Natural Philosophy', Isis, Vol. 60, Part 3, No. 203 (1969), pp.293-306.
MINCHINTON	W. E. Minchinton, The British Tinplate Industry, (1957).
NAMIER	L. B. Namier, 'Anthony Bacon, M.P. An Eighteenth Century Merchant', Journal of Economic and Business History II (1929), in W. E. Minchinton, ed. Industrial South Wales (1750-1914), (1969).

S.L.A.	R. Irwin, Supplementary Notes to 'The Origins of English Library', (1959), University of London. School of Librarianship and Archives. Occasional Publications No. 9.
Sci. Pap. Vol.I.	The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. I, The Electrical Researches, ed. James Clerk Maxwell, rev. Joseph Larmor. (1921).
Sci. Pap. Vol.II.	The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. II, Chemical and Dynamical, ed. Edward Thorpe. (1921).
S.T.C.	Short Title Catalogue, ed. Pollard and Redgrave, (1926).
SMILES	S. Smiles, Lives of the Engineers Boulton and Watt (1904)
TAYLOR	A. J. P. Taylor, R. R. James, et. al., Churchill, Four Faces and the Man, (1969).
THOMPSON	F. Thompson, A History of Chatsworth, (1949).
WELD	C. R. Weld, A History of the Royal Society, (1848, 2 Vols.)
WILKINS	C. Wilkins, A History of the Iron, Steel, Tinplate and Other Trades of Wales, (1903)
WILLIAMS	E. C. Williams, Bess of Hardwick, (1959).
WILSON	G. Wilson, The Life of the Hon.ble Henry Cavendish, (1851).
YOUNG	T. Young, 'Life of Cavendish', (From the Supplement to the Encyclopaedia Britannica 1816-1824). Reprinted as an appendix to The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. I. (1921), pp.435-447.
'M'	Letter, dated, Thornhill, 14th August 1788, from the Rev. J. Michell to Henry Cavendish. Chatsworth MS. X(b)15.

'C' Letter, undated, but probably late August 1788, which appears to be Cavendish's reply to Michell's letter, 14th August 1788. Chatsworth MS.

'S' A Geological Summary account of the upper strata formations in Britain, in Cavendish's hand-writing [Chatsworth MS. contained in parcel marked 'Journeys'.]

These three documents are recorded in Appendix I.

LIST OF PLATES

LIST OF TABLES

CHAPTER I

ANCESTRY AND EARLY YEARS

We have grown accustomed to the idea that great men in any age, and no less our own, have sprung from humble stock; not so Henry Cavendish, who came of a distinguished family of noble lineage, yet no one could have been more indifferent than he was to the external advantages of rank and fortune.(1)

Genealogists have traced the ancestry of the Cavendishes to a Norman family which settled in England at the time of the Conquest, but Sir John Cavendish, Lord Chief Justice of the King's Bench in the reign of Edward III, was the first bearer of the name, and from his day to the present the chain of descent is unbroken. Sir William Cavendish (1505-1557), however, was the true founder of the political greatness and prestige which have distinguished the Cavendishes in modern times.

Henry Cavendish, the great and justly celebrated chemist, natural philosopher, and astronomer, belonged to this family.

His rank among the benefactors of science and of mankind, is so elevated, that we are anxious to learn all the details, both of intellectual cultivation and moral character, that the labours of

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1. F. Bickley, The Cavendish Family (1911), p.1.

a biographer can discover and record. While numerous biographical sketches have been written since Wilson's, Life of Cavendish, his treatise still remains outstanding.

Wilson has this to say about the eminent philosopher: 'No other European nation has so imperfect a series of biographies of her philosophers as Britain possesses, and it is little creditable to us that we have often to turn, as in the case of Cavendish, to the Memoirs of a foreign society, for the best record of the personal history of even our most famous students of physics.'(1)

Although Cavendish was for fifty years a well-known and distinguished Fellow of the Royal Society, a member of the French Institute for a considerable period, and was the focus of interest to scientists throughout Europe, yet little can be learned about his early history. Had he been a poor man of obscure birth, this paucity of detail might not have surprised us, but he came of one of the oldest families in England, and he was closely related to other old families. Both his grand-fathers were Dukes: William, Second Duke of Devonshire, and Henry Grey, Duke of Kent; he was a nephew of the third Duke of Devonshire, and a cousin of the fourth Duke. He was related by birth or marriage to most of the English aristocratic families.

Is it possible that he would have reached such distinction without the advantages his lineage gave him? Few other noble families have indeed given to their country as many great women, compatriots,

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1. G. Wilson, The Life of the Hon. Henry Cavendish (1851), p.15.

statesmen, scientists, and men of letters.

Sir William Cavendish, the founder of the illustrious house, was a man of talent and real capacity, and soon attracted the attention of Henry VIII. He was invested with high office, knighted in 1546, and given grants of land in various parts of England, and his immediate family rose rapidly to high distinction. To understand this, reference must be made to that remarkable woman, Elizabeth Hardwick, who became his wife, and was more than an equal partner in establishing the fortunes of the family.

She was a younger daughter of a country gentleman in Derbyshire, and at an early age went through the formality of marriage with Robert Barlow, the son of a Derbyshire neighbour. He was a sickly child of fourteen, who did not live long, dying early in 1533. For fourteen years Elizabeth Barlow remained a widow until her marriage with Sir William, who was fifteen years her senior. He had been married twice before, and had had eight children, two of whom survived, but this in no way detracted from his eligibility in the eyes of 'Bess of Hardwick'.

The union was to bring substantial rewards, for by 1547 Sir William had sold his scattered property in England, and purchased lands in Nottinghamshire and Derbyshire, evidently in preparation for his third marriage with one whose heart was given to Derbyshire.(1) The marriage took place in 1547, and was as happy as it proved to be fruitful,

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1. E. Carleton Williams, Bess of Hardwick (1959), p.12.

for three sons and three daughters survived him to establish the greatness of the family.

Sir William died in October 1557, and Lady Cavendish was soon to become the wife of Sir William St. Loe, Captain of the Guard to Queen Elizabeth, who was possessed of large estates. He was a widower with a family, yet with her constant thirst for acquisition, 'Bess' induced him to settle all his property upon her and her heirs, to the exclusion of all his former children, and at his death in 1565 the entire estate went to enlarge the prospective possessions of the young Cavendishes.

A long and eventful life lay before her, and for her fourth, and last husband, she was to bring under her spell one of the greatest men in England, and on such terms as must have surpassed even her own quenchless optimism.

George Talbot, Sixth Earl of Shrewsbury, was in 1568 the most powerful nobleman of the realm, and his wife shared with him, if not equally, the responsible office of warden of the unfortunate Mary, Queen of Scots.

The noble Earl had children by a former marriage, but Lady St. Loe would not consent to marry him until he had arranged to give two of his children in marriage to two of hers. She had no family by any husband save Cavendish; hence all the wealth and influence of her four marriages converged for the benefit and advancement of the children of Sir William.(1)

1. See Table I. The Cavendishes of the Sixteenth and Seventeenth Centuries.

Whatever the Countess of Shrewsbury's faults were, she was zealous in promoting the interests of her children, and not more zealous than successful. For one son, Charles, was knighted, another, William, was made a Baron and later created an Earl, two daughters, Elizabeth and Mary, became Countesses, and a grandson, William, was made Duke of Newcastle, and a grand-daughter, Lady Arabella Stuart, first cousin of James I, was at one time a close contender for succession to the throne of England. Another Dukedom was added to the family in a later generation; William Cavendish, fourth Earl of Devonshire, was created first Duke of Devonshire, May 1694; and their fortunes have continued to prosper ever since, a consummation unusual for the times, and for which the Cavendishes were mainly indebted, at least in the first generation, to their mother.

Lady Shrewsbury now in the autumn of her life (1584-90) at sixth-seven, was not only weary of her charge, but the Shrewsburys had become nervous wrecks, and their marriage had foundered. There had been an easing of tension at the first sign that the Earl was to be relieved of the custody of the royal prisoner, but it was not till the execution of the Queen of Scots (1587) that the Countess was conscious of any apparent relief. Further, in 1590, the sixth Earl died, and there was no disguising the fact that this meant further relief for the aging Dowager.(1) It brought Arabella nearer to the throne; but she was also growing up, and thereby proving difficult.

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1. Williams, pp. 168, 188.

Evon so, she had been invited to court by the Queen, who had showered favours upon her, and to Lady Shrewsbury it seemed as if victory had been already won.(1) But as the years wore on the struggle with Arabella had undermined the Dowager's strength. Moreover Arabella had ceased to be 'persona grata' with the Queen.(2)

About this time Her Majesty was known to be gravely ill, and of course the country was buzzing with rumours about a successor.(3) In her last moments, when pressed by Cecil to make known her wishes, her old spirit fired up, and though she was unable to speak, she clearly indicated James as her successor, the 24th of March, 1603.(4)

Thus the whole fabric, of what to Bess of Hardwick had now become her life's ambition, crashed in ruins. To Arabella, the death of Queen Elizabeth meant freedom.

The new King and Queen from the first were kindly disposed to 'Cousin Arbelle', and periodically news reached the Dowager at Hardwick, of her grand-daughter's triumphal progress at Court. In spite of her four score years the Countess delighted to have her relations round, but of all her children William was the only one who brought any ray of comfort to his mother in her old age, and she looked to him to carry on his name, enhanced by further honours. Her dearest wish was to see William the founder of a titled family in Derbyshire, whose

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1. E. T. Bradley, Life of the Lady Arabella Stuart (1889), Vol. I, pp.62-65.

2. Bickley, p.29.

3. Williams, p.250.

4. Bradley, I, p.160.

THE CAVENDISHES OF THE SIXTEENTH AND SEVENTEENTH CENTURIES

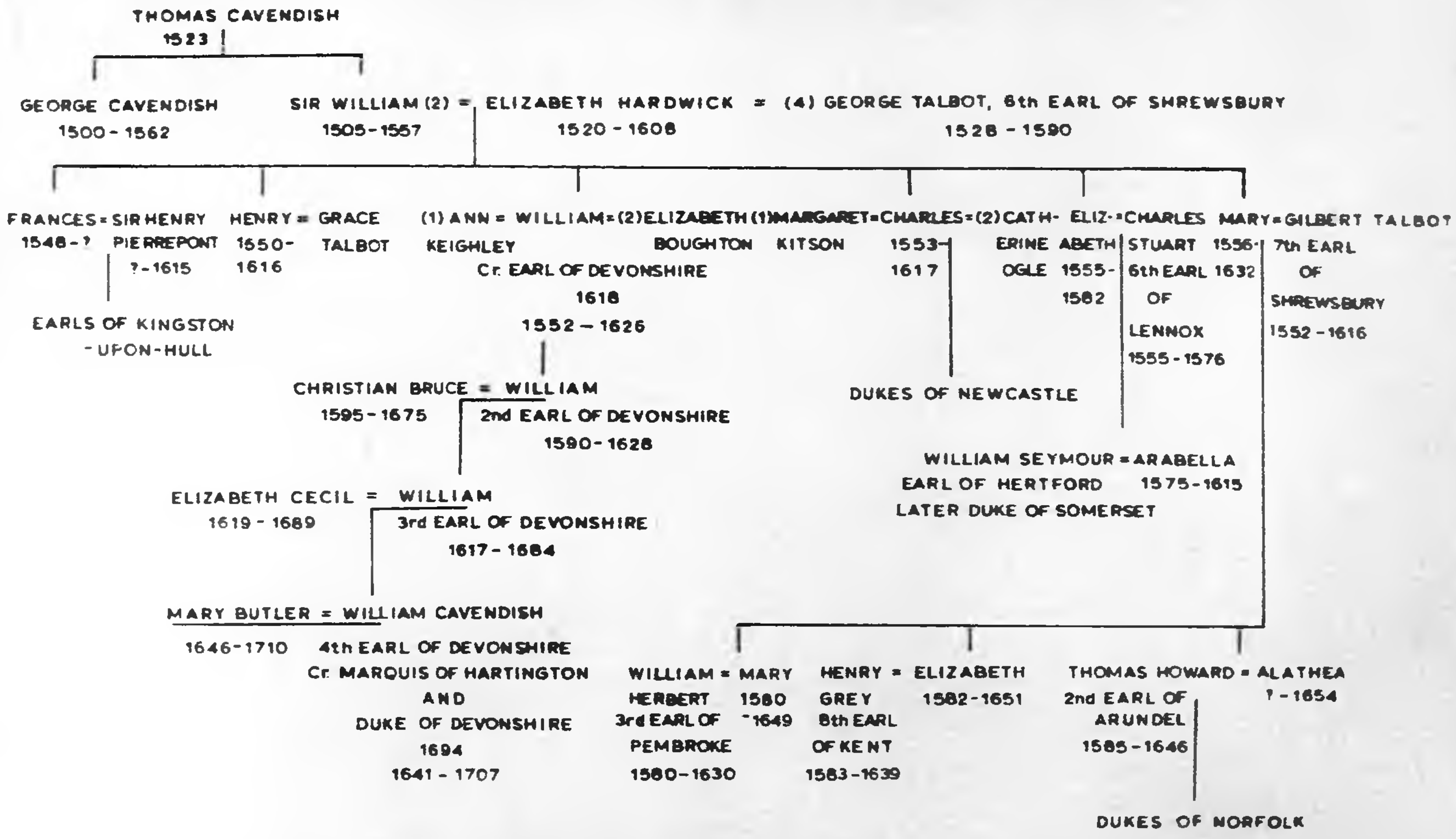

TABLE I

THE CAVENDISHES OF THE SIXTEENTH AND SEVENTEENTH CENTURIES prestige and possessions should outstrip those of the Talbots.

To achieve this ambition the Dowager enlisted the help of her grand child who was enjoying great favour at Court to seek a suitable opportunity to dispense what influence she had left on behalf of her uncle.[1]

Arabella had done much to help the Shrewsburys, by no means a pleasant family to belong to, and for the moment her trust in them was a little shaken. The Dowager too was upset, so she added a codicil to her will, 1601, revoking previous bequests as 'Arabella was no longer my verie loving grandchild'.[2]

William, who was not her favourite uncle, must have been aware of the difficulty attending Arabella's mission, but at last in April, 1605, her efforts to procure a barony for him were successful and he was created Baron Cavendish of Hardwick. Further advancement awaited him, for on the 7th of August, 1618, at the Bishop's Palace, Salisbury, he was made Earl of Devonshire, while attending the King on a tour of Wiltshire.[3]

It is plain therefore, that the immense wealth and influence secured for the descendants of 'Bess of Hardwick', were largely acquired as a result of her activities, and the slight digression into the indispensable rôle of Arabella, an essential instrument in her scheme, is justified to explain her part in the final act of her grandmother, - the establishment of the famous House of Devonshire. Furthermore,

1. Williams, pp.258-260.
2. Will of Elizabeth Hardwick, Countess of Shrewsbury, 1601, Chatsworth MSS.
3. Bickley, p.39.

it was her son Charles, who fathered the Dukes of Newcastle, and her daughter Frances, who mothered the Earls of Kingston-upon-Hull. She had seen her daughter, Mary, become Countess of Shrewsbury, and from her were descended the Dukes of Norfolk, the noblest family of the Kingdom.[1]

Perhaps it should be added that Henry Cavendish, 'Bess of Hardwick's' first-born son, the most gifted of her chilren, yet the most bitterly disliked because of his political intrigues,[2] was rightfully lord of the manor of Chatsworth, but she set aside the claims of primogeniture, in favour of her second son William.[3]

Thus, William is the progenitor of the Earls and Dukes of Devonshire, and of Henry Cavendish, the central figure of this thesis.

More than one hundred years were to elapse before the birth of the great philosopher - Henry Cavendish - during which time his ancestors continued to be prominent in the affairs of the country, and to add distinction to the already established fame of their own House.

Certain members of the family who flourished in the course of these hundred years were so influential, and distinguished that they cannot be overlooked.

The first Earl died in 1625, and his son the second Earl of Devonshire was a man of talent and many accomplishments, who will be remembered in connection with Thomas Hobbes, his tutor.[4] His successor

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1. P. M. Handover, Arbella Stuart (1957), p.233.

2. Williams, p.242.

3. Codicil, Will of Elizabeth Hardwick, Countess of Shrewsbury, (1601), Chatsworth MSS.

4. Bickley, p.41.

the third Earl bore the title for fifty years, and his death in 1654 marked the end of an epoch in the history of the Cavendishes.(1)

It was the fourth Earl who was the most powerful and prominent of the period. He was to oppose the dynasty to which his ancestors had been so faithful, and was to become the first exponent of those Whig principles which were henceforth to be the most salient family characteristic.

He passed his early years under the tutelage of his grandmother, the wise Countess Christian, but he was a born fighter, and his whole course was directed to preventing the succession of a Catholic King, and looked to William, Prince of Orange, as the future sovereign. His friend, Lord Russell, espoused the cause of Monmouth, which led to his ruin and execution, a catastrophe which moved Cavendish to tears. Ever devoted to his friend's memory, he married his eldest son to Russell's daughter Rachel, the grandmother of Henry Cavendish.

It was not long before the new King began to give substantial proof of his gratitude to the man who had worked so hard on his behalf. He was invested with various honours and positions of note, and on the 12th of May, 1694, the fourth Earl of Devonshire was advanced in the Peerage as Marquess of Hartington and first Duke of Devonshire.

The Duke was as high in Anne's favour as he had been in William's, but age and infirmity were telling on him, and on the 18th of April, 1707, he died. Although his pursuits were mainly political, Devonshire was far from negligent of the graces of social life. He was a Fellow of

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1. Bickley, p.64.

the Royal Society; well-read in the classics; of Horace he made a special study; and he told a friend that he drew the inspiration of his political life from the pages of Tacitus. Of his taste in architecture and painting he gave practical proof in the new Chatsworth; he was an amateur of music; and Lord Roscommon thought so highly of his critical powers that he used to send him his poems for revision. His own ventures in verse were few. Dryden thought his ode on the death of Queen Mary the finest written on that occasion, but neither that nor his Charms of Liberty have established a claim to immortality.

In person Devonshire was tall and strikingly handsome. He had great charm of manner, and, says Dryden, he never 'forgot the distinction between the profane wit and the gentleman'. Horace Walpole calls him 'a patriot among the men, a gallant among the ladies,' and it is true that he was not more virtuous than was the fashion of his age.

Devonshire was both generous and extravagant, giving largely to Greenwich Hospital and keeping a splendid table; a lover of sport, frequenting Newmarket for the racing and the cock-fighting; prone to take offence, ready with his sword as with his tongue, plaintiff or defendant in many law suits.[1]

After the first Duke's death politics monopolized the attention of the Cavendishes for the remainder of the century; in fact distinction was not to be encouraged in other fields, and those who showed themselves inclined to stray were regarded as shirkers of their duties towards their kin.

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1. Bickley, pp.178-181.

THE CAVENDISHES OF THE EIGHTEENTH CENTURY

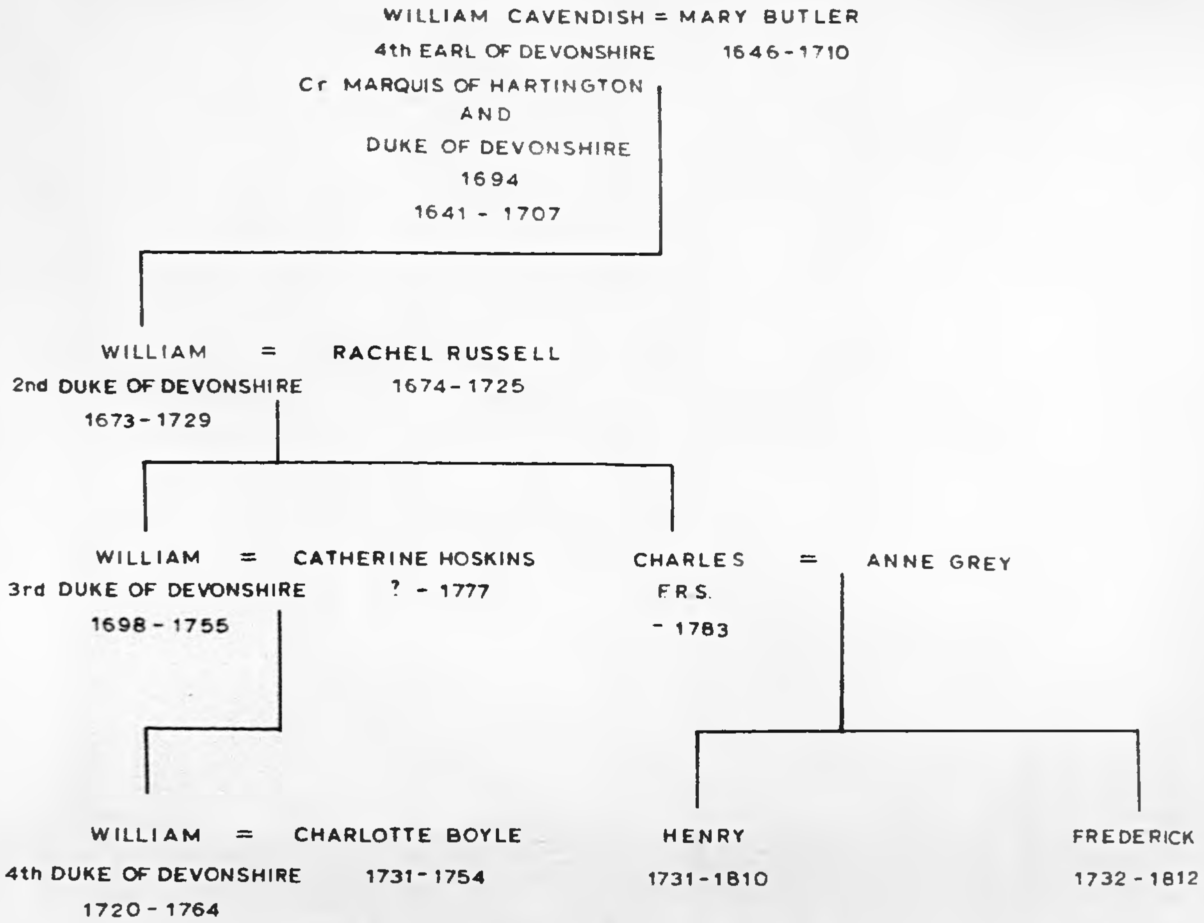

TABLE II

THE CAVENDISHES OF THE EIGHTEENTH CENTURY

Henry Cavendish at an early period in his life must have been conscious of this family tradition. It has been stated that the family were disappointed that Cavendish should have declined to enter public life, and that his father treated him with niggardliness in consequence. There is no real evidence to support this supposition, which would seem to rest mainly on the doubtful authority of Lord Brougham.[1] Cavendish with his nervous embarrassed manner, his extraordinary shyness, his thin shrill voice and hesitation of speech, was singularly unfitted for a public career, and it is unlikely he was ever pressed to embark upon it.[2] Certainly some members of the family looked on his conduct with an unfavourable eye. The fifth Duke of Devonshire, for instance, forbade his beautiful Georgiana to visit his kinsman's laboratory with the remark 'He is not a gentleman - he works'.[3]

Without producing one member of the family who could rank with the great statesmen of the age, the combined force of these able, and influential men, united by ties of blood, no less than by faith to a tradition, could not but leave its mark. This is particularly emphasized by the characteristic qualities of the third Duke.

Unlike his predecessors he was an university man, and after leaving Oxford he entered Parliament; but he will be remembered best as Governor of Ireland, whose temperament was so in tune with the Irish that the impression he made on his arrival stood the test of time

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1. Wilson, p.161.

2. The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. II, Chemical and Dynamical, ed. Edward Thorpe (1921), p.3.

3. Bickley, p.202.

even after he had left. Further, his excellence was noticed by Samuel Johnson, who said, 'he was a man strictly faithful to his word'. Waldegrave called him, 'a man of strict honour, true courage, and unaffected affability ... sincere, humane, and generous, who had sense, learning and modesty, with solid rather than showy parts'.(1)

Henry Cavendish, the scientist, the third Duke's nephew, displayed the same good qualities, and he could even awaken an affection in those who knew him best, and in their eyes he was blameless, commanding too, their deep respect.(2)

The third Duke died in 1755, when Cavendish was only twenty-four years old, and it is probable that the young scientist would meet his benevolent uncle, during those early and formative years. His father, Lord Charles Cavendish, a younger brother of the third Duke, was also living at the time, and it is known that the relationship between father and son was close. Perhaps all three met together from time to time.

A question, therefore, arises: could Cavendish have inherited any qualities, or was he influenced by any characteristics which were peculiar to the family? Many of its members have pursued literature and the arts, not a few have been actively interested in the sciences, but they, after all, have left no mark on the history of thought, or of scientific philosophy. Henry Cavendish stands altogether in a class apart.

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1. Bickley, pp.194-195.
2. Wilson, p.176.

Henry Cavendish was born on the 10th of October, 1731, at Nice, where his mother, Lady Anne Grey, fourth daughter of Henry, Duke of Kent, had gone, though ineffectually, for the recovery of her health. She returned to England, where her second son Frederick was born, and died when Henry was only two years old.

His father, Lord Charles Cavendish, was a younger son of the second Duke. He was devoted to science, but not so exclusively as to prevent him becoming a Member of Parliament and a gentleman of the Bedchamber to Frederick, Prince of Wales.

Little is known of Henry's earliest years, but in 1742 he became a pupil at Dr. Newcome's school at Hackney, reputedly a well-managed school, and attended by children of the upper classes. According to Wilson it was, 'a most excellent school', and the master, 'a sound classical scholar and a strict disciplinarian'.[1] Cavendish remained there 'till 1749, but we have no knowledge of his studies, nor of his progress. Then he went on to Peterhouse, Cambridge, matriculating, the 18th of December, 1749. In the College admission book he is described as Natu Maximus, and styled as 'Hon', which would be quite incorrect according to present day usage.[2] He left, the 23rd of February, 1753, without taking a degree, but for what reason we do not know.

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1. Wilson, p.16, f.n.

2. A. J. Berry, Henry Cavendish, p.12, f.n.
It may be of interest to add that a few of his earlier papers in the Philosophical Transactions are entitled as 'By the Hon. Henry Cavendish', but the later ones are designated as 'By Henry Cavendish Esq.'.

It is hardly credible that he feared the examination, so there must have been some particular explanation for his neglecting to follow the usual academic procedure. Perhaps he may have objected to some of the tests, which were then very stringent. No religious tests, however, were required for matriculating, but before proceeding to a degree each candidate was required to declare himself a member of the Church of England. It has been surmised that Cavendish had scruples on this subject, for throughout his life he never identified himself with the Church of England, or any religious body for that matter, and never attended a place of worship.

Two more of the Cavendish family were studying at Peterhouse for part of the time with Henry Cavendish, namely his younger brother Frederick, who entered the College two years after Henry, and also left without taking a degree, and his cousin Lord John Cavendish, fourth son of the third Duke of Devonshire, who, however, took his Master of Arts degree in 1753. All three were educated at Dr. Newcome's school. Frederick's failure to graduate can be fully understood because he had the misfortune to fall from an upper window of his college and land on his head in the court below. For some time his life was in danger, and even though he eventually recovered, the accident permanently affected his behaviour, and made it impossible for him to take any part in public life.(1)

After leaving Cambridge, so the story goes, Henry and his brother, Frederick, toured the continent but there is no record of the places

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1. Bickley, p.198.

they visited, nor are there any particulars of the journey beyond an account of the gruesome experience of their having seen a body in their hotel at Calais, laid out for burial, in a room adjoining that which they occupied, a sensation which greatly alarmed the elder brother.

The brothers seldom met, but the following extract from a letter, written by Frederick Cavendish to his brother, shows a joint interest in its subject matter, and a mutual regard in their personal relations.

"Market St,
Wed. March 1st, 1780.

Dear Brother,

As I know you observe the Aurora Borealis with much attention, I send you an account of one which appeared last night, and which in some respects was the most remarkable I have known. It had the most perfect corona I ever beheld, with radii streaming down on all sides, and overspreading the whole hemisphere ... Give my duty to my Father,

I hope you are both in good health,

I am,

Your affectionate
Brother,

Frederick Cavendish".[1]

When Cavendish left the university, he took up residence in his father's house in Great Marlborough Street in London, and continued to live there for the next thirty years till his father's death in 1783.

Lord Charles Cavendish was a gifted physicist, and devoted to

1. Chatsworth MSS. X(b)9.

scientific pursuits, and Henry began his own experimental work by assisting his father who had been elected to the Royal Society in 1727. He paid considerable attention to thermometry, and in 1757, when a Vice-President, contributed to the Philosophical Transactions descriptions of two forms of maximum and minimum thermometers, for which he received the Copley Medal.(1)

Father and son worked together using the same instruments, but for some reason or other, Lord Charles did not entirely approve his son's devotion to science, and restricted him in the means of pursuing his work. In what way it is uncertain, because Lord Charles Cavendish appreciated his son's genius and outstanding gifts, and according to good authority never treated him harshly, or unkindly, for Henry's scientific tastes were so congenial to his own.(2)

His father, who was not a wealthy nobleman, provided for him as generously as he could, granting Henry an annual allowance, which has been stated as varying from £120 to £500. Cavendish dined regularly at the Society Club, his father rationing him to five shillings for his meal, and not a penny more.(3) This may well have proved embarrassing for the young scientist, and could offer some explanation for his shyness in those early and impressionable years when he was supposed to be relatively poor.

It seems certain that he was accustomed in early manhood to very

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1. C. R. Weld, History of the Royal Society (1848, 2 vols), Vol. II, p.9.
2. Wilson, p.161.
3. Wilson, p.160.

frugal fare, but when he had turned forty years of age, he became fabulously rich, 'beyond the dreams of avarice'. No true account, however, is available to reveal from which relatives he acquired his fortune. There is a story of a military uncle, who disapproved of the contemptuous attitude adopted towards Henry by his relatives and was supposed to be the person who had bequeathed to him a legacy of £300,000.(1)

It is thus plain from its records, that Cavendish belonged to a family long rich in a tradition of political and public life, in which its members were always expected to take a leading part. That he never did so, nor even showed the slightest interest in public affairs has caused him to be regarded as a conspicuously weak link in the Cavendish chain.

Whether riches would have smoothed his pathway to fame, or whether the alleged insults of his family embittered his attitude to mankind, will ever remain a mystery. He himself never gave any indication of being affected by either of these. As for riches he was indifferent as a result, no doubt, of his early straightened circumstances, while throughout his life he was quite uninterested in his ducal relations, and singularly unconcerned in the glories of his family history.(2)

How regrettable to find that so outstanding a person as Cavendish did not conform in tastes and pleasures to the generality of mankind. But then, Cavendish was no ordinary mortal, and ordinary conventions

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1. Wilson, p.160.

2. W. R. Aykroyd, Three Philosophers (1935), p.71.

and rules of conduct were inapplicable to him. Thus it is difficult to escape from the conclusion that the peculiarities of his character belong more to the way he was made than to any external influences.

Yet, however much one may presume to assign to outward circumstances the development of a character so well defined as his, more stress should be laid on the early loss of his mother, whose affectionate kindness Frederick often lamented he never knew.(1) It was an irreparable loss, yet how strange a coincidence that three great philosophers Priestley, Cavendish and Lavoisier, became motherless while still young, but that whereas Priestley and Lavoisier were carefully reared by aunts, no such maternal substitute, from among his distinguished relations was found for Henry Cavendish.(2) From his eleventh to his twenty-second year, the most receptive time of life, he was at school and college, and so denied the wholesome benefits of a happy home background.

On the contrary, of course, it is known that countless youths have been poor and motherless, as Cavendish was, yet have grown to be warm hearted, generous, and even passionate men. Frederick Cavendish was exposed to the same influences as his brother Henry, but became notwithstanding, an exceedingly cheerful, genial, and benevolent, though somewhat eccentric character.

There can be no blue print for an ideal upbringing because individuals do not all respond alike to the same treatment. To account, therefore, for Cavendish's peculiarities by searching for causes connected

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(1) Wilson, p.172.

(2) Aykroyd, p.71.

with his early environment, is to venture into the deep and treacherous waters of psycho-analytic theory. Such a method was adopted by Anthony Storr, a psychiatrist, in portraying a character study of Sir Winston Churchill, whom he had never met.(1)

The remarkable resemblance in their peculiarities of these two men, Cavendish and Churchill, both as children and as men affords a striking parallel in fundamental characteristics, born though they were in different eras, one hundred and fifty years apart.

It is recognized that the psychological disturbances which people suffer are related to the emotional climate in which they are reared, and that neurosis and psychoses in adult life are attributed to a failure of environment in early life to meet the needs which are pressing to the child, a failure which later on results in a sense of something missing or longed for.(2)

Cavendish was deprived of all feminine influence, and so, throughout his life was shy and afraid of women. Yet, with men he inspired devotion in those who served him. How can this be explained?

It is often true to say that men who demand, and need, a great deal of attention from others are manifesting a kind of childlike helplessness, which evokes an appropriate response, however difficult it may be. Cavendish received such attention from his servants, and enjoyed unusual respect from his friends, like Michell, Blagden, Maskelyne Dalrymple, and even his brother Frederick.

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(1) A. J. P. Taylor, R. R. James, _et. al._, _Churchill, Four Faces and the Man_ (1969), p.217.

(2) Taylor, p.227.

Dr. Storr points out that neglect in early life can deprive a person of an inner source of self-esteem to enable him to cope with human reverses and disappointments. This trait of character was noticeable in Churchill which released a kind of ambition, tinged with an element of phantasy, and it is possible that England owed her survival in 1940 to this inner world of make believe, in which Winston found reality.[1]

To Cavendish ambition outside his world of science meant nothing. He cared little for the opinions of others, and was indifferent to their affairs. Such imperviousness to atmosphere applied equally to both men, and many tales can be told of their insensibility to people on social occasions.

Churchill retained the narcissistic attitude in adult life, and as he said of himself quite accurately, 'I have devoted more time to self-expression, than to self-discipline'. Had he been less egocentric he would not have achieved so much; had he been more self-disciplined he would have been less inspiring.[2] How equally true of Cavendish!

Cavendish's accounts of his investigations and discoveries are known masterpieces of sagacity and reasoning, and to posterity belong the works of research which have won for him a fame which his rank and connections would never have enabled him to attain without them. He would have been nothing more than a non-entity, and forgotten.

Can the knowledge of belonging to a privileged class offer some

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(1) Taylor, pp.224-225.

(2) Taylor, pp.242-243.

mitigation in later life for the feelings of early rejection?

Both men were members of families of particular distinction within that privileged class, and the fact that Churchill was an aristocrat must have been of considerable service to him. To Cavendish, his ducal relations meant nothing, and there is no evidence to suppose that his work and inspiration were influenced by his immediate relatives, or wealthy ancestors.

Thus, while there appears to be some similarity in the psychological aspects of their early life and characteristics, and one is also aware of the notability of the two men, there is a marked distinction between the qualities of a twentieth century politician, and a scientific scholar of the eighteenth century.

Cavendish belonged to a distinguished family which could have endowed him with fame and fortune; but he took no advantage of it. He could have had unlimited comfort to stimulate him to exertion; yet he rejected it. He was an unique personality, outwardly strange and eccentric; notwithstanding, he was universally respected by the age he had enlightened. If he shunned society, he won fame throughout the scientific world, and was beloved by his rivals.

He exhibited to mankind a perfect model of what a man of science should be, and was a splendid example of that success - so eagerly sought, so seldom obtained.(1)

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(1) Young, p.445.

CHAPTER II

THE YEARS OF EXPERIMENT

In the realm of science it has been the custom to regard Cavendish primarily as a chemist. It is certainly true that his chemical discoveries rank among the greatest of his scientific researches, though it may be questioned whether he himself would so reckon them, but to think of him simply as a chemist is to take a very partial and incomplete view of his activities. Indeed, at no period of his life as an experimentalist, was his energy entirely absorbed by chemical pursuits. In fact, he was a natural philosopher of the broadest type, who occupied himself in turn with every branch of physical science known in his time, and impressed the marks of his genius, and the extraordinary penetrative force of his intellect on them all.(1)

From the posthumous publication of a selection of his manuscripts we know even better than Cavendish's colleagues the depth and range of his researches. Joseph Larmor observed that there are perhaps few investigators of the first rank of whose work and aims and procedure we have now more complete knowledge than of his.(2) What needs emphasizing is the fact that, in spite of the manuscripts, it is just the aims of his work which have remained unexplored, and his

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1. The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. II, Chemical and Dynamical, ed. Thorpe (1921), p.v.

2. The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. I, The Electrical Researches, ed. James Clerk Maxwell (1921), p.viii, rev. Larmor.

scientific career as a consequence has appeared as obscure and enigmatic as ever. There are a number of uncommon facts relating to Cavendish's life and work, which have tended to stand in the way of any serious effort to understand the ideas motivating his research. On the one hand there is the vast amount of seemingly inexplicable manuscript material discovered after Cavendish's death, much of it highly original, and often prepared as though for publication. On the other hand, for one whose life was dedicated to science to a degree almost without precedent, Cavendish published relatively little - no books, and fewer than twenty papers from more than fifty years' researches. But these several papers, each delimited in content, and each characterized by that conciseness of argument and quantitative exactitude which made him an authority in his day, ranged over nearly every branch of natural philosophy.(1)

He showed few of the ambitions of his class and in general was an extraordinarily independent man, in so much that it is a commonly held misbelief that his various lines of research show no intelligible relationship, while the grounds for his choice of one or another at any given time are incomprehensible. Indeed, Cavendish's leading researches, his theoretical and experimental studies on dynamics, heat, factitious airs, and electricity are integral parts of a persistent goal. It is precisely because Cavendish's researches were deeply inter-related that he did not publish more of them; one type of investigation invariably led to another, and the original would be temporarily, then permanently,

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1. R. McCormack, 'Henry Cavendish: A Study of Rational Empiricism in Eighteenth-century Natural Philosophy', Isis, Vol. 60, Part 3, No. 203 (1969), p.293.

laid aside as something incomplete in itself. This is not to imply that Cavendish's reluctance to publish, and the other puzzling facets of his career, can be fully understood by reference solely to his published and private researches.[1]

It is well known that research in Britain during the eighteenth century was strongly influenced by the works of Sir Isaac Newton, and though Cavendish was stimulated by many of his contemporaries, Newton was the ultimate source of his inspiration. He was a close student of the Principia - forever his model of quantitative science.

Very little is known about Cavendish's scientific activities between 1753, when he left Cambridge to join his father in London, and 1766, when his first important contribution entitled 'Three papers containing Experiments on factitious Air', was published in the Philosophical Transactions.[2] The twenty two years, 1766-1788, that Cavendish devoted to chemical inquiry constitute indeed, one of the most brilliant periods of the history of science. In addition to chemistry, nearly every branch of natural science known in his time appealed to him with equal force, and he explored all with the same zeal and success. In his work on thermomentry, cryoscopy, and on terrestrial magnetism, he often breaks new ground and anticipated discoveries attributed to much later observers. Then again, his published work, and still more his unpublished manuscripts, show that meteorology, astronomy, electricity, heat, geology, geodesy and mathematics, came under his spell as he

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1. McCormach, (H.C.), p.294.

2. H. M. Leicester and H. S. Klickstein, A Source Book of Chemistry 1400-1900 (1952), p.134. Sci. Pap. Vol. II, pp.77-101.

seemed to turn from one to the other with equal devotion as their problems interested him, with the result that he made important contributions on these subjects which were read to The Royal Society.

Cavendish too showed great interest in aeronautics, when Blanchard, one of the most successful of earlier astronauts, made a balloon ascent in the neighbourhood of London, the 30th of November, 1784, accompanied by Dr. J. Jeffries, an American physician, who subsequently, also with Blanchard, made the first Channel crossing by balloon from Dover to Calais. There can be little doubt that Cavendish had arranged for samples of air to be taken at various heights during the ascent. The usual method at that period for procuring air for analysis was to empty stoppered bottled filled with water at the spot at which the air was collected. Though no details of altitudes were recorded, the results indicated clearly that the composition of the atmosphere was very constant.(1)

Cavendish's next paper, which was published in 1784, dealt at great length with the explosion of mixtures of hydrogen and oxygen by the electric spark, and his work led to the discovery of the composition of water. A bitter contest connected with this subject arose on the question of priority of the claimants to the discovery, and is considered apart, at the end of this chapter. Had Cavendish published the fourth part of his first paper, 'Experiments on factitious Air', this unfortunate dispute would very probably have been avoided.(2)

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1. Sci. Pap. Vol. II, pp.22,434.

2. Leicester and Klickstein, p.134, Sci. Pap., Vol. II, pp.77-101, 161-181. A. J. Berry, Henry Cavendish (1960), p.61.

Cavendish had no difficulty in changing the subject of his study at a moment's notice, and it was his constant practice to carry on at one and the same time widely dissimilar inquiries.

In 1790, Cavendish communicated to the Royal Society, a paper on the Aurora, seen on the 23rd of February, 1784, entitled, 'On the Height of the Luminous Arch'.(1) In connection with Cavendish's studies on this subject, there is a letter from his brother Frederick, an extract from which is quoted in Chapter One, who had observed a fine display of the Aurora four years previously.(2)

Despite Cavendish's peculiarities, he was sufficiently public spirited to serve on committees of the Royal Society when set up to make recommendations on matters of national importance, and his advice was eagerly sought and accepted. The story of the lightning conductor is an example which shows Cavendish co-operating with others in an electrical investigation in the interest of the nation.

In 1772, the government received intelligence of the destruction of several powder magazines at Brescia in Italy due to lightning, and as their own magazines at Purfleet were totally unprotected, the Board of Ordnance approached the Royal Society for their opinion on the best means of safeguarding them. The Council, accordingly, appointed a small committee of which the celebrated Benjamin Franklin, Cavendish, and a Mr. Wilson were members.(3) At that time Mr. Wilson was the

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1. Sci. Pap., Vol. II, pp.233-235. Berry, p.158.

2. Chatsworth MSS., X(b)9. This letter appears in full in Sci. Pap., Vol. II, p.69.

3. C. R. Weld, A History of the Royal Society (1848), 2 Vols., pp.95-97.

contractor for the house painting there; he also had some reputation as an electrician, and when the committee recommended pointed conductors, he dissented from this recommendation. Mr. Wilson registered his protest, but not satisfied with this alone, published a long Paper in the Philosophical Transactions in favour of blunt conductors, although the soundness of his judgment was refuted in the strongest manner by Franklin and other electricians.

The government determined on using pointed conductors, but unfortunately five years later in 1777, the Board House at Purfleet was struck by lightning and slightly damaged, though the powder was not exploded. The incident ironically enough, furnished a triumph for Mr. Wilson. After more dissent from Wilson, the Royal Society appointed a committee of nine, including Cavendish and Priestley, which unanimously recommended conductors 'as acutely pointed as possible' adding that, 'the experiments and reasons alledged [sic] to the contrary by Mr. Wilson are inconclusive'.(1)

The authority of Cavendish in electrical science was, of course, established by his first paper in 1771, entitled, 'An attempt to explain some of the principal Phænomena of Electricity by Means of an Elastic Fluid', and it was in consequence not surprising to find him nominated by the Royal Society as one of the committee in the dispute just considered.

The whole of his electrical researches now occupied his mind, right up to the death of Lord Charles Cavendish in 1783; in fact it

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1. Sci. Pap. Vol. I, p.6.

is well known that any branch of natural knowledge in which there were possibilities of precise quantitative study claimed Cavendish's attention, and nowhere is this more clearly evident than in his electrical researches. In these investigations he reached the very heights of his altogether exceptional genius.

Henry appears to have been living with his father during the whole period of his electrical researches, and it must be supposed therefore that they were made in Great Marlborough Street, and probably in a set of stables mentioned by Dr. Thomas Thomson.[1]

His first paper of 1771, and that on the Torpedo, are the only publications relating to electricity.[2] True, there were some manuscripts entitled, 'Thoughts concerning Electricity', which, though never published by him, Maxwell considered that Cavendish intended for a book, to form a suitable introduction to the account of the experiments, as indicating the leading ideas of Cavendish's researches.[3] The Cavendish Society for whom Wilson prepared his Life of Cavendish, with an account of his chemical research, did not consider it came within their design to publish his electrical researches.

Cavendish's papers on electricity consisted of twenty parcels, eighteen of them belonging to the years 1771, 1772, and 1773, and had

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1. G. Wilson, Life of the Honourable Henry Cavendish (1851), p.159.
2. Sci. Pap. Vol. I, p.10.
3. Sci. Pap. Vol. I, p.13. Berry, pp.90-91.

never appeared in print until J. Clerk Maxwell, F.R.S., undertook this commendable, yet laborious task, and finally had them published in 1879.[1] The two remaining parcels are dated 1775, and 1776, and are connected with the author's celebrated second paper on the Torpedo, the last one he published on that branch of physics. It was read before the Royal Society on the 18th of January, 1775, and was published in the following year under the title: 'An account of some attempts to imitate the effects of the Torpedo by Electricity'.[2]

Before that, there had been some interest in scientific circles on shocks given by electric fishes, and papers on this phenomenon had been communicated to the Royal Society. A paper by John Walsh on the torpedo was based on his observations contained in two letters to Benjamin Franklin.[3]

The torpedo is a well-known inhabitant of the warm waters of the Atlantic and Indian Oceans and the Mediterranean Sea, and it appears that Walsh obtained a specimen for his experiments from around the Isle de Ré, near La Rochelle. He was convinced that the shocks given by the torpedo must be electrical, although no human being had observed any spark of light to be emitted by the animal.[4] His paper attracted the attention of the great anatomist, John Hunter, who published an account of the electric organs of the torpedo in the <u>Philosophical Transactions</u> for the same year. Hunter referred to Walsh as the first

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1. J. Clerk Maxwell, <u>The Electrical Researches of the Honourable Henry Cavendish, F.R.S.</u>, (1879).
2. <u>Sci. Pap.</u>, Vol. I, pp.194-211.
3. <u>Sci. Pap.</u>, Vol. I, p.194.
4. Berry, p.111.

discoverer of animal electricity.

As a result, however, of further experiments made by Cavendish, proof was established of a difference in the intensity of the shocks received from the torpedo according as the fish was immersed in water or held in the air, the shock in the latter case being the more powerful, but made clear that a completed circuit is a necessity for a shock to be obtained. He illustrated this by a reference to an observation quoted by Walsh which has a direct bearing on the subject:

'One of the fishermen employed by Walsh assured him that he always knew when he had a torpedo in his net by the shocks he received while the fish was at several feet distance ... and before the torpedo was drawn out of the water ... for there can be little doubt, but some electricity would pass through the net to the man's hands, and from thence, through his body and the bottom of the boat ... to the water under the boat; the quantity of electric fluid, however, taking this circuit, would most likely bear so small a proportion to the whole, that this effect cannot be accounted for without supposing the fish to exert at that time a surprisingly greater force than what it usually does'.(1)

Another illustration of the presence of an electric force can be experienced, 'when the torpedo happens to be left on shore by the retreat of the tide, it loosens the sands by flapping its fins till the whole body, except the spiracles, is buried; and it is said to happen sometimes that a person accidentally treading on it in that

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1. Sci. Pap., Vol. I, p.205.

situation, with naked feet, is thrown down by it'.(1)

The practical electricians, however, particularly a Mr. Ronayne, were by no means satisfied that the effects of these fishes were really produced by electricity.

Cavendish had completely satisfied not only Mr. Walsh, but what was more important, himself, that the electric phenomena of the torpedo are such as might arise from the discharge of a large quantity of electricity at a very feeble degree of electrification. It must therefore have been to satisfy other persons on this point that Cavendish took the trouble to construct an artificial torpedo, an ingenious device of wood covered with leather, with electric organs of pewter supplied with electricity from a battery of Leyden jars by wires protected by glass tubes.

The torpedo, so as to conform to conditions as near maritime as possible, had a trough of salt water, the saltness of which was carefully adjusted so as to be equal to that of the sea. It had also a basket to lie in, and a bed of sand to be buried in, and there were pieces of sole-leather, well soaked in salt-water, which Cavendish placed between the torpedo and his hands, so that he might form some idea of what would happen if a traveller with wet shoes were to tread on a live torpedo half buried in the sand.(2)

On Saturday, the 27th of May, 1775, Cavendish invited a select company of men of science to take part with him in experiments with his artificial torpedo. They were John Hunter, the well-known anatomist,

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1. Sci. Pap. Vol. I, p.204. Berry, p.118.
2. Sci. Pap., Vol. I, pp.204-205.

Joseph Priestley, the chemist, Timothy Lane, the inventor of the discharging electrometer, Edward Nairne, the eminent scientific instrument maker, and Thomas Ronayne from Cork, the disbeliever in the electrical character of the torpedo.(1)

They all received shocks from Cavendish's artificial torpedo, and, as Maxwell remarked, 'probably learnt a good deal about electricity'. But, it was neither to satisfy them, nor to communicate to them his electrical discoveries, that Cavendish admitted them into his laboratory on this memorable occasion. It was to obtain the testimony of these eminent men to the fact that the shocks of the artificial torpedo agreed in a sufficient manner with Walsh's descriptions of the live fish. to warrant the hypothesis that the shock of the real torpedo may also be an electrical phenomenon.

It is interesting to note that this is one of the rare occasions in which the presence of visitors to Cavendish's laboratory is recorded, and likewise it was one of only two occasions, according to Maxwell, on which Cavendish, after he had settled his own opinion on any subject, thought it worth his while to set other people right who differed from him.(2)

There can be no doubt regarding the success attending Cavendish's experiments with his artificial torpedo, and it is certain that his research was a source of admiration to the scientific circles of his own and of later times.

In his paper on the torpedo Cavendish alluded to 'some experiments

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1. <u>Sci. Pap.</u>, Vol. I, pp.9, 301-310.

2. <u>Sci. Pap.</u>, Vol. I, pp.8-9.

of which I propose shortly to lay an account before this Society', but he never followed up this proposal by divulging the method by which he obtained the results, but proceeded to state: 'that iron wire conducts about 400 million times better than rain or distilled water, and that sea-water, or a solution of one part of salt in 30 of water, conducts 100 times, and a saturated solution of sea-water about 720 times better than rain-water'.(1)

Such was the reputation of Cavendish for scientific accuracy, that these bare statements were immediately accepted as scientific information, yet no one had ever conjectured by what method he actually obtained them more than forty years before the invention of the galvanometer, the only instrument known to compare electrical resistances. But, says Maxwell, 'Cavendish was his own Galvanometer'. In order to compare the intensity of currents he caused them to pass through his own body, and by comparing the intensity of the sensation he felt in his wrists and elbow, he estimated which of the two shocks was the more powerful.(2)

Of all substances pure water has caused most diversity of opinion as a determinent of resistance. It has been found indeed that the presence of the minutest trace of impurity in water diminishes its resistance enormously; for example a few minutes exposure to air, or traces of tobacco smoke, was found to spoil it for a determination of resistance. Thus the famous scientist Kohlrausch found it necessary

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1. <u>Sci. Pap.</u>, Vol. I, p.23.
2. <u>Sci. Pap.</u>, Vol. I, p.24.

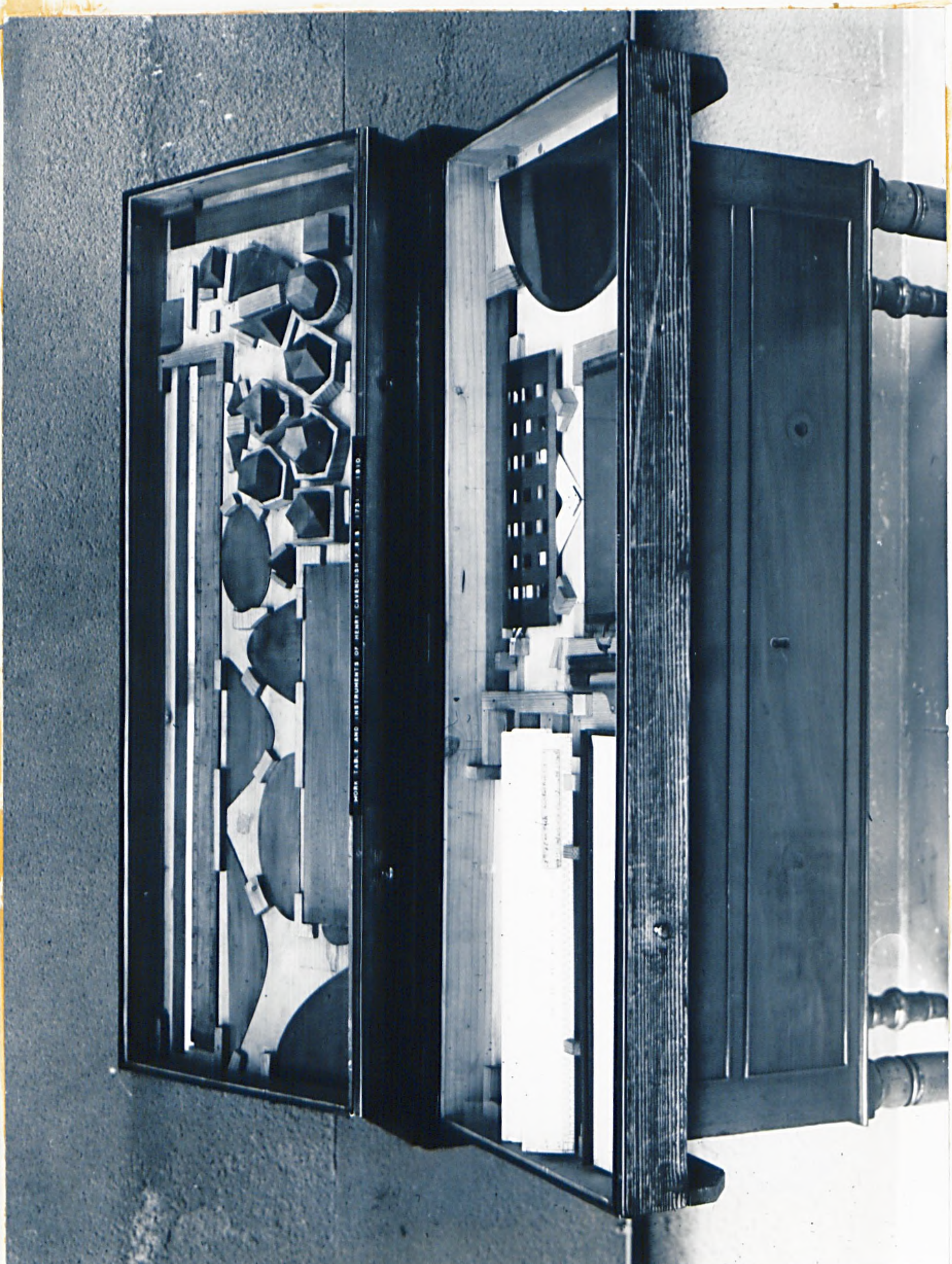
WORK TABLE AND INSTRUMENTS OF HENRY CAVENDISH F.R.S. 1731 - 1810

PLATE II

HIS WORK-TABLE WITH MATHEMATICAL INSTRUMENTS

A corner in the orangery at Chatsworth House displays some pieces of apparatus belonging to Cavendish, including exhibits pertaining to physics and mathematics.

Here is shown a work table together with an assortment of geometrical instruments and figures.

to use water quite freshly distilled for his experiments on conductivity, if the result to determine the actual resistance was not to be ruined. Therefore, the hypothesis that water is a non-conductor of electricity, if not true, cannot be disproved. Some of these remarkable properties of water were detected by Cavendish. He found that the resistance of pump-water was $4^1/6$ times less than that of rain-water, and that of rain-water was 2.4 times less than that of distilled water.(1)

Hence, in the series of experiments which Cavendish invented, set up and developed, he showed that resistance was a force which resists the current, and the result obtained by him in 1781 is an anticipation of the law of electrical resistance discovered independently by Ohm, and published by him in 1827. It was not till long after the latter date that the importance of Ohm's law was fully appreciated, and that the measurement of electrical resistance became a recognized branch of research.(2)

Cavendish's electrical investigations, as published by Maxwell in 1879, are a monumental achievement of patience and thoroughness, and the scientific circles throughout the world are the richer, but it is doubted if sufficient recognition has been accorded to Maxwell for this work. How all this came about is of some interest.

Maxwell was not a man who enjoyed good health, and for this reason left London at the early age of thirty-four, and retired to his estate in the south of Scotland in 1865. About this time William, seventh Duke of Devonshire, then Chancellor of the University of Cambridge

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1. Sci. Pap., Vol. I, pp.26.-27.
2. Sci. Pap., Vol. I. p.25.

founded and endowed the Cavendish Chair of Experimental Physics, and Maxwell was appointed as the first Professor in 1871. From 1874 up to his death in 1879, Maxwell devoted himself with great ardour to the study of Cavendish's manuscripts, and actually repeated many of the experiments almost as Cavendish performed them, but in which he himself was the guinea-pig.(1)

In the 'Galvanometer experiment', whoever visited Maxwell's laboratory at the time had to submit to it. Some visitors, however, failed to appreciate the originality and efficiency of the method; there was, for instance, a young American astronomer who had travelled thousands of miles to make Maxwell's acquaintance and to talk to him about astronomy, but, instead, he was made to listen to a lengthy talk about Cavendish and more or less forced to take off his coat, plunge his hands into basins of water and submit himself to a whole series of electrical shocks.(2)

In the Cavendish manuscripts there are details of a laborious series of observations undertaken to determine the sources of the variation compass, and the dipping needle, belonging to the Royal Society. On the 16th of September, 1773, we find, 'observations of needle in garden by Father and self', and a 'comparison of Society's compass in house and in soc/iety's/ /sic/ garden with Father's compass in room'.(3) Lord Charles Cavendish, who was also addicted

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1. E. Larsen, The Cavendish Laboratory (1962), p.19.

2. T. C. Fitzpatrick, A. Schuster et al., A History of the Cavendish Laboratory (1910), pp.32-33.

3. Sci. Pap., Vol. I, p.29.

to scientific pursuits, not only placed his instruments at his son's disposal, but made observations of the compass in concert with him, and these observations were undertaken in order to make the instruments belonging to the Royal Society more available for accurate measurements.[1] He even had the magnetic instruments moved a mile and a half away, because of the proximity of some iron railings which could have affected the results.[2]

A considerable portion of the manuscripts is taken up with, 'Directions for using the Dipping Needle', written out at greater or less length, (probably according to the scientific knowledge of the recipient) for several persons, of whom one is Dalrymple, Hydrographer to the Hon. East India Company. There is, incidentally, a long and interesting letter among the Chatsworth manuscripts, written by Dalrymple, re observations with the dipping needle on a voyage to India, 1776.[3]

From the very outset of his career as a scientific observer, Cavendish seems to have occupied himself with the problems of terrestrial magnetism, for his interest in that subject continued unabated so long as he lived, and certainly between 1759 and 1809 - fifty years.

Much of the material preserved at Chatsworth relates to this subject.[4] Dr. Chree, the superintendent of the Kew Observatory,

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1. Weld, Vol. II, p.76.
2. Berry, p.156.
3. Chatsworth MSS. X(b)6.
4. <u>Sci. Pap.</u> Vol. I, p.29.

who carefully examined these papers, has furnished a very complete account of their contents.[1] He shows how Cavendish anticipated the ideas and procedure of subsequent observers, determining for example the best form of dip-needles in tracing the influence of bending of the needle on the observed value of its inclinations, and as regards other sources of error too. Thus, Dr. Chree's summary of results constitutes an important contribution to the magnetic history of the earth and its known close relation to the Solar Cycles during the last forty years of the eighteenth century, for which our information is so scanty and uncertain.[2]

It was about this time too, the latter half of the eighteenth century, that meterological observations began to attract an increasing amount of attention, and the early volumes of the Philosophical Transactions contain numerous communications on the subject.

In 1773, the Royal Society instituted, under Cavendish's superintendence, regular observations on atmospheric temperature, pressure, humidity, rainfall and wind as well as magnetic variation and inclination, at their house in Crane Court and subsequently in their new buildings at Somerset House. These records were tabulated and discussed in successive volumes of the Transactions down to 1843, then discontinued, when on the recommendation of the Council of the Society, the Government established a meteorological and magnetic observatory in association with the Royal Observatory at Greenwich, built in 1675.

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1. Sci. Pap., Vol. II, pp.438-492.

2. Sci. Pap., Vol. II, pp.viii, and 438-492.

A couple of years after their installation at Crane Court the Council of the Society requested Cavendish to examine the condition and mode of working of the instruments, and his report was published in the Philosophical Transactions, under the title, 'An Account of the Meteorological Instruments used at The Royal Society's House'. It contains a description of the thermometers, barometers, rain-gauge, hygrometer, variation compass, and dipping-needle.(1)

According to Sir Edward Thorpe, this report to the Society, displays Cavendish at his best. It reveals the range of his knowledge, his painstaking care, his sense of accuracy, his perspicacity, and thoroughness with which he studied any problem he attacked. Instruments designed for measurement had always a special attraction for him, and he seems to have taken a peculiar pleasure in working with them and in studying their behaviour with a view to getting the best results out of them. He had no great interest in the technical side of invention; his main concern seemed to be to make such instruments as he could construct out of rough material serve his purpose by skilful and intelligent use. With him it was a case of 'the man behind the gun'.(2)

Cavendish, like his father, had paid considerable attention to thermometry, and in this report he took advantage afforded by it to indicate certain sources of error in the mode of graduation of the thermometer, and in the manner of its use.

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1. Weld, Vol. II, p.76. Sci. Pap., Vol. II, pp.112-126.
2. Sci. Pap., Vol. II, p.56.

Arising out of his study of thermometers Cavendish embarked on his last series of investigations on the subject of heat, which had occupied him at intervals over a period of thirty years of his scientific activities. Fortunately these were to be published,[1] and were concerned with the freezing of mercury, and with an examination of the properties of freezing mixtures. From the times of the alchemists it was universally believed that mercury could not be frozen at the lowest temperatures so far attainable. This opinion prevailed up to the time of Fahrenheit, whose name is usually associated with the first mercury thermometer.[2]

This study in cryoscopy or cryogenics[3] induced Cavendish to institute a further series of experiments at Hudson's Bay, with the assistance of Mr. John McNab, the Master at Henley House, a station situated on the Albany River, some one hundred and fifty miles distant from Fort Albany. Cavendish sent out to McNab bottles containing solutions of nitric and sulphuric acid of various strengths, as well as of ordinary alcohol, with 'accurately adjusted thermometers', accompanied by instructions for their use.[4]

The results of these investigations were communicated to the Royal Society in 1786, and published in a paper entitled, 'An Account

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1. Berry, p.144.

2. Berry, pp.130-154.

3. J. Thewlis, ed. Encyclopaedic Dictionary of Physics, (1961, 4 vols.). 'Cryoscopy', Vol. II, p.199, the name given to the general field of scientific work at low temperatures.

4. See letter from Dr. Maty to Cavendish, 26. Dec. 1773. Chatsworth MS. X(b)12.

of Experiments made by Mr. John McNab at Henley House, Hudson's Bay, relating to Freezing Mixtures'.(1) Nevertheless, Cavendish did not remain satisfied with his work, because he realized that these numerous experiments still left certain difficulties to be cleared up, and he accordingly arranged with Mr. McNab to carry out a new series on both acids with a new set of instructions. Two years later the results of this work were published in a paper entitled 'An Account of Experiments made by Mr. John McNab at Albany Fort, Hudson's Bay, relative to the Freezing of Nitrous and Vitriolic Acids'.(2)

These elaborate investigations, the accuracy of which has been confirmed by modern observers, particularly by Knietsch, more than a century later, had been completely neglected, and it is nothing short of marvellous that Cavendish should have succeeded in getting results so near the truth. He not only determined the points of 'easiest freezing' and of 'contrary flexure' with precision, but his estimation of the corresponding strengths and temperatures are a striking testimony to the skill and exactness of his work, in spite of his limited means and the imperfections of his appliances.(3)

It would appear, therefore, from the absence of all reference to these researches on the part of later observers, that Cavendish's work on the freezing of aqueous solutions of nitric and sulphuric acid was either unknown to them or that its significance was not

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1. <u>Sci. Pap.</u>, Vol. II, p.195.

2. <u>Sci. Pap.</u>, Vol. II, pp.214-223.

3. <u>Sci. Pap.</u>, Vol. II, p.66.

recognized, and not even quoted, except by Thorpe, in the Introduction to Volume II of Cavendish's Scientific Papers.(1)

Thus, there is abundant evidence that in the co-operative tasks which united the scientific men of the time, Cavendish, standing far beyond most of his contemporaries in intellect and vision, was always ready to take unsparing pains, and to devote himself without limit to the assistance of his colleagues. The operations and discussions preparatory to the gravity survey of Schiehallion, summarized in the Scientific Papers Volume II, are an example.(2)

There is no evidence, therefore according to Sir. Joseph Larmor, that Cavendish's researches aimed at any personal gratification alone; and so it is easy to understand how the driving force of his curiosity and conscious power would impel him to the exploration of new fields, in temporary preference to the final polishing of work already achieved.(3)

It was in 1798 that Cavendish published what is generally considered to be his most celebrated paper, entitled, 'Experiments to determine the Density of the Earth'.(4)

Newton had calculated the density of the earth from the general theory of gravitation, but from many circumstances his results were considered inaccurate. He was, however, the first to suggest the

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1. Sci. Pap., Vol. II. pp.56-66. Berry, p.154.
2. Sci. Pap., Vol. I, p.x.
3. Sci. Pap., Vol. I, p.ix.
4. Sci. Pap., Vol. II, pp.249-286.

desirableness of making experiments upon the attraction of a mountain.(1)

Already, about 1735, a group of French academicians organized an expedition to South America, and endured much hardship on a geodetic survey with instruments of imperfect construction. They expressed the hope that some suitable mountain could be found to pursue experiments of this kind with successful conclusions. Bouguer, a prominent member of the expedition, in 1738, made the first experiments on the deviation of the plumb-line, on Chimborazo, a mountain in Ecuador, some 20,000 feet in height.(2) Many years later in 1772, the Rev. Nevil Maskelyne, B.D., F.R.S., the Astronomer-Royal, read a paper before the Royal Society strongly urging the necessity of such experiments. The Council resolved on carrying Dr. Maskelyne's suggestion into effect, and a 'Committee of Attraction' was thus appointed. Cavendish was a member, and one of its most ardent supporters.(3)

Its meetings began in 1772, and continued for the next two years. Among Cavendish's unpublished papers were found numerous notes and calculations relating to the attraction of mountains on plumb-lines.(4)

The Committee, having considered reports of certain hills in Yorkshire and Cumberland were unable to find one suitable for the

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1. Weld, Vol. II, pp.78-81.

2. Berry, p.162.

3. Chatsworth MS. X(b)1. Sci. Pap., Vol. II, p.402.

4. R. McCormach, 'John Michell and Henry Cavendish: weighing the stars'. British Journal for the History of Science, Vol. 4, No. 14 (1968), pp.152-155. Sci. Pap., Vol. II, pp.392-393, 401-407.

purpose, but agreed on a mountain in Perthshire, called Schiehallion, 3,547 feet in height, which for situation, size and figure appeared a proper place for the intended experiments. The Committee subsequently reported, 'that it would add to the lustre and authenticity of the observations to be made in Scotland if Mr. Maskelyne could be prevailed on to undertake the direction of them on the spot'.(1)

Maskelyne, who was present as a member of the Council when the resolution was passed, at once signified his consent. He was later rewarded with the Copley Medal for his labours. The unenviable and laborious task of calculating the density of the earth, details of which were published in 1778, was undertaken by Dr. Hutton, who at once acknowledged the assistance he had derived from suggestions which had been received from Cavendish.

There is little doubt but what this subject had been in Cavendish's mind for many years prior to the famous memoir of 1798. The principle of the method he employed was suggested by his friend Michell whose experiment was more precise than that of Maskelynes. The calculations of Maskelyne required a knowledge of the mass of the mountain, obtained by measuring its volume and estimating its average density.(2)

Cavendish had been gently urging Michell to go ahead with his plan for 'weighing the world'. He thus expressed the hope of trying the experiment during the summer (1783)(3) but would not promise too

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1. Weld, Vol. II, p.80.
2. McCormach, (J.M. and H.C.), p.153.
3. My insertion.

much. Because of his natural indolence and indifferent state of health his experiments moved slowly. In the end it was Cavendish who performed the task. The celebrated experiment became known as the Cavendish Experiment and at the outset of his paper of 1798, in which he gave a complete description of it, he paid generous tribute to his departed friend Michell, who 'contrived a method of determining the density of the earth by rendering sensible the attraction of small quantities of matter; but ... he did not complete the apparatus till a short time before his death, and did not live to make any experiments with it'.(1) It was subsequently employed for measuring small attractions and repulsions by Coulomb, with whose name it is usually associated.

The torsion balance, as the instrument was called, came into the possession of the Rev. Francis John Hyde Wollaston, Jacksonian Professor at Cambridge, one of the observers who furnished Cavendish with data for his computation of the height of the aurora. As Wollaston was unable to make use of it, he transfered it to Cavendish, who proceeded to erect it, after very considerable modifications, in an outhouse in his garden at Clapham.

The experiment of 'weighing the world', or in other words, of determining the density of the earth made a strong appeal to Cavendish. 'It united the principle of universal gravitation - the fixed point of his Newtonian philosophy - with the sciences of geology and astronomy, interests that had come very probably as a result of his friendship

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1. McCormach, (J.M. and H.C.), p.154. Sci. Pap. Vol. II, p.249.

with Michell, to occupy the first place in his researches for the late 1780's on.'[1]

Thus, if weighing the world was regarded as the most celebrated experiment made by Cavendish, then what is considered to be his most scientific investigation, the discovery of the composition of water, must be acclaimed the most notable. But, it was not until the completion of a posthumous wrangle, following accusations of dishonesty that the honour due to him was finally acknowledged by contestants who claimed priority. The inquiry was long and complicated, but a brief survey of this protracted controversy must now be presented.

Cavendish's experiments on the composition of water were made in the summer of 1781, but as he felt it necessary to make further observations to satisfy himself before publishing his results, he deliberately delayed the reading of his paper, entitled, 'Experiments on Air', to the Royal Society, till January, 1784.[2]

In the first paragraph, he stated, 'the following experiments were made principally with a view to find out the cause of the diminution which common air is well known to suffer by all the various ways in which it is phlogistigated, and to discover what becomes of the air thus lost or condensed; and as they seem not only to determine this point, but also to throw great light on the constitution of dephlogisticated air, I hope they may be not unworthy the acceptance of this society.'[3]

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1. McCormach, (J.M. and H.C.), p.154.
2. Weld, Vol. II, pp.172-185.
3. <u>Sci. Pap.</u>, Vol. II, pp.161-181. Leicester and Klickstein, pp.142-153. <u>Berry</u>, p.69.

PLATE III

A MEETING OF THE ROYAL SOCIETY

The following group is not an actual meeting, but the setting chosen was the library of the Royal Institute. The portraits were taken from what was thought to be the best available of each scientist.

The picture, now on view at Chatsworth, is taken from the engraving by William Walker (1791-1867) and was finished in 1862. The engraving was executed from an original drawing in chiaroscuro by Sir John Gilbert, and there are two designs by him kept at the National Portrait Gallery. There were a number of persons involved in this work, Gilbert on the design; the figures were drawn by John F. Skill and finished by William and Elizabeth Walker and George Zobel, but apparently William Walker was the guiding spirit behind it, and the one who supplied the expenses. The engraving was put out privately on a subscription basis, at five to eight guineas each.


Thomas Young
Jos. Banks
Edw. Jenner
Wm. Smith
H. Cavendish
John Dalton
Humphry Davy
Nevil Maskelyne
Wm. Herschel
James Watt

1. H. Cavendish
2. James Watt
3. John Dalton
4. Mc. I. Brunel
5. Mattw. Boulton
6. Thos. Telford
7. John Rennie
8. Robt. Mylne
9. Saml. Crompton
10. Charles Tennant
11. Edmund Cartwright
12. Francis Ronalds
13. Stanhope
14. Joseph Bramah
15. R. Trevithick
16. Wm. Smith
17. Jos. Banks
18. Edw. Jenner
19. Nevil Maskelyne
20. Wm. Herschel
21. Francis Baily
22. W. J. Frodsham
23. John Leslie
24. John Playfair
25. D. Rutherford
26. P. Dolland
27. Thomas Young
28. Robert Brown
29. Denes Gilbert
30. Henry Kater
31. Edw. Howard
32. Wm. Allen
33. Wm. Henry
34. William Hyde Wollaston
35. Chas. Hatchett
36. Humphry Davy
37. Henry Maudsley
38. Saml. Bentham
39. Rd. Watson
40. J. Huddart
41. Rumford
42. Wm. Murdoch
43. Wm. Chapman
44. Wm. Jessop
45. William Congreve
46. Bryan Donkin
47. Edn. Troughton
48. Thomas Thomson
49. William Symington
50. Patrick Miller
51. Alex Nasmyth

In other words, Cavendish was investigating the products of combustion, and the discovery of the composition of water, which arose from these experiments, was incidental, and in no sense was it the object which led to their performance.

This delay in the reading of his paper, caused his claims as the discoverer of the composition of water, to be contested, and by no others than the celebrated engineer James Watt and the great French chemist, Antoine Laurent Lavoisier.

It had been known for some years that a certain mixture of inflammable and dephlogisticated air (hydrogen and oxygen), or common air and hydrogen, could be fired by the electric spark. The experiment had been made by Volta and Macquer in 1776-7; and in the spring of 1781 Dr. Joseph Priestley made what he called 'a random experiment' of the same kind to entertain some philosophical friends; and amongst those who witnessed it was a Mr. Waltire, a lecturer in Natural Philosophy at Birmingham, and a Dr. Withering.[1]

He exploded a mixture of common air and hydrogen in a glass globe by sending an electric spark through it, and after the explosion it was noticed that the sides of the glass were bedewed with moisture. Mr. Waltire who had observed this experiment afterwards repeated it in a copper flask, for the purpose of testing 'whether heat is heavy or not'.[2]

Meanwhile, Cavendish, who had for some years been occupied

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1. S. Smiles, Lives of the Engineers Boulton and Watt (1904), p.348. See Appendix III.

2. Wilson, P.40.

in the special study of pneumatic chemistry, and satisfactorily solved the question of the true composition of atmospheric air,[1] having had his attention directed to Mr. Warltire's experiment, repeated it in London in the summer of 1781, employing a glass vessel instead of a copper one; and again the deposit of dew was observed on the sides of the glass. This phenomenon, which Priestley had disregarded, appeared to him to be of considerable importance, and likely to throw great light upon the subject of the disappearance of oxygen during combustion, which he had been investigating experimentally by means of his well-known eudiometer.[2] The liquid which resulted from the detonations was very carefully analysed, and proved in all the experiments with hydrogen and air, and in some of those with hydrogen and oxygen, to be pure water; but in certain of the latter it contained a sensible quantity of nitric acid. Till the source of this was ascertained, it would have been premature to conclude that hydrogen and oxygen could be turned into pure water.[3]

Cavendish, who was never in a hurry to publish his results, did not do so, even though the conclusions arrived at by the experiments warranted publication, because he was engaged in further researches, which for the moment, precluded it. Had he done so, or even preserved silence till he had completed his investigations, there would have been no water controversy. But with the communicativeness which distinguishes

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1. Wilson, pp.40-41.
2. Wilson, p.59.
3. Wilson, p.60.

the true man of science, Cavendish made them known to Priestley, and, through his friend Dr. Blagden, to Lavoisier.

Thus, Cavendish's researches made in the summer of 1781, were communicated to Priestley before the 26th of March, 1783, and to Lavoisier before the 24th of June, in the same year, but they were not read to the Royal Society till the 15th of January, 1784. It is plain, therefore, that while Cavendish can claim priority of observation, Priestley, Watt and Lavoisier disclosed their views concerning the nature of water, similar to his, in written form in 1783.

Priestley made some experiments on air in 1783, of the same kind as those of Cavendish in 1781, and they are related in a paper printed in the Philosophical Transactions, where he acknowledged his indebtedness to Cavendish.[1] Herein lies the blunder, as Priestley transmitted these experiments to his friend Watt, (without ever referring to Cavendish as their originator), who realising their true value wrote to Priestley demonstrating what conclusions his experiments warranted, and which were identical with those already drawn by Cavendish.

This letter was a commentary on all the researches of Priestley, referred to in his paper of 1783, and Watt designed to have it read publicly at the Royal Society along with the paper on which it commented. Had this been done the water controversy might never have arisen.[2]

It is probable that both arrived at the same conclusions

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1. Wilson, p.61.

2. Wilson, pp.61-62.

independently of each other; Cavendish from the results of his own experiments, and Watt from those of Priestley. Each was quite competent to have made the discovery, and it was unnecessary for the fame of either to strip a leaf of laurel from the brow of the other. Moreover, one is unwilling to believe that Cavendish would have knowingly appropriated to himself the idea of Watt, as that Watt would have knowingly appropriated the idea of Cavendish. As it was, however, Cavendish and Watt both claimed priority in the discovery.(1)

At all events, Priestley discovered after receiving Watt's letter that some further researches had proved fallacious for both of them; consequently Watt requested that his letter to Priestley, to be read to the Royal Society in April 1783, should be withheld, until the results of some new experiments could be ascertained. His request was complied with.(2)

All parties went on with their researches, and towards the end of the following November Watt sent a revised edition of the letter, bearing the date the 26th of November 1783, to his friend De Luc, an eager partisan of Watt's claims, though he was quite unfitted to act as an advocate in the dispute. Nevertheless, he was entrusted by Watt, yet to be elected a Fellow, to present his paper to the Royal Society. The reading of it was delayed till the 29th of April, 1784, before which time, on the 18th of January, Cavendish's paper on the same subject had been communicated to the Society.

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1. Smiles, p.351.

2. Wilson, p.62. Sci. Pap., Vol. II, pp.43-45.

The foregoing are the only facts learned from the documents published in the lifetime of Watt and Cavendish, and on the question of relative priority any difficulty could have been settled, because each was recording evidence to justify his own particular claim to the disputed discovery.

Neither accused each other publicly, though in private each asserted his priority over his rival. Ostensibly there had been no dispute between these two great man, they had shaken hands at one of Sir Joseph Bank's soirées, and during his Journey of 1785, Cavendish found his way to Birmingham, and took an unusual interest in Watt's recent inventions.(1) At a late period of his life, when all bitter feelings on the subject had subsided, Watt declared himself indifferent to the subject of controversy: 'After all', said he, 'it matters little whether Cavendish or I discovered the composition of water; the great thing is, that it is discovered'.(2)

The controversy as regards priority died down during the life-time of the parties principally concerned, and it seems to have made no difference in their friendly relations. It was, however, revived by the action of Arago, Cuvier's successor as Secretary of the French Academy, who came to this country to collect material for his posthumous 'Éloge' on Watt which was published in 1839. In the course of his investigations, he came to the conclusion that Watt, and not Cavendish, was the real discoverer of the composition of water. He published this,

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1. Wilson, P.146.
2. Smiles, p.352.

accompanied by what amounted to an accusation against Cavendish of plagiarism, based on the sight of Watt's letter to Priestly, of 1783.

The scientific world of Britain was incensed at such a charge, and in his Presidential Address to the British Association, which met in Birmingham, shortly after Watt's 'Éloge' was published, provoked a vigorous rejoinder from the Rev. Vernon Harcourt. He pointed out the numerous mistakes Arago had committed, for after all, as an astronomer and physicist, he was unfitted to deliver a satisfactory judgment on a matter which belonged primarily to Chemistry.(1) Embittered by the charge of plagiarism, sides were then taken in this country, followed by a considerable correspondence, thus occasioning what is known in the history of science as the Water Controversy.

Both men, Watt and Cavendish, bore unimpeachable characters, and had they been friendly in 1783, this dispute could have been avoided. One was in Birmingham, the other in London, but each was informed of the others movements by third parties. Those who made mischief between the great philosophers were eminent men of science, who made their observations with the best intentions.

Priestley passed Cavendish's experiments to Watt, and Watt's conclusions to Cavendish; Blagden, Cavendish's assistant, passed the findings of Cavendish and Watt to Lavoisier, while a Mr. De Luc, F.R.S. informed Watt that Cavendish had pilfered his theory, and so belongs to De Luc the unenviable distinction of having been the deliberate mischief-maker, who provoked the Water Controversy.

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1. Sci. Pap., Vol. II, p.46.

2. Wilson, p.66.

Jean Andre de Luc, (1727-1817), occupies a curious position among the Dramatis Personae of the Water Drama. He was born a Swiss; became an accomplished meteorologist and a member of the Royal Society, though rarely attended its meetings, but was limited in other scientific attainments; yet he was known to men like Lavoisier, Laplace, and other French men of science. He became attached to the court of George III as a reader to Queen Charlotte, and spent much of his time at Windsor when the Court was in residence there.(1)

These are hardly qualifications to become a reliable champion of Watt's claims, as opposed to those of Cavendish, to have been the first to discover the composition of water, for he knew little English and less chemistry. Nevertheless, De Luc was a person of character and learning, and the water controversy would never have assumed such importance had he been a person less distinguished.

The 1st of March, 1784, marks the beginning of the Water Controversy as between Cavendish and Watt, and to some extent Lavoisier. That day De Luc, having recently returned from Paris, wrote a most imprudent letter to Watt informing him about Cavendish's paper, adding venomously, that not a word had been said about him, fervently defending Lavoisier and Laplace, from the charge of plagarism, but urging it against Cavendish.

This was quite sufficient to poison Watt's mind against Cavendish, even though De Luc is generous enough to suppose that Cavendish was an unconscious pilferer.

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1. Wilson, p.66.

In view of all his disqualifications, there was scarcely any person of Cavendish's scientific contemporaries less entitled than De Luc to act as umpire between the two English rivals. De Luc was mischievously hasty, as Watt was uncharitably petulant. Watt continued to nurse the grievance privately; that he felt keenly on the subject is obvious from his letter to Mr. Fry of Bristol, the 15th of May, 1784, but to have written with such bitterness, was at variance with a man of so generous a nature.(1) He would not publicly accuse Cavendish, but as an apparently injured man, he sought redress, and while on a visit to London had an interview with the President of the Royal Society, Sir Joseph Banks, though what transpired at the meeting is not known, but Sir Joseph wrote a note to Watt asking him to have the letters on 'Air' read to the Royal Society, and it was therefore arranged that, (a) the letter to Priestley, the 26th of April, 1783, and (b) the letter to De Luc, the 26th of November, 1783, should be read successively.

The former was read on the 22nd, and the latter on the 29th of April, 1784.

It must be observed that no charge of any kind was made by Watt in either of the letters read to the Royal Society, and in writing to Blagden, the 27th of May, 1784, he says, 'My only reason for wishing my letter to Dr. Priestley to be read before the Royal Society, was to show them what my ideas on the subject were at the time it was written'.(1)

The importance of this is to expose the critics of Watt who

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1. Weld, p.180. Wilson, p.75. Smiles, p.352.

2. Wilson, p.76.

alleged that he had accused Cavendish of plagiarism, when he had not publicly done so, nor even claimed priority. Watt made no such charge or claim; he simply asserted that his views concerning water went back to 1783, and left his rivals to establish an earlier date.

A conference at this point, between the two philosophers would have cleared the air by demonstrating to Watt that Cavendish had preceded him in experimenting on the production of water from its elements.

The strife does not end here, but now shifts to Blagden, who after Priestley and De Luc, becomes the third aider and abetter in the dispute. Before the subject is abandoned altogether, a brief reference must be made to Blagden, who had been appointed Secretary of the Royal Society, between the reading of Cavendish's paper in 1784, and its subsequent publication. It became part of his duties to act as editor of papers submitted for publication, and it was in this dual capacity of Secretary and experimental assistant that he received much undeserved criticism from the defenders of Watt and Lavoisier.

It was the practice of the Royal Society, long before and after 1784, to permit authors the privilege of making alterations and additions to their papers, and stipulating them as such, between the reading and the printing of them. Cavendish's paper of 1784, contained three interpolations, the first two of which were in Blagden's handwriting; the other was inserted by Cavendish himself. There were also some errors of date, for which Blagden, as editor, was responsible.(1)

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1. Wilson, pp.77, 124-125, 136-138. <u>Sci. Pap.</u>, Vol. II, p.36.

There is not the slightest doubt that the insertions in Blagden's hand-writing were made with Cavendish's approval, while the errors of date made not the slightest difference to the relative position of the claimants. It happened by some mistake that the separate copies of Cavendish's paper of 1784, bore the date of 1783, and Blagden was cruelly accused of officious intermeddling, and even of being paid for it. Such a vicious charge was without foundation, and as soon as the error was discovered, Cavendish at once wrote to the editor of the Journal de Physique à Paris, requesting him to correct it.(1)

One biographer has described this repugnant dispute, as one of the most prolonged and boring battles about priority in scientific discovery which has ever taken place.(2)

Reference must now be made to Lavoisier.

At this time, the scientific world was a small knit community, so it was only to be expected that rumours of Cavendish's experiments would soon be heard across the channel. Lavoisier, who had received some account of these experiments during Blagden's visit to Paris in 1783, realised their value and proceeded to repeat them, in a rough and ready way, before certain members of the French Academy of Science, without ever referring to Blagden as his informant. When these were published, thus anabling Lavoisier to announce a claim of priority in the discovery of the composition of water, Blagden immediately impeached his veracity and accused him of plagiarism. He followed this up by writing a long letter to Lorenz Crell, 1786, which appeared in his

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1. Wilson, pp.124-125. Berry, p.85.

2. W. R. Aykroyd, <u>Three Philosophers.</u> (1935), p.82.

Scientific Journal, Chemische Annalen, making it quite clear that he was the principal instrument through which the first news of the discovery that had already been made, was communicated to Mr. Lavoisier.[1]

It is at this point that Lavoisier committed the most unworthy and unwarranted action of his career; one which none of his contemporaries or successors, even among his own country men, have been able to defend. At least one of Lavoisier's colleagues was aware of the real facts and merits of the case is evident from a letter which the great La Place addressed to De Luc. on the 28th of June, 1783.[2] The statements contained in this letter, which have never been contradicted, would seem to leave no doubt on the question of priority as between Cavendish and Lavoisier concerning the experimental facts, or, indeed as to the inference which each drew from them as to the non-elementary nature of water.

Lavoisier, it should be added, did make one extremely useful and original contribution to the subject: he made it clear that he had been the first to prove the composition of water by analysis.[3] It should, however, be emphasized that Lavoisier discovered no new substances, and devised no improved apparatus; rather he gave the first correct interpretation of facts already known. In utilizing the work of his contemporaries, especially that of Black, Cavendish, and Priestley, in conjunction with experiments of his own, he accomplished for chemistry

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1. <u>Sci. Pap.</u>, Vol.II, pp.41-43. Wilson, pp.144,362. Berry, pp.81-82.
2. <u>Sci. Pap.</u>, Vol. ii, pp.42-43.
3. Wilson, p.157. Berry, pp.82-84.

what Isaac Newton had done for mechanics a century earlier.[1]

In this brief summary the only verdict that can be delivered, having considered the evidence, is the acquittal of all the participants, with the exception of Lavoisier, from the charge of having acted, or having sought to act, with malice prepense, in defending their own, or their friend's claims.

On Cavendish, no blame rests; Watt is open to the reproach of having listened too readily to De Luc; Priestley who could have appropriated a large share of the merit belonging to Cavendish, displayed honesty which heightened his good name; Blagden stands absolved from any heavier charge than that of excusable carelessness in correcting a printer's proof in Cavendish's paper, while De Luc, though hasty, could not be found guilty of any design to wrong Cavendish. Though De Luc set the machinery in motion, Arago provided the fuel.

Time has settled the dust of the controversy: agreement is now unanimous on the rights and wrongs of the case, while Wilson's <u>Life of Cavendish</u>, 1851, still contains the classic account of the water drama.

It is the discovery of the composition of water attributed to Cavendish that marks the birth of modern chemical science.[2]

In reflecting therefore, on Cavendish's researches, investigations and discoveries, certain features immediately occur to any observer, and these are characteristic of him, - his wide range of interests with depth of inquiry. This inquisitiveness released trends which

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1. Leicester and Klickstein, p.154.

2. Aykroyd, p.85.

made him a pioneer for improvements which took shape later.

He was a thorough scholar who made valuable contributions to physics, as well as to chemistry.(1) His passion for accuracy and detail is evident in all his work, but he was not an eternal measurer, nor a scientific dilettante, but a person of ideas who had a remarkable gift of knowing almost intuitively what kinds of problems were worth investigations.(2)

One writer strikes the right note when he says that, 'the notion that Cavendish was motivated by a directionless empiricism cannot be sustained'.(3) He comes forward strongly as a man of ideas whose life was always directed towards a course for the future progress of science.

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1. Leicester and Klickstein, p.134.
2. Berry, p.21.
3. McCormach, (H.C.), p.306.

CHAPTER III

CAVENDISH'S JOURNEYS (1785-1793)

Cavendish rarely left London for any purpose which might be described as a holiday. Neither the countryside nor the sea had attraction for him. To Cavendish a change of occupation was as good, if not better than a holiday, and it was well-known that he could turn from one investigation to another with perfect ease; indeed, he was a remarkably many-sided man, and it was the usual practice for him to pursue research more or less simultaneously, in very different branches of science.

The science of geology at this period was in its infancy, and through the influence of his friend the Rev. John Michell, Cavendish became involved. Thus, among his unpublished papers, it is not surprising to find records of a series of geological excursions in England and Wales spanning the years 1785 to 1793.

Wilson in his Life of Cavendish draws attention to these papers which were placed at his disposal through the good offices of the Rev. W. V. Harcourt, and the courtesy of Lord Burlington, and concurs, in the hope expressed by Mr. Harcourt, 'that at least the more important among them will yet be published in full'.(1)

These papers are enclosed in a parcel labelled 'Journeys', but the title is stretched to include many accounts of engineering and

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1. G. Wilson, The Life of the Hon. Henry Cavendish (1851), p.51.

manufacturing processes which he encountered on these journeys; processes such as dyeing in the west of England, iron manufacture and mechanical engineering at Birmingham and its vicinity, alum manufacture at Whitby, mining reduction and working of tin, copper, lead, iron, steel, alum-schist and the like in Yorkshire, Derbyshire, Staffordshire, and in the south west country, as well as metallurgical operations in South Wales. All these he describes at great length and with his usual admirable clearness; yet no published record has ever been made available of this mass of knowledge.

How could this be?

Sir Joseph Larmor, and Sir Archibald Geikie, are known to have thought the manuscripts to have no particular value to warrant publication, but surely this view is hardly acceptable.(1) The changes (even the lack of change) which have taken place in the manufacturing world since Cavendish described it over two hundred years ago provide a fascinating study to the lay man, as well as to students of science of the p present day.

The extensive tours undertaken by Cavendish occupied a relatively short period in the closing years of the eighteenth century, and took place during the summer and autumn, in the years 1785, 1786, 1787, and 1793, while a further journey, undated, though probably in 1788, and identified with Cavendish, is also recorded. They were so widespread as to include the greater part of England but especially the southern and western counties, the Midlands, and the counties of Yorkshire,

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1. The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. II: Chemical and Dynamical, ed. Edward Thorpe (1921), pp.431-432.

Cumberland and Westmoreland. In fact Cavendish travelled as far as Whitby on the north-east coast, and Truro in the south west, while his 1785 Journey took him through most of the counties of South Wales but there is no record that he visited the south-eastern counties of England.

Besides these journeys, there are records of two others carried out for him by Blagden. One was a brief visit to France in 1787, and the other, a more protracted excursion recorded in Cavendish's handwriting, was conducted through Belgium to central Europe in 1789.

The journeys are recounted as a succession of diary entries, probably written at leisure and for the most part by Cavendish. Some of them have been transcribed by an amanuenisis, but Cavendish has corrected the mistakes where the writer had difficulty in deciphering certain words in the text, or where he found himself in trouble with some unfamiliar scientific terms.

In the same parcel there is also an untitled essay which Cavendish has written summarizing the geological observations he made on his journeys, including a general survey of the uppermost strata formation prevalent throughout the country. There were also two letters amongst these manuscripts, one from Michell to Cavendish, and the other one is Cavendish's reply.(1)

What was the object of these Journeys?

It is reasonably certain that the chief purpose in embarking on such a series of tours was entirely scientific and in a special sense too, viz; for the investigation of the geological and mineralogical

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1. The three documents are reproduced in Appendix I, and the brief references, 'C', 'M', and 'S' noted in the Glossary and Index, referring to these MSS. are used here, when allusion is made to them.

features, and for a collection of mineral specimens, characteristic of the districts through which Cavendish passed. No doubt he had also another reason in mind, namely to familiarize himself with technical and manufacturing operations depending upon the applications of chemistry and physics.

The manuscript of this geological summary, in Cavendish's own hand-writing was submitted to Sir Archibald Geikie in order to contribute his impressions of Cavendish as a geologist. He says that Cavendish evidently had a keen interest in tracing out the distribution of some of the more conspicuous geological formations across central and southern England, but he identified them as he confessed, only by their superficial characters.(1)

Geikie points out that these characters are often deceptive, and one of them on which Cavendish seems to have laid considerable stress was their colour. He has referred frequently throughout the text to colour names.(2) When he found a yellow limestone, he concluded that it lay immediately below the clay (Gault) which underlies the chalk.(3) Michell pointed out to him that another yellow limestone below the 'Lyas' was extensively developed from Leicestershire to Yorkshire, and further north.(4) Cavendish accepted this statement calling Michell's formation the Ancient Yellow Limestone.(5) There can be no doubt, says Geikie, that this was what we know as the magnesian limestone which

1. 'S', p.7.
2. 'S', p.5.
3. 'S', p.4.
4. 'M', pp.4-6.
5. 'S', p.12.

overlies the coal-measures as Michell pointed out.[1]

Geikie was satisfied that Cavendish recognised that a succession of formations could be traced from the chalk downwards through clay (gault) then sands (greensand) to his 'yellow limestone' which seems to have been the portion of the calcareous zones in the Oolithic series below which he saw that the 'Lyas' lies.[2] He seems to have formed a general notion of the distribution and trend of these formations in the wide extent of country which he had traversed. He perceived that they are less inclined to the horizon than the older rocks which lie to the west of them, and he correctly inferred that, 'for the most part the farther we go to the W. or N.W., the lower the strata we meet with'.[3]

He gives a curious proof, comments Geikie, that 'a very imperfect knowledge of the strata is to be acquired by merely looking at the surface, as is my case.'[4] He took the clay which lies below the gravels of London to be the same as that which lies below the chalk, and 'he supposed that the chalk has been entirely washed away from the London plain'.[5] He did not know that this thick formation lies still intact below the London clay, protected from denudation by the mass of overlying tertiary deposits.

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1. Sci. Pap., Vol. II, p.432. 'M', p.6.
2. 'S', pp.5, 6, 11.
3. 'S', p.11.
4. 'S', p.7.
5. 'S', pp.2-3.

According to Geikie Cavendish entirely missed the meaning of the Derbyshire Toadstone, preferring Michell's idea that it is 'clay which was heated in its place', instead of Whitehurst's who recognised the volcanic origin of the rock.(1)

It is curious to reflect that while Cavendish was perambulating England in geological excursions, William Smith was busy with those observations and influences among the very same rocks, which gave him the true key to the stratigraphical succession, and laid a sound foundation for stratigraphical geology. Indeed, William Smith, (1769-1839), stands in the front rank of the discoverers who flourished in Britain at the turn of the century. He became convinced that each stratum contained its own peculiar fossils, and might be discriminated by them. In 1815 he was able to submit a complete coloured map of the strata of England and Wales to the Society of Arts. As an original discoverer his fame was secure, and during his own lifetime he was acclaimed the Father of English Geology, while abroad, after the lapse of over a century, he is styled the Father of Stratigraphical and Historical Geology.(2)

In concluding his observations Sir Archibald considers that Cavendish's paper should not be published, because it is of no geological importance, nor does it add anything of consequence to his scientific renown.(3)

Nor, let it be added, if the paper had been published, and so

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1. 'S', p.14.

2. A.G. Davis, 'William Smith, Civil Engineer, Geologist (1769-1839)', Transactions of the Newcomen Society, Vol. XXIII, 1942-1943, (1948), pp.93-98. D.N.G.

3. Sci. Pap., Vol. II, p.432.

JOURNEY – 1785

SUNDAY JULY 17th — SATURDAY AUGUST 6th

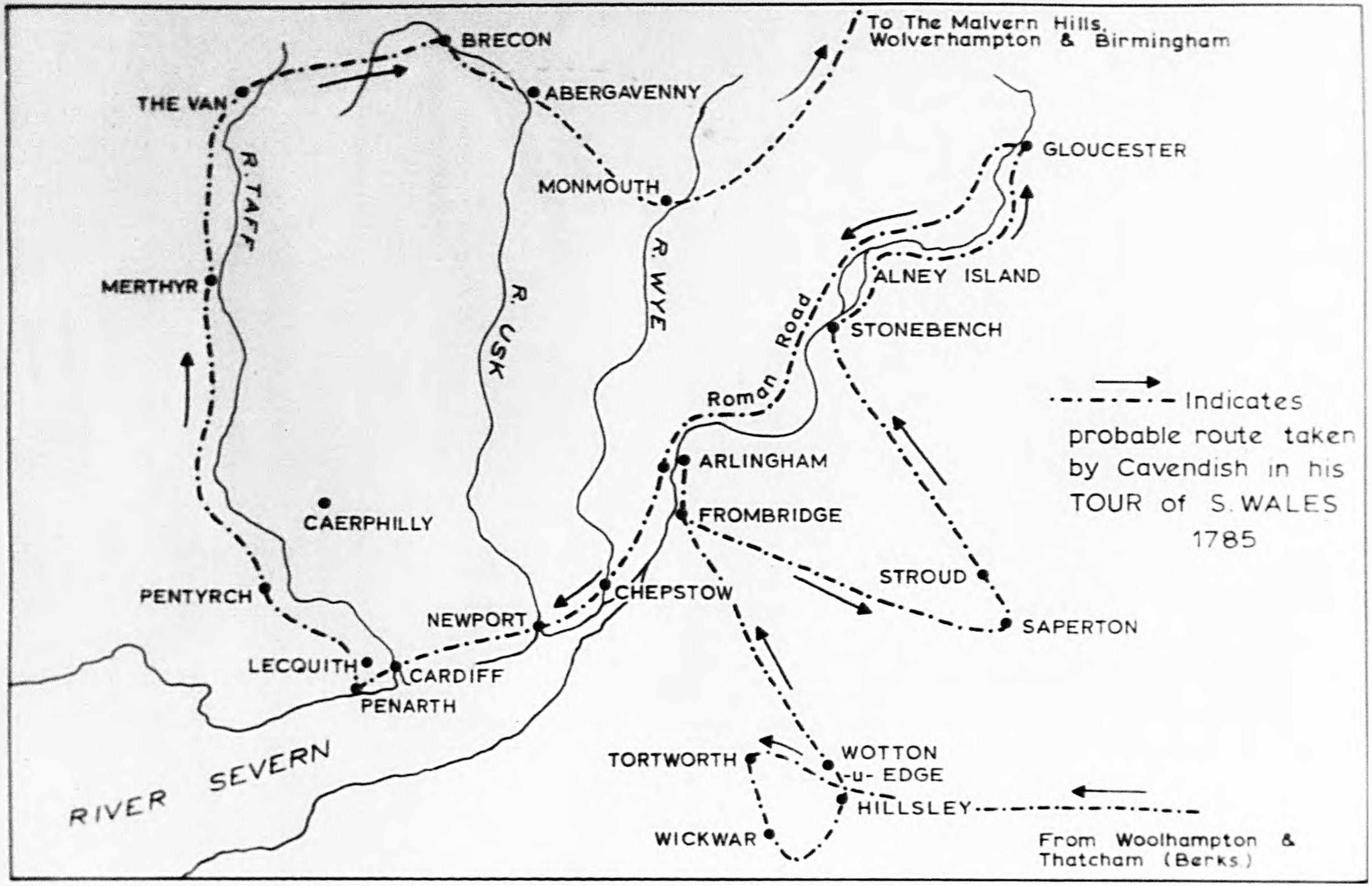

PLATE IV

CAVENDISH'S JOURNEY 1785

made available for scientists in the future to judge it for themselves, would Cavendish's reputation have suffered, to any material extent?

After all Cavendish did not profess to be an authority on this new branch of science, while the question of the scientific value of the paper is of less importance now than it was fifty years ago, and less still in the eighteenth century. What is of moment is the measure of the depth and range of his interests at that time which is so realistic and revealing as to justify bringing to light anything associated with the great philosopher, and this a biographer would naturally wish to do.

Of all Cavendish's Journeys, the 1785 tour contains the fullest account with sixty two pages of the most varied, interesting and detailed information that a traveller could provide, compiled as a journal yet in language clear, concise, and descriptive. Before the journey is described, a brief reference must be made to the state of contemporary Britain of that period.

During the second half of the eighteenth century the population had risen sharply; the progress of the nation was great, while the advance in wealth was even greater, and industry had begun that surge forward which was to make Britain the workshop of the world. In fact the American War much more than the writings of Adam Smith made evident the decay of the old economic policy, and hastened its end. Whilst the American Revolution was taking place the genius of inventors, and the happy initiative of manufacturers were creating a new America in the very heart of England.(1)

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1. P. Mantoux, Industrial Revolution in the Eighteenth Century (1961), p.99.

The volume of foreign trade, the main source of wealth for a nation, and the size of the Mercantile Marine were growing progressively year by year. According to the Custom House Books, the tonnage of commercial vessels leaving English ports in 1700 did not amount to more than 317,000 registered tons; by 1800 the figures had reached 1,924,000, the increade being steepest during the twenty years preceding this date.(1)

For the moment English manufacturing processes were too rude to admit of any large scale production; thus industrial life at home was still chiefly agricultural, and local, as movement was somewhat restricted because of the primitive road system. The older main roads which had lasted through the middle ages had broken down before the growth of traffic, and the increase in the number of wagons and carriages. The new lines of communication were destined to lay often along mere country lanes hitherto no more than horse tracks.

However, a new Era began when the engineering genius of Brindley joined Manchester with its port of Liverpool in 1767 by a canal. Its success was immediate and led to the country-wide introduction of water ways for transportation, and Great Britain was soon to be traversed in every direction by 3,000 miles of navigable canals.(2)

At about the same time a new importance was given to coal which lay beneath our English soil. The stores of iron which had lain side by side within the northern counties had been unworked because of the

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1. Mantoux, p.100.

2. Chatsworth MS., X(a)4. Journey 1785, p.8 - Appendix I.

shortage or scarcity of wood which was looked upon as the only fuel by which it could be smelted.(1) In the middle of the eighteenth century a process for smelting with coal was found to be effective so the whole outlook for the iron trade was revolutionized.(2) Iron was to become the working material of the modern world, and it was its production which more than anything else gave to England the premier place in industrial Europe.(3)

Cavendish was well aware of what was happening in the country, and with his penetrating mind in the field of science he was anxious to absorb all the information he could properly and conveniently accumulate from his visits to the large industrial works belonging to the most prominent owners of the century. It is equally plain from his instructive and knowledgeable Journal of 1785, that the owners and the officials of these busy concerns, were just as ready to give as he was to receive any available help about the many machines and processes of manufacture.

Cavendish could foresee in coal a future use as a fuel for motive power to produce an industrial revolution itself. The value of coal as a means of generating mechanical force was revealed in the discovery by which Watt in 1765 transformed the steam-engine from what was then a mere toy into one of the most wonderful machines known to industry. It was opportune too, as the invention of the steam-engine came at a time when the supply of labour could not meet the demands of the manu-

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1. Chatsworth MS. X(a)4. Journey 1785, pp.10, 14-18., - Appendix I.
2. Chatsworth MS. X(a)4. Journey 1785, pp.10, 40-51., - Appendix I.
3. Chatsworth MS. X(a) 4. Journey 1785, pp.19-30., - Appendix I.

facturer. Three successive inventions in the space of a dozen years, that of the spinning-jenny in 1764 by the weaver Hargreaves, of the spinning-machine in 1768 by the barber Arkwright, of the 'mule' by the weaver Crompton in 1776, were followed by the discovery of the power-loom.

These would have been comparatively useless had it not been for the steam-engine, that 'new and inexhaustible labour force'. It was the combination of such a force, with such means of applying it that enabled Britain during the years of her struggle with France and Napoleon, almost to monopolize the woollen and cotton trades, and that raised her into the greatest manufacturing country in the world.(1)

Such was the position in contemporary England during the latter part of the Cavendish age, and throughout the country during his travels he would see for himself signs of the revolution in industry which had already begun. He had this opportunity when he entered the industrial regions of South Wales, but to venture there he had first of all to compete with an indifferent road system - a hazardous outlook. True there was feverish activity in road building about this time, and one engineer stands pre-eminent, Jack Metcalfe, the blind-carrier of Knaresborough who invented a cheap way of giving a firm surface to bogs by which they could be easily crossed; but every district had not a Metcalfe. It was not however until the days of Telford and McAdam, towards the end of the eighteenth century, that England obtained a network of good roads.(2)

1. J. R. Green, A Short History of the English People (1874, revised 1919), p.792.

2. W.H.G. Armytage, A Social History of Engineering (1961), pp.83-84. Mantoux, p.119.

It is not known how Cavendish fared in these tours, except that he would record each day the distance he travelled by means of a way-wiser attached to his carriage.(1) Either he was prepared to accept all the difficulties ahead with complacency or to meet the challenge involved in a spirit of adventure. Perhaps the first part of his 1785 tour was plain-sailing, but eventually he had to negotiate the crossing of the River Severn into Wales, which he could do in one of three ways: he could sail by market boat from Bristol to one of the Welsh ports, or cross the river at 'The Passage' by an uncertain and dangerous ferry, or travel by land to the first bridge across the Severn. This was at Gloucester, but by this route, or by the more northerly Wye Gap, the hills which Defoe thought 'horrid and frightful' were barren and uninviting.(2) Then from Gloucester there were two main roads into South Wales, both Roman in origin. One ran along the coast, and the other wound through the hills, but both these trunk roads were indifferently maintained; the coastal road the worse as Young testifies, but both were better than the roads which linked the villages.(3)

As Cavendish was in the vicinity of Gloucester at this time he probably crossed by the bridge, and elected to follow the coast road into South Wales, because he does call attention to the cliffs at Newnham on the west bank of the Severn. Indeed he showed much genuine interest in the river and the region round about. He had watched the drawing of brass and iron wire at Frombridge, he took a critical note

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1. Sci. Pap., Vol. II, p.431.

2. A. H. John, The Industrial Development of South Wales (1950), p.2.

3. John, p.3.

of the dimensions of the tunnel cutting at Saperton for the canal extension, and at Stroud he was informed that the old canal had not yet paid a dividend to the proprietors, while the Severn 'Bore' proved a great attraction for him, and he gleaned some information from a local inhabitant, about the behaviour of the noisy tidal wave.(1) He will be observed rubbing shoulders with all and sundry, making inquiries of workmen in quarries, men in foundries, a post-boy on his delivery, managers of works, proprietors of big industrial concerns - with every stratum of public life he was ready to enter into friendly conversation. Yet, he was characterized as a misanthrope, a social outcast, an oddity in more ways than one.

How strange an assessment! It gives cause for disappointment that these Journeys have been treated too perfunctorily.

However, travellers and wayfarers who persisted, despite the condition of these roads, found a community composed largely of peasant agriculturalists, and a few but increasing number of industrial workers. Agriculture described by Robert Owen the great Welsh economist, as traditional at the end of the sixteenth century, was still seen by Arthur Young in 'His Travels' at the end of the eighteenth century, so slow was the desire or urge for change.(2)

Each village had its tailor, sadler and shoe-makers, while here and there were clock-makers, and in the larger towns, printers. More widespread was the domestic industry of spinning and weaving of wool.

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1. Chatsworth MS. X(a)4. Journey 1785, pp.6-9, - Appendix I.
2. John, p.5.

Coal which was subsequently to become so important, wherever it outcropped was worked by farmers only for their agricultural and domestic needs.

More important as inland centres of industry, were the scattered furnaces and forges, which had become more numerous since the beginning of the century. Between Aberavon and Swansea where collieries were supplemented by tinplate and copper works, the influence of industrialism on the economy of the neighbourhood was already important.

Capitalists far beyond the border had also appeared in the iron industry. In 1749 Jordan and Homfray of Stafforshire took over the Mellingryffith works, while the Forge, of the same name, was established by Rees Powell of Llanharan shortly before 1749. Other active ironmasters at the middle of the century were Nicholas Pryce of Pentyrch Forge, and the Lewises of Llanishen.(1) With one or two exceptions, the coal industry was still completely in the hands of the local landlords.

In the week beginning Monday, the 25th of July Cavendish began his industrial tour of South Wales at Mr. Lewis's works, but, 'The furnace at Pentyrch not being in blast we could only examine the forges'.(2) He describes the process of heat treatment of the iron, but as 'they were putting a new hearth in the furnace',(3) Cavendish was unable to observe the process, so he had to rely on an explanation of the method of smelting and tapping.(4) The visit occupied at least

1. John, p.8.
2. Chatsworth MS. X(a)4, Journey 1785, p.10, - Appendix I.
3. Chatsworth MS. X(a)4, Journey 1785, pp.15, 17, - Appendix I.
4. Chatsworth MS. X(a)4, Journey 1785, p.28, - Appendix I.

a day, but as the territory round the valley of the Taaf appealed to him he was prepared to break away from the grime of industrialism to wander among the hills around Pentyrch.

From here he ascended the Garth to Caerphilly Common in search of more geological material but the next day, Wednesday the 27th of July he visited the Mellingryffith works.[1] This was a typical tin-plate works of the eighteenth century, the only one of which any records have been preserved to throw light on the conduct of the industry at that time.[2] In 1768 a Bristol firm took over these works and installed a manager, and as they were within easy distance of Cardiff and not far from Bristol, they could secure supplies of raw material and machinery by sea, including Cornish tin, while from the nearby Pentyrch Forge they were able to obtain some bar iron. Coal, bran, and charcoal were acquired locally.[3] Bolts for ships were made at Mellingryffith;[4] in fact the American War had created much work for the iron industry of South Wales, including the manufacture of cannon balls, and other munitions, while during the Napoleonic Wars even spectacular development took place as conditions were most favourable.[5]

Cavendish now makes another diversion, 'having heard that the

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1. Chatsworth MS. X(a)4, Journey 1785, p.19, - Appendix I.
2. W. E. Minchinton, The British Tinplate Industry (1957), pp.20-24.
3. Chatsworth MS. X(a)4, Journey 1785, p.20, - Appendix I.
4. Chatsworth MS. X(a)4, Journey 1785, p.21, - Appendix I.
5. John, p.25.

blue lyas limestone was at Penarth Point we went thither',[1] and wanders on the banks of the Severn before making the long journey to Messrs. Humphries Works at Merthyr. He meets Mr. Birch,[2] the engineer at these works who was a person of some influence in the Aberdare Valley, and Cavendish was much impressed with his idea to convert the superfluous air which escaped from the main cylinder of the engine into 'the working of a forge'.[3] Not far away, a mile in fact from Merthyr, were the Cyfarthfa Forges belonging to Mr. Bacon, the great ironmaster. He was originally a London merchant who knew South Wales well, and in 1765 entered into partnership with William Brownrigg to establish the Cyfarthfa Furnace at Merthyr, and because of the call for war material Bacon extended his operations by leasing other furnaces.

Like many centres of the iron industry South Wales had always benefited from War and its demands which enabled Anthony Bacon to make Cyfarthfa Ironworks into the largest munition works yet established in the coalfields.[4]

The visit to Cyfarthfa could not have been a prolonged one, for on the same day Cavendish records 'proceeding up the valley of the Taaf towards the Van',[5] thence making for the ancient town of

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1. Chatsworth MS. X(a)4, Journey 1785, p.18, - Appendix I.
2. Dramatis Personae - Appendix III.
3. Chatsworth MS. X(a)4, Journey 1785, p.25, - Appendix I.
4. John, p.99.
5. Chatsworth MS. X(a)4, Journey 1785, p.31, - Appendix I, - See Plate XV.

Monmouth as their objective, 'many miles away'. They may have looked upon Monmouth as the Gateway to England and a suitable resting place before launching a final assault on the west midlands towns, with Birmingham as their goal.

It was at Birmingham, that Cavendish met Watt, apparently for the first and only time, but it was no chance affair. That such a retiring individual as Cavendish should have taken the initiative to call upon his rival and display keen interest in his inventions refutes the charge that Cavendish hated him because on one occasion he grudged him the merit of a discovery, or robbed him of it. It has been said that 'we hate those whom we have wronged', but there was nothing to indicate hatred in Cavendish's visit to Watt.(1)

The meeting must have been mutually welcomed, and it is plain that Cavendish displayed much interest in anything the great engineer had to show him. He saw a machine for twisting the handles of horse-whips;(2) he was informed of the great inconvenience complained of in the needle manufactory of their warping in hardening; at Snow Hill he records a visit to a rolling mill for the manufacture of silvered plates, and comments on the rotary motion given to the steam engine.(3) Cavendish adds, that it was invented, or at least the patent for it obtained by a Mr. Picard who has sold it to the present proprietors, but Mr. Watt claims the original idea. Perhaps also Cavendish may have learned the truth of how mischieviously Picard

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1. Wilson, p.162.

2. Chatsworth MS. X(a)4, Journey 1785, p.32, - Appendix I.

3. Chatsworth MS. X(a)4, Journey 1785, p.32, - Appendix I.

became possessed of this patent.

During the latter part of their time together Watt explained to Cavendish at the Soho Works how the fashionable gilt button was treated in its manufacture, and also took trouble to describe and demonstrate the improvements he had effected in his steam-engine.(1)

Cavendish must have taken a more sincere interest in Watt's claims as an inventor, than he rarely took in questions of relative priority or originality, which confirms the premise that any hard feeling which existed between the two men as strangers in 1784, was transformed into mutual respect immediately they met in 1785. In the account given by Cavendish he chooses to mention Watt by name on four occasions.(2)

After his salutary meeting with Watt, Cavendish in company with his friend Blagden continued his journey in the direction of 'Woolverhampton' till they came to Mr. Wilkinson's Ironworks at Willey near Broseley.(3)

Mr. Wilkinson takes charge of his visitors and explains the special features of the minerals he uses in his furnace, and points out that; 'His iron is all made with coak from ore and coal found on the spot. The ore is of two kinds, called pinny and flinty ore, the latter harder than the former, but both he considers as a clay stone, impregnated with iron.'(4) Mr. Wilkinson also described a

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1. Chatsworth MS. X(a)4, Journey 1785, p.35, - Appendix I.
2. Chatsworth MS. X(a)4, Journey 1785, pp.35-38, - Appendix I.
3. Chatsworth MS. X(a)4, Journey 1785, p.40, - Appendix I.
4. Chatsworth MS. X(a)4, Journey 1785, p.40, - Appendix I.

JOURNEY – 1786

AUG 22nd 1786

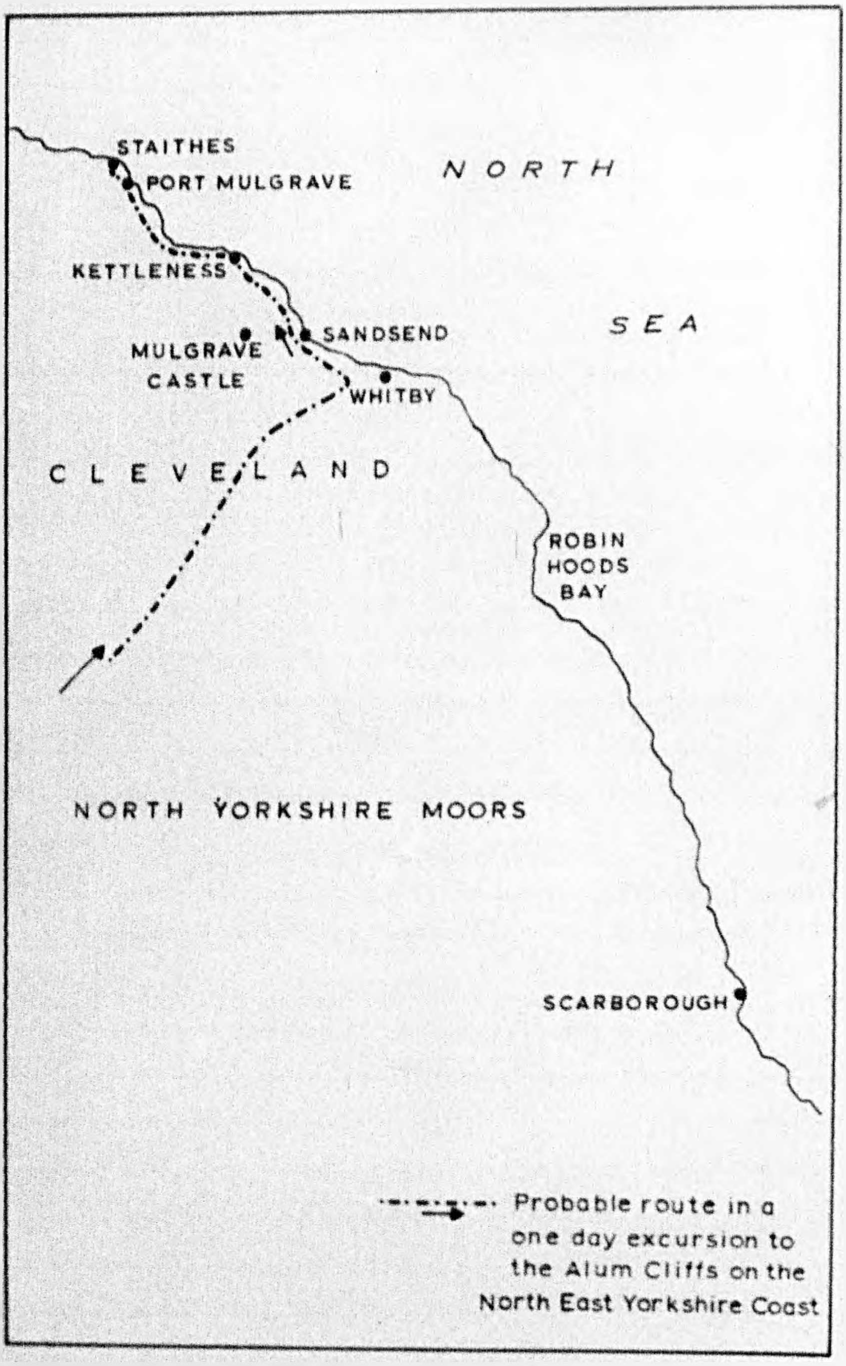

PLATE V

CAVENDISH'S JOURNEY 1786

faulty seam of coal near his works, which he called a 'hog's back'. The works contains 'two steam engines, one for the blast, and the other to raise water to work the hammers'. 'The forged iron Mr. Wilkinson here makes is chiefly used for nails, it is not so malleable and tough as the charcoal iron made in England; but that Mr. Wilkinson imputes to the nature of the ore, and says, 'this coak iron is better than it could be made by charcoal with the same ore; the reason he assigns is, that more of the original pig is worked away'.

The end of this long journey is in sight, but it is crowded with more visits to the industrial part of Shropshire where Cavendish describes in much detail what he saw. At. Mr. Rathbone's works at Coalbrookdale where the Iron Bridge was cast, 'they have two furnaces', and he was happy to add that the engine was of Watt's construction.(1) Intrigued by something he noticed there as unusual, he inquired of the use of the balls of fresh horse-dung lying in a basket. He learned that they were put into the boiler of the engine when any leak was noticed, as it worked into the leak and stopped it.(2) Not far from the Iron Bridge Cavendish came to the distillation plant also belonging to Mr. Rathbone, which manufactured coal-tar.(3) He describes the distilling process, but says, 'they also shewed us some pitch exactly like Lord Dundonald's'.(4) They said that they could not afford this tar, though much cheaper than the foreign, on account of the great

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1. Chatsworth MS. X(a)4, Journey 1785, p.45, - Appendix I.
2. Chatsworth MS. X(a)4, Journey 1785, p.54, - Appendix I.
3. Chatsworth MS. X(a)4, Journey 1785, pp.47-48, - Appendix I.
4. See Dramatis Personae, - Appendix III.

JOURNEY – 1787

DATED JULY 15th 1787

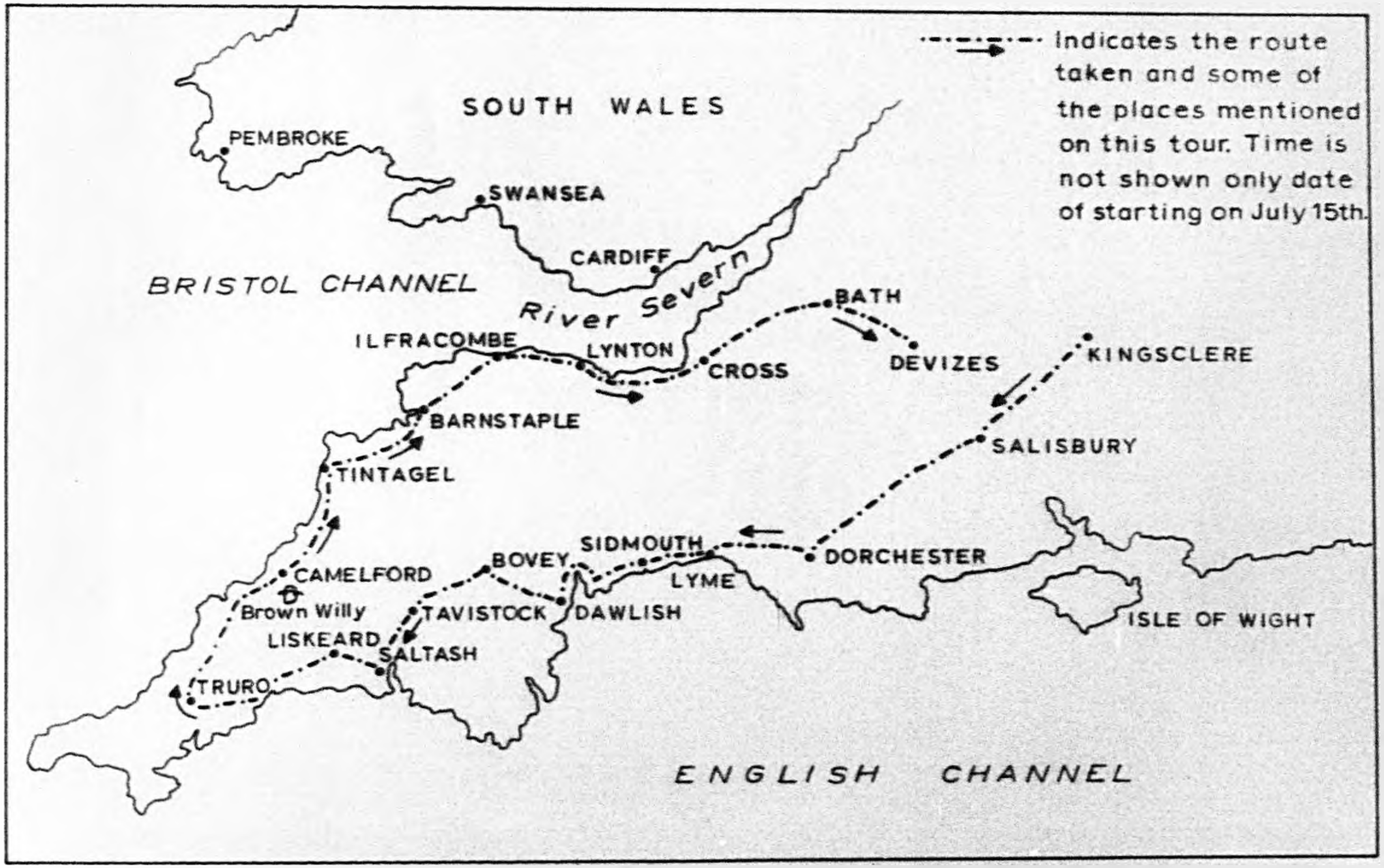

PLATE VI

CAVENDISH'S JOURNEY 1787(i)

expense of casks for packing it up. It is used by the craft upon the Severn. Many of the bargemen prefer it to every other kind, but others complain that it being of a very penetrating nature is too soon absorbed by the wood and Oakum, and exposes the vessels to grow leaky.(1) The visit made to Coalbrookdale was probably a little diversion, for he says, 'we returned to Mr. Wilkinson's Forges at Willey by Broseley, to see the operation of Shingling'.(2)

The last recorded entry in his journal of 1785 was on Saturday, the 6th of August, after a tour which began on the 19th of July. Birmingham was the finishing post, but on his way there, between Bilson and Wednesbury, he made a brief detour to visit Mr. Wilkinson's new works at Bradley, describing the furnace and forges with customary care and detail, and remembering to add in conclusion a reminder, that the engine was of Watt's construction.

So the Journey of 1785 came to an end and with it the fullest account we have of any tour he undertook. The following year saw the shortest of them: it was a visit to the Yorkshire coast on the 22nd of August, primarily to investigate the alum resources at Whitby. He describes the quarrying of the alum-schist, and its processes right to the finished product, when the alum is packed up ready for sale.(3)

In the next year, 1787, Cavendish makes two separate journeys to the south west country, the first of which is described under a

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1. Chatsworth MS. X(a)4, Journey 1785, p.48, - Appendix I.
2. Chatsworth MS. X(a)4, Journey 1785, p.50, - Appendix I.
3. Chatsworth MS. X(a)5, Journey 1786, p.4, - Appendix I.

single diary entry, the 15th of July; hence the duration of this tour is unknown, except that he returned to record the start of his second journey on the 30th of July. Each tour had its own distinct objective. The first journey was a geological expedition with geodetic readings taken at selected points on the way in accordance with the barometric method: the points en route he indicated by the entry, 'here observed the barom'.(1)

The second tour, over much the same ground was an engineering exploit, not unlike the extensive industrial visits he made during his 1785 journey in South Wales. This time he concentrates on visits to tin and copper mines witnessing a variety of processes connected with these metals, and is permitted the privilege, 'shown to very few persons', of observing the secret process of Japanning of copper.(2)

Cavendish and Blagden must have felt a deep attraction for this part of the country, having been there 'in a former journey'.(3) The account of the first tour is compiled in the handwriting of Cavendish, who refers to his companion Blagden, but the following journey is a much fuller description in the hand of a copyist where allusion is made to 'Mr. Cavendish', so it may well be that Blagden recorded the visit even though Cavendish corrected the mistakes of the writer.

The first of the 1787 tours started on the 15th of July, when the party left Kingsclere bound for the chalk downs in the direction

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1. Chatsworth MS. X(a)7, Journey 1787(i), pp.1,3,6 - Appendix I.
2. Chatsworth MS. X(a)6, Journey 1787(ii), p.4, - Appendix I.
3. Chatsworth MS. X(a)7, Journey 1787(i), pp.5, 8, - Appendix I.

JOURNEY – 1787

JULY 30th – AUGUST 10th

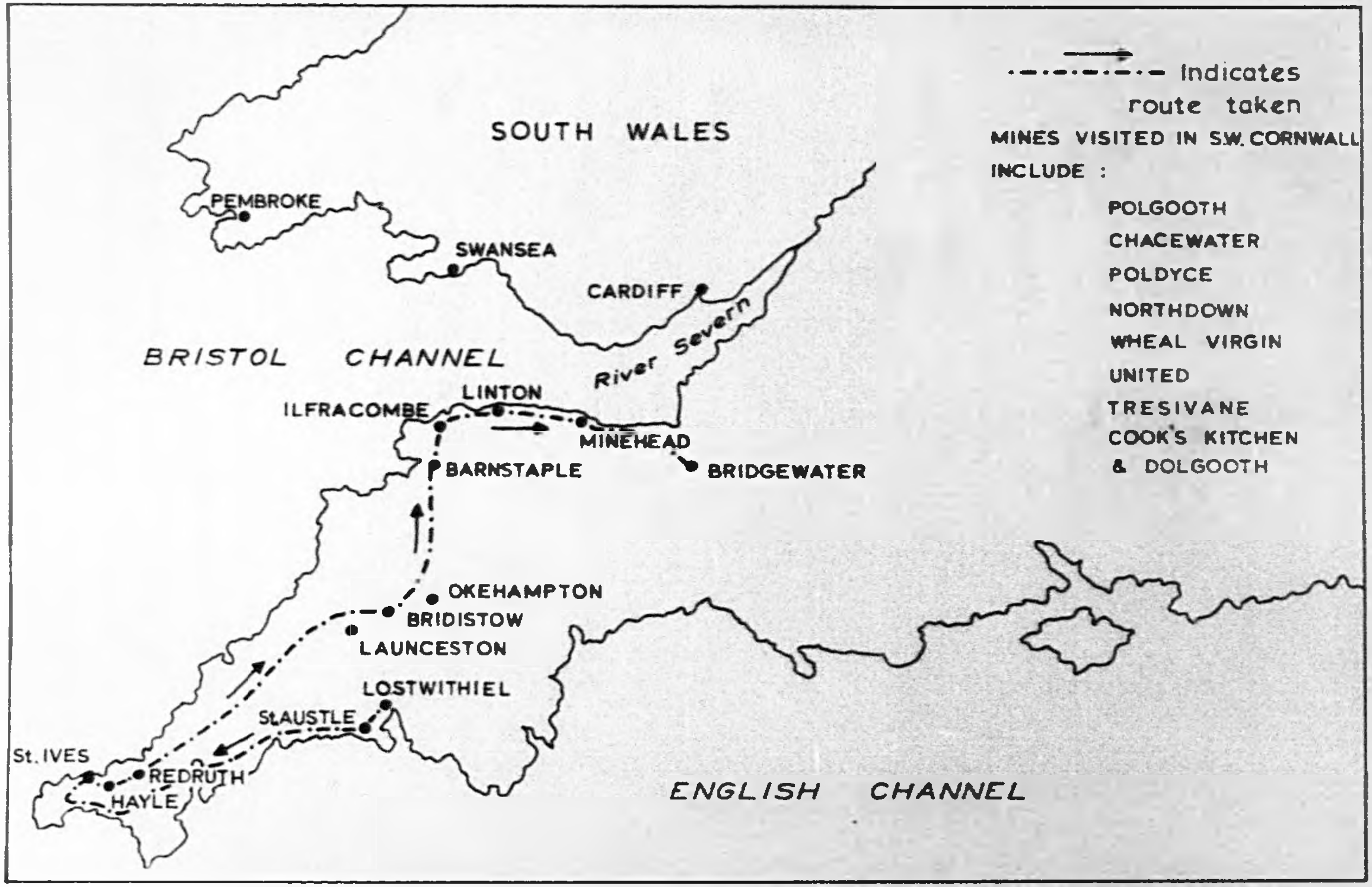

PLATE VII

CAVENDISH'S JOURNEY 1787(ii)

of Salisbury. One is not lead to anticipate graphic descriptions of the landscape from Cavendish yet he does outline scenes which appeal to him in an interesting and easy style. He sees the vista of that lovely Cathedral rising before him as its spire appeared considerably above the distant hills. It is well known that the spire, 404 feet in height, is the tallest in England, and was added between 1335 and 1375, one hundred years after the Cathedral was built. 'The country from Salisbury to beyond Dorchester, though all chalk', he observes, 'was fuller of wood and hedgerows than chalk countries usually are, but scarce any streams in the valleys, except the Blandford and Dorchester rivers.

These journeys gave Cavendish opportunity to recount the grandeur of the scenic beauty he met in his travels, the marvels of the universe, the notable features in peoples of different localities, but such descriptions find no place in the records of these journeys.

However that may be, there are occasions when he is more realistic; he says in describing the banks of the Severn about Bridgnorth, 'The Terras-Walk commands a remarkable scene from the singular appearance of these rocks all around, but especially on the opposite side of the River Severn, the eastern, and from the fine view of the river underneath. The remains of the old castle battered by Oliver Cromwell exhibit a remarkable instance of a leaning tower or ruin which produces a fine effect. The town is supplied with water from the Severn by means of wheel-work, turned by the current of the river, without any other fall than what is produced by stopping the current in that part, and the height of great part of the town above the river, is very considerable. We were told they had no other water'.[1]

Thus Cavendish's touches of description were always neat and apt, and as he moved round Lyme Bay, concentrating on the geology of the area, he took careful note of the red loam of Devon, the white clay of Kingsteignton, and pauses to inspect the coal formation of Bovey, possibly because Dr. Blagden had been there on a previous journey.[2]

Throughout this tour he never loses sight of rock formations, nor reflects to ascertain heights here and there, and on reaching Hey Tor, the highest point of Dartmoor, so it seemed from 'Lyme and other distant places', he found the road system hazardous, and thus wisely employed the services of a guide.[3]

As soon as he entered Cornwall at the estuary of the Tamar, he observed Wedgwood's clay pits at St. Stephens near Saltash. This is interesting as throwing light on, or underlining another kind of aristocracy which arose during the latter part of the eighteenth century. They were the new captains of industry, who were ready to see the possibilities of fortune ahead, and were quick to seize opportunities to make them. Shortly they were to rival the oldest families in the land.

Wedgwood, the potter, was a typical example of this new born class, and together with his friend Thomas Bentley had shown fervent interest in the Mersey to Trent Canal which was to pass through the

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1. Chatsworth MS. X(a)4, Journey 1785, pp.56-57, - Appendix I.
2. Chatsworth MS. X(a)7, Journey 1787(i), p.5, - Appendix I.
3. Chatsworth MS. X(a)7, Journey 1787(i), p.6, - Appendix I.

Potteries, and so provide a means of cheaper transit for his Cornish clay.(1)

If Connwall was known for its China clay, it was famous for its granite, even though Cavendish says that, 'Cornwall consists chiefly of Killas, the granite seldom appearing except in the high hills'.(2) He names these hills, and takes readings with his barometer to calculate the heights of those near and far away, and his deductions are particularly noteworthy.(3) The granite hills of Caradon, the Cheese rings, Brown Willy and Rowtor, stand out most prominently, as Cavendish noticed, and in a recent poem by Sir John Betjeman titled, 'One and All', the poet pictured a similar scene;

'A waste of undulating ocean
From which juts out, a second Scilly
The Isles of Roughtor and Brown Willy'.

In this journey, as in most of the others too, Cavendish gives the impression of choosing certain places along his line of route, and making them centres for short-excursions in the vicinity - a commendable way of avoiding routine. He now moves into North Devon and thence in the direction of Bath which provided little geological interest for him. Finally, he completes his tour by remarking that, 'The road from Bath to Devizes has been changed near last place so that I did not pass by that place where in a former journey I saw stone just below the Devizes but as the road thereabouts is mended with

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1. Mantoux, p.128.
2. Chatsworth MS. X(a)7, Journey 1787(i), p.6, - Appendix I.
3. Chatsworth MS. X(a)7, Journey 1787(i), p.6, - Appendix I.

yellow limestone that stone was most likely the same. For several miles before we came to Devizes the country was low and we saw no stone of any kind.'[1]

Before Cavendish undertook a tour over much the same circuit for a second time, there must have been an intervening period before he began his next journey on the 30th of July, but how much time was occupied, and in what way, is not known. This journey is quite different and distinct from the former, and is largely concerned with tin mining operations in Cornwall, and the preparation of the metal from its ore by a process of 'streaming' which is described fully by Cavendish.[2]

In some mines, for example the Chacewater mine, the lode is known to be a mixture of tin and copper, and in consequence the ore is subject to a separating process. To raise the ore from the mine a small steam engine was used, and it is interesting to note that a double steam-engine was used at Poldyce mine to pump the water from the workings. At this time the Cornish miners were as baffled as they had ever been in their attempts to get rid of the water which hindered mining operations and it seemed that Watt offered the greatest advantages to Cornish industry.[3] Boulton and Watt were now in the process of selling their new steam engine with its rotative motion to clients in Cornwall. A Mr. Edwards, the great Cornish industrialist, who will be mentioned again, was among the first to inquire for the

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1. Chatsworth MS. X(a)7, Journey 1787(i), p.8, - Appendix I.
2. Chatsworth MS. X(a)6, Journey 1787(ii), pp.1-8, - Appendix I.
3. S. Smiles, Lives of the Engineers Boulton and Watt (1904), pp.99-231.

JOURNEY UNDATED

(PROBABLY JULY/AUG 1788)

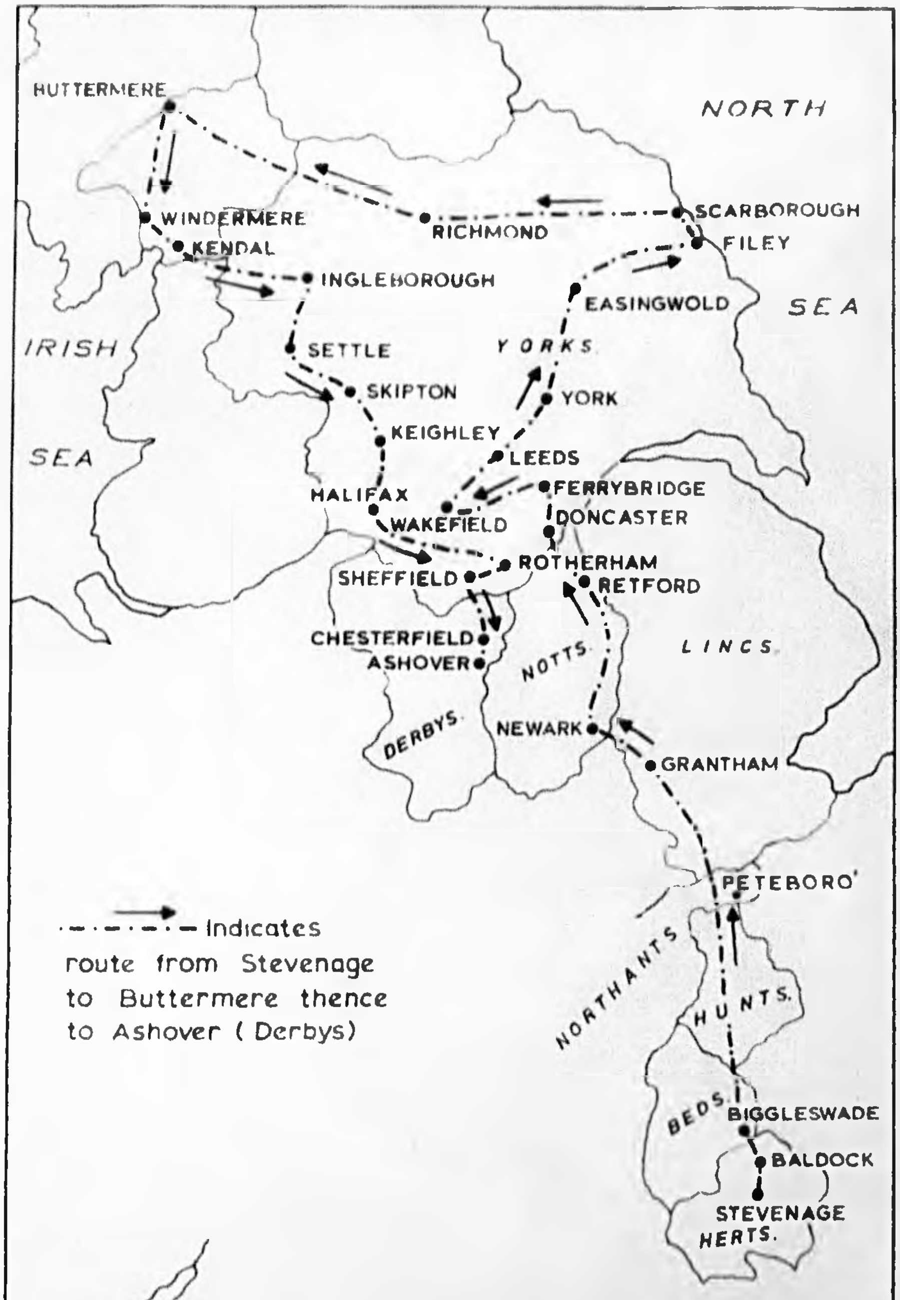

PLATE VIII

CAVENDISH'S JOURNEY 1788?

rotative engine then being planned.[1]

The ore raised from the mine, was now melted to obtain the tin, and this was done in a blowing furnace or smelting furnace, dependent upon the kind of fuel selected to be used, which is described clearly by Cavendish.[2]

Little was known of the tin-plate industry in Britain before the eighteenth century, except from the only records of the trade in existence, which belong to the Mellingryffith works near Pentyrch, a thriving enterprise at that time. Tin-plate making was probably of German origin as far back as the fourteenth century, but was not introduced into England until late in the sixteenth century and won increasing favour, but only as a village craft. The Thirty Years War in 1618 disrupted the manufacture of tin-plate, and it was not until after the Restoration that the industry was revived in Britain.[3] Growth was slow in the first half of the eighteenth century, but when the Seven Years War ended, the trade expanded as the iron industry switched from munitions to make available supplies of bar-iron for other uses, including tin-plate manufacture.[4]

The German tin-plate had been priced out of the British market; as a result the demand for Japanned and tinned ware inproved, and to

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1. T. R. Harris, 'John Edwards (1731-1807), Cornish Industrialist', Transactions of the Newcomen Society, Vol. XXIII (1942-1943), (1948), p.15.

2. Chatsworth MS. X(a)6, Journey 1787(ii), p.16, - Appendix I.

3. Minchinton, pp.1-6.

4. Minchinton, p.15.

meet this growing need new works were set up in places as far apart as Rotherham in Yorkshire, and Woolard in Somerset, but most of them were situated in the west of the country, in the west Midlands, the Forest of Dean, and South Wales.(1)

The industry required above all proximity to supplies of suitable iron and abundant supplies of water for the cleaning processes,(2) and for driving the rolling mills; moreover, water carriage was the main means of transport for both raw materials and the finished product. Since there was no coal in Cornwall tinplate developed as the end-product of iron making rather than of tin making. Accordingly works were set up within the area where suitable 'tough iron' was made, at places like Mellingryffith,(3) and where water for power and transport was available.(4)

By 1800, a tinplate industry, small in scale and subsidiary to the iron industry, had been securely established in Great Britain.

When the ore is extracted from the mine, the process is not necessarily over: for where it is a mixture of tin and copper, as in Chacewater, there is still the copper to be extracted by separation from the tin. Cavendish describes how this is done: 'They break the ore to examine it, to separate the parts which are worth working for tin from those which are to be worked for copper; and the latter parts are then broke smaller, and the mere refuse being thrown aside,

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1. Minchinton, pp.16, 21.
2. Chatsworth MS. X(a)6, Journey 1787(ii), pp.6-8, - Appendix I.
3. Minchinton, pp.20-24.
4. Minchinton, p.16.

the good parts are put in a heap to be carried to the smelting house'.[1] The first part of the process is to roast the ore which the manager, Mr. Edwards explained to Cavendish,[2] who would see for himself the heat treatment in a reverberatory furnace. Then too, he was shown the method of Japanning the copper, a great secret and seen by very few persons.[3]

There were other mines which were worked for copper, and are mentioned by Cavendish, such as Cooks Kitchen, and Dolcooth, while he had also been in conversation with the Captain of the Tresivane mine, a man named Mitchell, who explained to him the complicated strata of his own mine.[4]

Smelting of the ore had been attempted as early as 1700, near St. Austell, and like other works later, failed either through bad siting, the parties not understanding the business, or for lack of capital. Eventually works were established at Hayle, and while it cannot be said with certainty, they continued under the name of the Cornish Copper Company up to the year 1820. The success of this venture was due chiefly to the exertions of John Edwards, a young man of Ludgvan, who speedily acquired the entire management and direction of the whole concern, and as a result of his unwearied exertions, the business continued with success up to the period of his decease in January, 1807.[5]

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1. Chatsworth MS. X(a)6, Journey 1787(ii), pp.11-12, - Appendix I.
2. Chatsworth MS. X(a)6, Journey 1787(ii), pp.22-24, - Appendix I.
3. Chatsworth MS. X(a)6, Journey 1787(ii), pp.24-25, - Appendix I. Japanned bars were bars of copper dipped when red hot into water to giv the red colour found on bars imported from the East. Harris, p.16.
4. Chatsworth MS. X(a)6, Journey 1787(ii), pp.20-21. See also Appendix II
5. Harris, p.16, and Appendix III.

The last entry made by Cavendish on this journey is that of the 10th of August, when he mentions the cliffs at Tintagel, a place called Bridistow, between Launceston and Okehampton, and Hatherleigh at considerable distances apart, and not in his direct line of route to Barnstaple and the North Devon coast.(1) This again, supports the view that he used a place as a centre from which he could make brief excursions. When he reached Ilfracombe he continued from there on the coast road till he moved inland to complete his tour about Bridgwater, just previous to which he visited a copper mine two miles short of Stowey.

All the journeys attributed to Cavendish offer some problems which needs understanding and explanation, but perhaps the undated journey is the most perplexing, because two questions arise. When did the journey take place, and who took part in it? The account follows a pattern similar to previous ones, the moving from place to place with a description of the geology of the districts passed through, and a knowledgeable reference to the many industrial concerns and processes encountered.

There are two letters recorded in Appendix I, those of Michell and Cavendish, and each refers to a Mr. Beatson in connection with a substance called 'plumbago' which is mentioned on only one other occasion, i.e. in the undated journey.(2) The route of this journey passed through the country identified with the Beatson's, namely

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1. See Plate VII, .

2. See Dramatis Personae - Appendix III.

Thornhill and Rotherham.[1] Incidentally the date of Michell's letter was the 14th of August, 1788.

These combined factors give the impression that there is a connection between them to confirm the probability that the undated journey took place about late July and early August 1788, and was undertaken by Cavendish in company with Blagden. The account would appear to be written by Cavendish, and is not merely a geological report compiled for him, because it is lively and descriptive, full of personal narratives, as the way-farers engage workmen and masters of industry in conversation.[2] Michell is also referred to as the authority on yellow limestone, and the coal measures in his own district round Thornhill and Halifax.[3]

The journey is again a combined geological and metallurgical tour with the many miles on the outward stages covered rapidly. Only a brief account of the terrain is given from leaving the chalk hills near Stevenage until the party arrives on the Yorkshire coast. At this point a passage was evidently made by sea in order to view the cliffs and to observe the rock strata from a point of vantage, and in the course of the trip such places as Scarborough Castle, Filey Brig, and Staithes were noted.[4]

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1. Chatsworth MS. X(a)3, Journey 1788?, p.9, - Appendix I.
2. Chatsworth MS. X(a)3, Journey 1788?, pp.7, 10, - Appendix I.
3. Chatsworth MS. X(a)3, Journey 1788?, pp.8, 13, - Appendix I.
4. Chatsworth MS. X(a)3, Journey 1788?, p.3, - Appendix I.

JOURNEY – 1793

AUG. 24th – SEPT 1st 1793

PLATE IX

CAVENDISH'S JOURNEY 1793

From here Cavendish moves in a westerly direction, and it would appear that the region around Borrowdale was the extreme limit of his travels before making the return journey.(1) Through the rugged country of the Lakes and Fells, he presses on but not oblivious of the landscape. He notes the prevailing formations of slate, the quarries where it is found with the special features pointed out by the workmen, and the black variety called by Dr. Blagden, 'ragstone'.(2) Twice he mentions the darkness thus giving the impression that his daily journeys were long ones when he took advantage of the better weather, and the daylight of the summer months.(3)

There are times when Cavendish shows unconsciously that the metallurgical operations provide a greater scientific interest than the observation of the stratigraphical characteristics. His accounts of them are more complete and specialist as recorded by him. As he enters the industrial regions around Sheffield, there the several furnaces, and works offer more scope for his application of chemistry and physics, for which no doubt he is constantly on the alert. The well known works of Walker's at Rotherham and Smith's at Chesterfield enabled him to learn more of the tinplate industry, and the treatment and operations and mining of the iron ore, and a good working knowledge of the technical terms used in the industry.(4)

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1. Chatsworth MS. X(a)3, Journey 1788?, p.6, - Appendix I.
2. Chatsworth MS. X(a)3, Journey 1788?, p.6, - Appendix I.
3. Chatsworth MS. X(a)3, Journey 1788?, pp.2, 5, - Appendix I.
4. Chatsworth MS. X(a)3, Journey 1788?, pp.9, 11, - Appendix I.

This undated journey is a most comprehensive survey of the territory covered, and the information obtained, including the personal observations recorded by Michell of his own excavations at Thornhill. It may well be thought that the whole account was written later at leisure from notes taken during the tour, as some continuity is sensed; besides, a further inference gained from the words, 'as well as I remember from', suggests that the account was written subsequently.[1]

The terminus of this considerable journey would appear to be 'the sands of Wooburn', not so very far from its starting point.[2]

The last journey undertaken by Cavendish, that of 1793, was perhaps the most punctiliously recorded. Each day's excursion was dated, and very careful notice taken of distances at various stages in his itinerary. There is no doubt that on this occasion he had his way-wiser attached to his carriage. The expedition was chiefly geological when numerous specimens were collected and numbered, each one the subject of a separate description. It is therefore interesting to note in relation to Specimen No. 5, that the new Church referred to at Banbury, is that of the Parish Church of St. Mary's. The old Medieval Church was demolished in 1790, and the new church consecrated and opened in 1797.[3] Another interesting feature too occurs as Cavendish comes to the coal country near Ashby in Leicestershire. He mentions the Lound (Lount) collieries which are situated a mile or so south of Melbourne, where mining operations have continued

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1. Chatsworth MS. X(a)3, Journey 1788?, p.9, - Appendix I.
2. Chatsworth MS. X(a)3, Journey 1788?, p.12, - Appendix I.
3. Chatsworth MS. X(a)2, Journey 1793, p.2, - Appendix I.

BLAGDEN'S JOURNEY TO FRANCE 1787

SEPT. 25th – OCT. 13th

1787

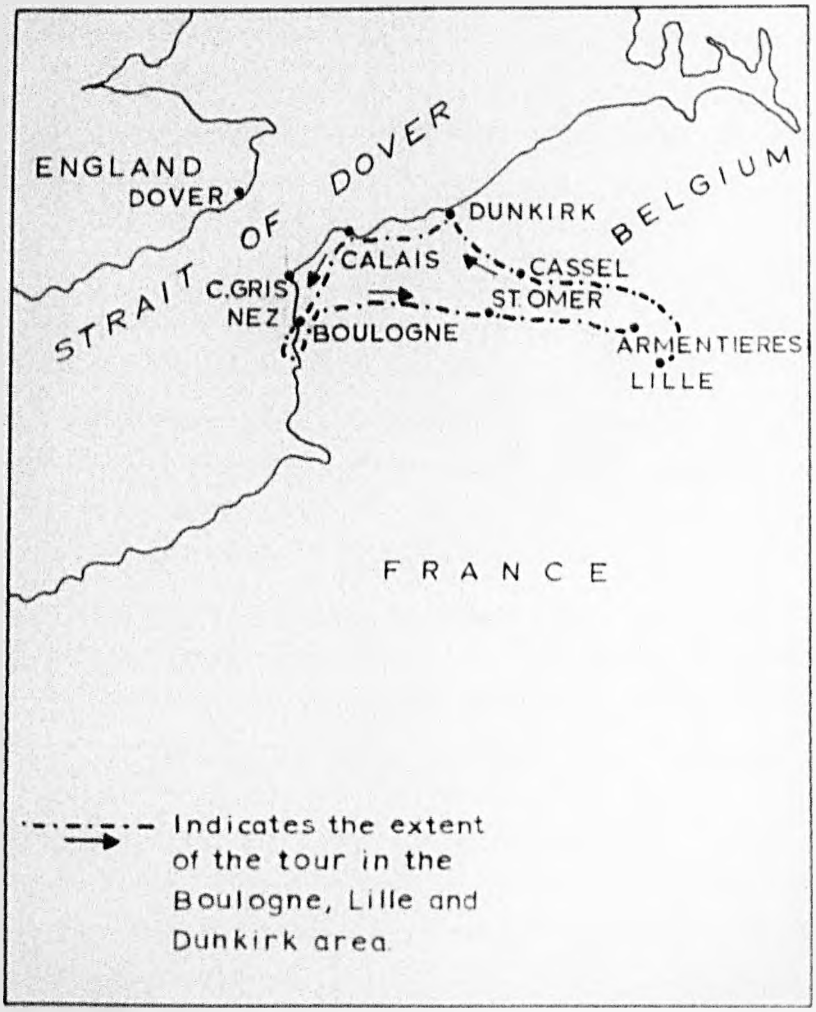

PLATE X

BLAGDEN'S JOURNEY 1787

until quite recently when they were closed down.

It must be evident that industrial visits had a special attraction for Cavendish, and for a very good reason; they gave him an opportunity to satisfy himself on scientific principles related to chemistry and physics when applied to operations of a technical nature. The smelting of lead ore in a Cupola furnace at Stangge was probably an experience new to him on these journeys.(1)

Cavendish once again refers to Watt, whose partnership with Boulton at this time was the talk of the engineering world because of the improvements connected with their steam engines. Watt who was always ready to engage in any investigation to satisfy his inquiring mind, is now experimenting with steam pressure. Cavendish is interested to make his observations and even quotes Boulton's opinion, but a Mr. Lawson, an important member of the firm of Boulton and Watt, gives another version.(2)

This is by way of an interruption, or diversion, of the general theme of the journey, but as Cavendish compiles his accounts of the tours in the form of a diary flashes of interest, such as that described, are constantly to be found in the manuscripts.(3) The remainder of the journey is a note of the mineral specimens he adds to his already considerable collection, but his comment with regard to the position of Lincoln is striking; it 'stands in a gap in a

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1. Chatsworth MS. X(a)2, Journey 1793 , p.6, - Appendix I.
2. See Dramatis Personae - Appendix III.
3. Chatsworth MS. X(a)2, Journey 1793, p.7, - Appendix I.

ridge of yellow limestone hills not high but rising pretty bold.'[1]

The remaining manuscripts contained in this parcel marked 'Journeys' are accounts of two separate tours on the continent undertaken by Blagden. The first of these was a brief excursion in the neighbourhood of Calais and Boulogne in the autumn of 1787. In a letter to Cavendish, dated the 23rd of September, Dover, Blagden said, 'I hop over to France with the Commissioners tomorrow'.[2]

The 25th of September, was the beginning of this journey when he 'embarked for Calais but wind being scanty went to Boulogne'.[3] Could this mean that the crossing was made in a sailing vessel? As the next recorded entry was the 29th of September, it is evident that he remained in the Calais and Boulogne areas several days for minor explorations, employing a guide to assist him in his travels, and to collect various geological specimens.

But perhaps two items stand out as the most interesting material Blagden records on this tour. He mentions the famous reflecting circle used for finding longitudes at sea, a piece of scientific apparatus developed by Lenoir.[4] From all accounts this particular model proved difficult to handle.[5] Another interesting feature was the problem of obtaining coal supplies from collieries in their own districts, so that many French consumers 'have also coal from England

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1. Chatsworth MS. X(a)2, Journey 1793, p.8, - Appendix I.
2. Chatsworth MS. X(b)14.
3. Chatsworth MS. X(a)1, Blagden's Journey 1787, p.1, - Appendix I.
4. See Dramatis Personae - Appendix III.
5. Chatsworth MS. X(a)1, Blagden's Journey 1787, p.3, - Appendix I.

BLAGDEN'S JOURNEY INTO EUROPE
1789
SEPT. 25th - NOV. 1st

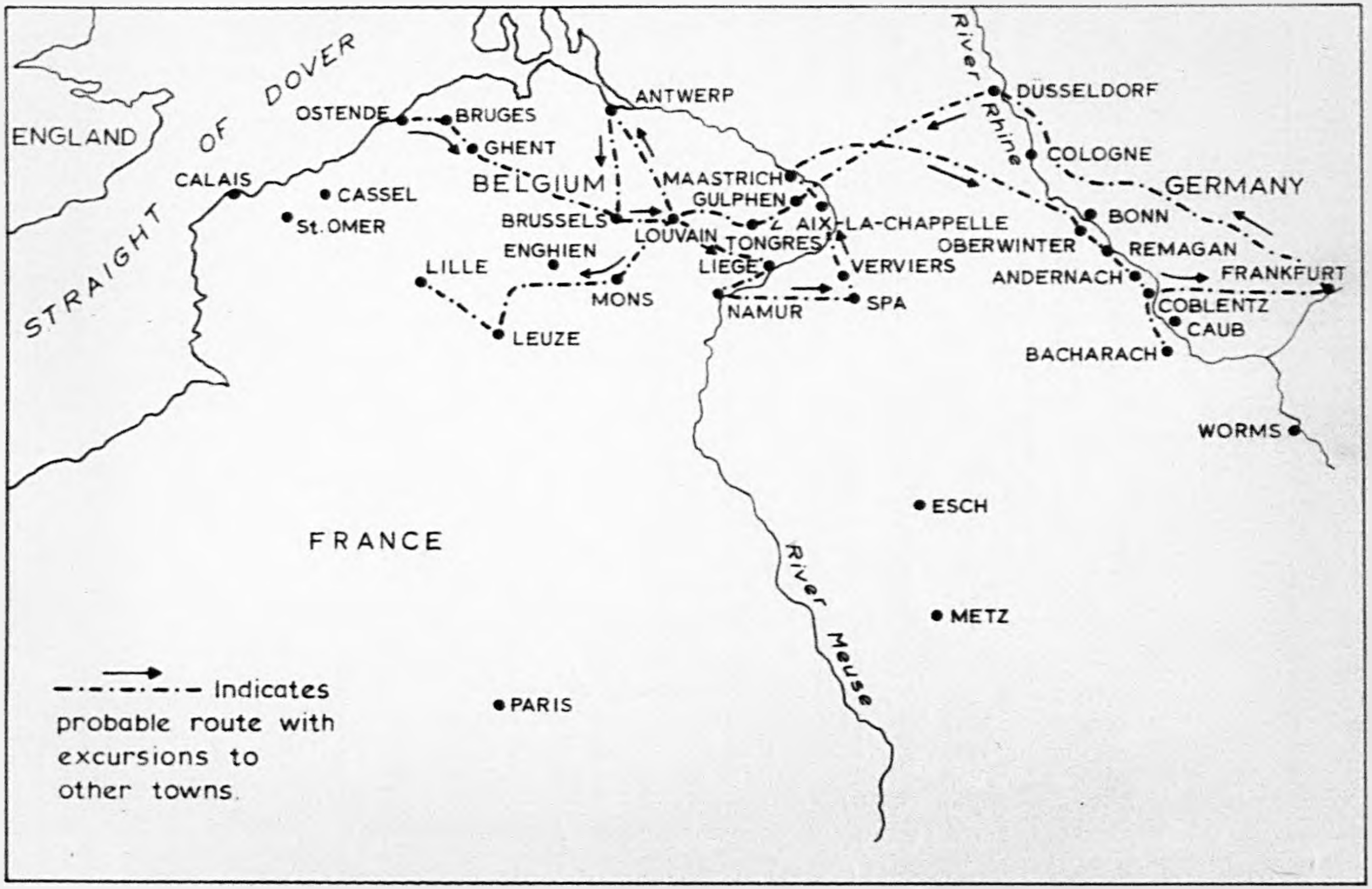

PLATE XI

BLAGDEN'S JOURNEY 1789

by way of Dunkirk which not withstanding the imposts comes cheaper ... Mr. Mouran at Calais burns coal partly from England, partly from Ardingheim'.[1]

The other journey made by Blagden in 1789 was the most extended of them all, and continued for six weeks from the 20th of September, to the 1st of November.[2] It seems that the first week was devoted to visiting some of the more important cities of Belgium, though no observations have been recorded. This expedition was undoubtedly the most interesting from a geological point of view, and unquestionably the most exacting. Thus it is not surprising that Blagden who was only forty one years of age at the time, and seventeen years younger than Cavendish, was more equal to the task of withstanding the physical strain, and thus better prepared to face the advanture.

After all, these journeys, and there are eight in all, were heroic enterprises, at a time when there was no great comfort in travel or accommodation. Conditions were austere in almost every department of life, compared with modern standards, and to endure these hardships for the joy of academic achievement so far from home, is a feat to be admired by a more sophisticated age.

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1. Chatsworth MS. X(a)1, Blagden's Journey 1787, p.4, - Appendix I. See Dramatis Personae - Appendix III.

2. Chatsworth MS. X(a)8, Blagden's Jourey 1789, p.1, - Appendix I.

CHAPTER IV

THE PRIVATE LIBRARY OF HENRY CAVENDISH

The term 'private library' means different things to different people. To the bibliographer, or the bookseller, it may suggest a collection gathered together by a bibliophile, in much the same way as porcelain or glass or clocks are sometimes collected.[1] But, these private collections were not usually working libraries: they were altogether different from the 'private library' built up for the purpose of individual study or personal enjoyment. This type of collection may be distinguished from the former as being 'domestic', because in general it is inseparable from the 'home', so often the basis round which our family life, as well as our literary and intellectual heritage, is built.

In order to gauge the importance of the 'domestic' library, it must be considered in relation to its background, because it is desirable to know, not only something of the works themselves, but of their owner, and if possible, of his purpose in collecting them; the sources from which they came, and the use he made of them. This city of books is a living entity, differing from any other sort of collection, designed to be within the easy reach of owner or reader for his enrichment and joy.

The tradition of the English Library was well established as

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1. R. Irwin, The Origins of the English Library (1958), p.145.

far back as Bede's day, but the turning point occurred with the suppression of the monasteries between 1536 and 1540, when the contents of their libraries were wantonly defaced and burnt. Even the Royal Library was destroyed, and the losses at Oxford, Duke Humphrey's Library, and at Cambridge were equally disastrous. The dispersal of these libraries was not entirely unforeseen because the monastic system had declined, many of the houses were poorly administered, and sadly in debt, and so by 1540, the monastic library came to an inglorious end. The rise of the new universities in the thirteenth century, brought changes which concentrated study in the two centres of Oxford and Cambridge, but the impact of the new learning, attributed largely to the influence of Erasmus, involved an even more drastic change. The old educational methods were out of date, and the new tools needed by the institutions were printed editions from the presses, rather than manuscripts from the 'monastic scriptoria'. How the die-hard cry, 'we must root out printing, or printing will root out us', must have echoed through many a monastic cloister.(1)

The great libraries, such as the library of Henry Cavendish, stemmed from the fifteenth century when the invention of printing and the introduction of paper led to a steady increase in the number of books published. In England the growth of libraries was delayed owing to the troubles of the sixteenth century, while the problem of how to deal with the growing quantity of books scarcely arose before the Restoration; in France the change was felt earlier.

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1. Irwin, Origins, pp.23, 108-109.

The medieval library, therefore, in England was known to be small, by modern standards, and a normal private collection would rarely exceed a few score volumes. Occasionally there was the larger collection, such as that of S. John Fisher, Bishop of Rochester (1459-1535), whose library was plundered by Cromwell just before his martyrdom. It was described by a contemporary as 'the notablest Library of Books in all England, two long galleries full, the Books were sorted in stalls and a Register of the names of every Book at the end of every stall'.(1) The Bishop intended his collection to go to St. John's College, Cambridge. Another well-known library of this period was that of Lord Lumley (1534-1609), who secured many of Cranmer's books, while he also inherited part of the collection from his father-in-law, the Earl of Arundel, but even his library by 1596 had reached only a total of 2,800 volumes.

It is, therefore, improbable that any English libraries in the sixteenth century rivalled in size the great collection of the French historian Jacques de Thou (1553-1617), which amounted to 8,000 printed books, nor was there anything in England at this time to rival the richly bound library of Jean Grolier (1479-1565), said to have contained 3,000 volumes, of which 550 treasured specimens survived its dispersal in the seventeenth century. There are a number of well preserved copies at present in the Chatsworth library. However, with the turn of the century a change was taking place: the English library was beginning to compare favourably with the French.

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1. Irwin, Origins, p.163.

The great library of the Jurist John Selden must have equalled in size De Thou's collection; over 8,000 of his books were acquired by the Bodleian after his death, in 1654, and he must therefore be accounted one of the chief patrons of English libraries in the Commonwealth period. He was for a time keeper of the records at the Tower, and the author of many legal and political works, but to the ordinary reader he is best known for his, Table Talk, 1689, His scholarship and moderating influence over the Puritans during a difficult period doubtless saved the Royal Library, which the extremists would have dispersed.

From Selden onwards, the steady rise in private collections took place, and entirely outstripped the institutional libraries of the day. They were beyond doubt more accessible, rendered greater service, and virtually more 'public' than either the Bodleian at Oxford, or the University Library at Cambridge. The contents of the Royal Library could not compare with them as an aid to scholarship and learning.

One of these was the great collection, at Chelsea, belonging to Sir Hans. Sloane, who was both Secretary and later President of the Royal Society, which included some 40,000 printed books and 3,516 MSS. His shelves comprised quantities of material which did not belong to his particular interests of medicine and natural history. The library ultimately became the main foundation of the British Museum, and the Act of 1753 providing for this hardly refers to its special interest in the field of science.

The even greater collection made by Robert and Edward Harley, the first and second Earls of Oxford, was estimated in 1741, at about

50,000 printed books, and 7,639 volumes of MSS.

Thus library collections in England in the eighteenth century were sometimes the creation of the scholar nobleman, and as such deserve our particular attention.

Such a collection was that assembled by Henry Cavendish, of the celebrated line of Devonshires, whose seat was at Chatsworth. The varied assortment which constituted the large library of the distinguished scientist was housed separately in his Dean Street Mansion, in Soho.(1) Here he had collected an extensive and carefully chosen library of works on science: to it he welcomed all those who were engaged in research, provided that they followed the rules of an ordinary circulating library: he, himself, punctiliously signed a formal receipt for such of the volumes as he took out with him. After the death of a German gentleman, who had been his librarian, he appointed a day when he attended personally, every week, in order to accommodate the few who thought themselves justified in applying to him for such books as they wished to consult.(2)

When Henry Cavendish died in 1810, his now famous collection passed to his cousin Lord George Cavendish, whom he had designated his heir.(3)

It was not, however, till 1834, on the death of Lord George, that this library was inherited by William Spencer Cavendish, sixth

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1. G. Wilson, Life of Cavendish (1851), p.163.

2. The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. I, The Electrical Researches, ed. James Clerk Maxwell, rev. Joseph Larmor (1921), p.445.

3. Wilson, p.173.

Duke of Devonshire, who already had a notable library. He added to it by buying the complete libraries of Dampier, Bishop of Ely, and of John Kemble, and made other wide and discerning purchases.

According to Francis Thompson, Mr. Cavendish's library was first received in the Oak Room, supported by props, and furnished with temporary shelves.[1] After remaining in the Oak Room for a considerable period, it was temporarily transferred to what is now known as the Cavendish landing until it was removed in 1905.

To house the new addition, in permanent quarters, the sixth Duke called upon the services of the architect, Wyatville, who had carried out many structural changes at Chatsworth during the early part of the nineteenth century. Wyatville was equally successful in converting the old Long Gallery into a new home for the Henry Cavendish Library, and there it is today.[2]

It is surprising, from an inspection of over a thousand volumes of this library, to find so varied a selection of attractive titles. The philosophical works of Cavendish naturally occupy pride of place, but there is much evidence to convince a literary historian that his catalogue of books reveals a man who was interested in things human as well as scientific, and was in tune with the reading habits of his time. His mode of dress, however, was in a different category, the costume of a previous century, but if a man's clothes reflect an extension of his personality, how much more vividly is this true of

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1. F. Thompson, <u>A History of Chatsworth</u> (1949), p.134.
2. See Plate XII.

PLATE XII

A PORTION OF THE LIBRARY AT CHATSWORTH SHOWING POSITION OF CAVENDISH'S BOOKS

The photograph on the opposite page has been taken specially to show the North end of the Library at Chatsworth where part of the actual collection of the books belonging to the Henry Cavendish Library is today.

the books with which he surrounds himself.

It was reputed to be a great period for eccentrics, and there is no reason why eccentricity should not show itself in the collection of books as much as in any other form of unconventional behaviour.(1) A much earlier eccentric, Richard de Bury, Bishop of Durham, (1281-1345), the first large English collector, was forced to climb over his pile of books to reach his bed. In a much later period, we can instance Thomas Rawlinson (1681-1725), nicknamed by Addison as 'Tom Folio', 'a learned idiot', whose rooms were stuffed so completely with books that he had perforce to sleep in the passage. Then there was Thomas Britton, the musical coal-man; he would set out on Saturday afternoons in his blue smock, with coal sack slung over his back, book-hunting at Christopher Bateman's shop in Paternoster Row, where he would rub shoulders with some of the greatest aristocrats of the day, amongst whom was the Duke of Devonshire.(2) Britton's home was in a converted stable, the ground floor was his coal-shop, and upstairs he kept his collection of musical instruments, and his library of about 1,400 volumes. Here also, for almost forty years, were given his celebrated Thursday concerts.(3)

Cavendish was quite a different sort of eccentric. He obeyed a strict routine in all things, which is not an unusual habit to be found in people, yet in Cavendish it became fanatical.

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1. Irwin, <u>Origins</u>, p.173.

2. R. Irwin, Supplementary Notes to 'The Origins of the English Library' (1959), University of London. School of Librarianship and Archives. Occasional Publications, No. 9, p.10.

3. Irwin, Origins, pp.183-184.

Indeed his whole life was governed by a strict adherence to system and uniformity. In the world of books, he was a hoarder, not a maniac, and from a detailed study of his catalogue a bibliographer would learn that he was not only wise, but human as well. What he could not do, was to suffer, either fuss or fools - gladly.(1)

So much for the man: what of the details of his library?

The catalogue of the library measures sixteen, by twelve, by four inches in thickness, and has recently been rebound with a hard serviceable cover, overlaid in soft brown leather. The spine, with an overlap of two inches on each side, is of the original old calf brown leather, divided into six prominent divisions. The second division from the top is in red, displaying the title 'Catalogue' in gold lettering. It contains eighteen subject classes, covering four hundred and eighty pages of parchment paper, with plenty of spare leaves for additional entries. There are listed 9,000 separate titles in a library of nearly 12,000 volumes. In addition maps, plans, and surveys, comprise 656 sheets, bound together in six giant volumes each measuring 22 inches by 16½ inches. There are 282 sheets which are detailed maps of the counties, and a few towns of England and Wales, A survey of the European countries comprise 242 sheets, while the lesser known continents of Africa, Asia and America are disposed of on 36 sheets. Australasia was not ~~yet~~ yet discovered. The rest of the world, comprising the East and West Indies, is contained in 96 sheets. The task of sorting so large a collection of material into

1. Wilson, p.166.

some kind of orderliness, to make it worthy of the name of a library; then to compile a record of its contents to be styled a catalogue was no mean achievement.

How did all this orderliness come about?

There is a story of Cavendish, that at one time his library was in a somewhat disordered state, so having heard of the name of a gentleman in poor circumstances who was capable of classifying the books in a satisfactory manner, Cavendish allowed him to reside in the house while engaged upon this work. After the books had been properly arranged, this gentleman retired into the country, but sometime afterwards his name cropped up in the course of a dinner at the Royal Society Club at which Cavendish was present, whereupon Mr. Cavendish made inquiries as to how he was faring, to which the person replied, 'I fear very indifferently'.

Cavendish appeared genuinely sorry and concerned, and when it was suggested that he might like to do something to help him, he ejaculated, 'me, me, me, what could I do?'. It was hinted that a little annuity for life, 'for he is not in the best of health', would indeed be a welcome gesture. 'Well, well, well, a cheque for ten thousand pounds, would that do?' was the answer. 'Oh, Sir, more than sufficient, more than sufficient.'(1)

A comprehensive plan for sorting and arranging the books would be undertaken first of all, and to handle 12,000 volumes would take a long time. It is not surprising, therefore, that the gentleman

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1. Wilson, p.174.

concerned found it necessary to retire into the country to recuperate. Whether he was ever persuaded to compile the Catalogue is doubtful. Throughout the book the handwriting varies both in form and quality from what is familiarly known as the 'copper-plate' hand to a less stylish variety, the whole giving the impression that the work was undertaken by more than one person.(1)

So large a venture, with an average of twenty entries to record on each page, would take months to complete. The specimen page - Astronomy - Plate XIII is typical of the kind of material collated and recorded, and the general arrangement must have been a long and tedious exercise. To assign a date for the completion of the catalogue is difficult, but as entries appear as late as 1794, it is reasonable to assume that the work on the Catalogue was finished about this time - the close of the eighteenth century. There is an insertion in the history class of a publication dated 1794, and as this date is the latest recorded, it could be one of the last entries before the catalogue assumed its present form, and the only copy in existence is that at Chatsworth.(2)

Who might consult this catalogue? Were there many people about capable of reading the volumes in the library?

There can be little doubt about the answer. From the days of Chaucer, in the fourteenth century, there has been progress in literacy, and though its extent has been queried, there can be no question that

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1. For an example of a different hand, see H.C.C. Natural Philosophy Section, C. p.48.

2. H.C.C., History, Section H, p.33.

it was steady.[1] There was also an undoubted spread of personal reading, and works like the Canterbury Tales, Piers Plowman, and Thomas à Kempis, The Imitation of Christ, a book which maintained its popularity unabated through the centuries of religious dissension, have survived to this day. It may be argued that the leisure, stability, and security, of our English home life had its roots in the fifteenth century, and as real libraries start when men begin to manifest such qualities as these, it is possible to fix this period as the starting point.

There is no better illustration of this fact than the home life of Sir Thomas More, scholar, statesman and martyr, which the homeless Erasmus regarded with envy and admiration, for his library and garden at Chelsea were great attractions. More must have had many of his books with him in the Tower, because during a visit, Rich, the soliciter General, took two attendants with him to truss up his books in a sack for confiscation.[2]

Libraries were growing steadily, though individual collections varied in size, and some of the larger ones posed new and difficult problems. Hence there came into being what was later called 'Library Economy'. When few English libraries possessed more than a thousand or so books, Gabriel Naudé, in 1627, published in France his, 'Avis Pour Dresser Une Bibliothèque', the first serious attempt at an outline of library organisation.

In 1642, Cardinal Mazarin gave Naudé the task of collecting and arranging the great library which bears his name, some 40,000

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1. R. Irwin, The Heritage of the English Library (1964), Ch. XI, pp.197-221.
2. Irwin, Origins, p.163.

volumes which he had gathered from England, Germany, Flanders and Italy, and which he had regarded with some justice as the eighth wonder of the world.

Naudé himself was not without experience, for his own private collection amounted to 8,000 volumes, but the masterly manner in which he set to work on the 'Bibliothèque Mazarin', ended in a real achievement. All the volumes were bound in morocco and stamped with the Cardinal's arms; and with surprising magnanimity the library was dedicated, 'à tous ceux qui-y-voloient aller estudier'.

Naudé's work was indeed, a pioneer attempt in library economy to combine both in selection and classification, scholarship and practical use which he valued above considerations of 'rarity and prestige'. He declared in favour of 'quality' rather than 'quantity'. He used the word quality in a liberal sense, and in this respect he had Pliny's dictum in mind that, 'there is no book whatsoever, be it never so bad, but may in time be sought for by some person or other'.(1)

That Naudé's book was an important land-mark is quite plain. He was taking the long view, having in mind some practical and realistic scheme of library organisation, because nothing like it had appeared in England so far.(2)

Librarians lacked the wide vision to produce such a work.

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1. Irwin, Origins, p.134.

2. A translation of Naudé's work by John Evelyn was published in London in 1661, under the title of, Instructions concerning erecting of a library.

Sir Thomas Bodley might have attempted something of the kind, but then the Bodleian in the seventeenth century had not experienced the problem of quantity. Beginning with 2,000 volumes it reached 16,000 in 1620, but it was not till 1714 that the number of printed books totalled 30,000.

There is little doubt then that Naudé's book made a wide impression during the period, and influenced bibliographers of that and succeeding ages. In fact it may well be that John Durie, keeper of the Royal Library from the death of Charles I to the Restoration, when conceiving the idea of a national library, based his conception on Naudé's work, but this ideal was premature.

It is quite probable that Cavendish, who would be acquainted with Naudé's publication followed his pattern, and from the disposition and arrangement of his library there is every indication that this was so.

A first glance at his catalogue would confirm his compliance with a recommended order of precedence, 'That the most universal and antient do always march in front'. Astronomy, Mathematics, Natural Philosphy, and Natural History, in that order, account for 3,690 separate editions, or more than a third of his library.

The facsimile of a leaf from the Astronomy section of the Cavendish Catalogue, Plate XIII is a model of exactitude in writing and in details of reference, but this standard of orderliness, does not persist in other sections and in fact they vary in the amount of information recorded. Throughout the catalogue entries of editions will be found in different languages, bearing also different dates

Astronomy.

Joh. Sarsius Ratio ponderum librae et Simbellae Neap. 1627 4° D15

Nic. Mulerius Frisica Tabula lunae solares Alcmar 1611 4°

Or. Finaeus De mundi sphaera lib 2 Lut par. 1553 4° D15

Tables requisite to be used with the Nautical Ephemeris for finding the Latitude and Longitude at Sea Lond 1781 8° D15

C. Dauotus ad Astronom Judicia facilis Introductio Lugd 1557 4° D15

Graphi Petri Schema — 4° D15 B99

Gemma Frisius Diver. libelli — —

Pet. Apianus Cosmographia per Gemma Frisium aucta Antw. 1545 4° D15

Pat Murdoch Mercators sailing applied to the true figure of the Earth Lond 1741 4° D15

Jo. Keil Epistola ad Jean Bernoulli Lond 1720 4° D15

Cleomedes Meteora Gr. lat comment Rob. Balforeus Burdig 1605 4° D15

Pet Gassendus Apologia in librum Morini Lugd. 1649 4° D15

Fed. Saminiatus Tabula Astronomica Antw. 1699 4° D15

Comte de Pagan Tables Astronomiques Par 1658 4° D15

Gal. Galileo Systema Cosmicum Lugd Bat. 1699 4° D15

Joh Zumbach Planetolabium Lugd Bat. 1691 4° D15

J. Pou Leon Dulivis Theorie des Longitudes Par 1647 4° D15

Fr. Bonav Cavalerius Directorium Uranometricum Bonon 1652 4° D15

Jo Ant. Maginus De planis triangulis et al Mathem. Ven. 1592 4° D16

Pet Paolo Caravagio Geometria applicationum Mediol 1659 4°

Mathemat

Euclid optica et Catoptrica Par. Wech. 1557 4° D16

Edw Hatton Arithmetick Lond 1699 4° D16

Jo Craig De calculo Fluentium et de optica Analytica Lond 1718 4° D16

Edw. Hatton the Merchants Magazine Lond 1734 4° D16

Grandeurs incommensurables (Traité des) et le 10 livre d'Euclide illustré Par: 1640 4° D16

PLATE XIII

THE CAVENDISH CATALOGUE

On the opposite page is a photograph of a leaf from the Astronomy section of the Cavendish Catalogue. It is immaculately written and recorded with storage reference, e.g. D15, place and date of publication, size of the volume, and the letter of the alphabet in the top left hand corner, assigned to the particular classification. The classes, however, are not generally arranged alphabetically, though it does happen to be so in this case.

and places of publication, as well as indicating book sizes, and the numbers of volumes of separate titles. Further, as the date and place of publication are so often omitted, it must not be assumed in such cases that the place of publication is therefore, London, because Edinburgh, York, Oxford, Cambridge, Dublin, and Bath, to name only a few, are included.

Can a comprehensive picture of Cavendish's library be obtained?

This has been attempted, as the diagrams on pages 139 and 143 will show, but in compiling an analysis of nearly ten thousand separate titles comprising the catalogue only a general impression can be given of the structure of the Henry Cavendish Library. It is to be anticipated that a predominance of scientific material should be found there, and to some extent this is true, as a brief reference to the first diagram will prove. But, what is even more impressive, is the variety of subject matter also indicated by the analysis.

The first four sections or classes, of his scientific books, exceed one third of the editions of his entire library, and nearly half of these volumes were published in the latter half of the eighteenth century. Poetry and Plays is a class only slightly larger than his mathematical works and half of which were published after 1752. This date, which has no particular significance, has been selected as one well within the second half of the century, as a reasonable dividing line and by which time Henry Cavendish had reached manhood.

In language content, his books on science were published chiefly in Latin and French, but quite half of these were printed in English as well. Likewise, in Poetry and Plays, half of them were written in English.

This is some indication that Cavendish was modernizing his library, and keeping in step with the times, during the latter half of the eighteenth century.

An analysis of his books on Voyages and Travels, and Geography, tell the same story of the trend to live with the present, and to maintain an up-to-date standard in his library. On the contrary, his History books are inclined to show a reverse trend, where he preserves a balance by not overlooking the virtues of the past, for the majority of these books are either in Latin or French, of which nearly a quarter were published before 1752. Presumably then, the History class was largely inherited, and this portion of his library served as works of reference. A similar inference may be drawn from the Auctores Classici, where, of his 657 editions, more than two-thirds were published before 1700, and all but a mere handful, printed in Latin. These again, it is noteworthy that in the small sections of Novels the majority of the publications were written and published in France, and belong to the earlier years, 1700-1752.

This was a period of enlightenment, and reading was a progressive part of it, with Novels, belonging to what Coleridge called the 'passtime' books, supposed to be a feature of the century. The works of Authors, and the Academic Translations and Journals, also relate to this time. The reading habit had gripped everyone and taken root in what was regarded as a social age. Wherever people congregated, at meetings, gatherings, coffee-houses, or any place which prompted conversation, political pamphlets, journals, and novels would be discussed.

Thus, to summarize the general formation of the Cavendish Library, it could be said that one third of the books belong to each of the three periods given in the analysis, and of the various classes or sections, Natural Philosophy, the largest class, contains one fifth of all the editions in his library, while in languages Latin prevails slightly over English in accounting for one third of the individual titles.

On the specimen page from the Catalogue there appears a capital letter, 'A', on the top left corner. All the eighteen classes are indicated in this way, alphabetically from 'A' to 'S', omitting capital 'I' to avoid confusion with the letter 'J' which however is included. The pages within each class are numbered, hence this illustration from the Astronomy class is 'A', 5. A re-numbering has apparently taken place.

On the right hand side of each page are two columns, the first one gives the size of the edition, whether duodecimo, quarto, or octavo, and in the front, when applicable, a figure indicates the number of volumes in the library of that edition. Cavendish made it clear that this was so in his own handwriting on one page only of the Catalogue.(1) The end column contains the references to the storage system in a dual combination of either letters or numbers, e.g. A, 1-4, B, 3-6, R, 4-5, or Adc, Pke, Fco. In the Poetry and Plays class, there appears a succession of letter references, beginning RZA, RZB, RZC ... and so on, to the end of the alphabet. This is the most systematic series of

1. H.C.C., Autores Classici, Section L.2.

ANALYSIS OF THE CAVENDISH LIBRARY
NUMBER OF EDITIONS

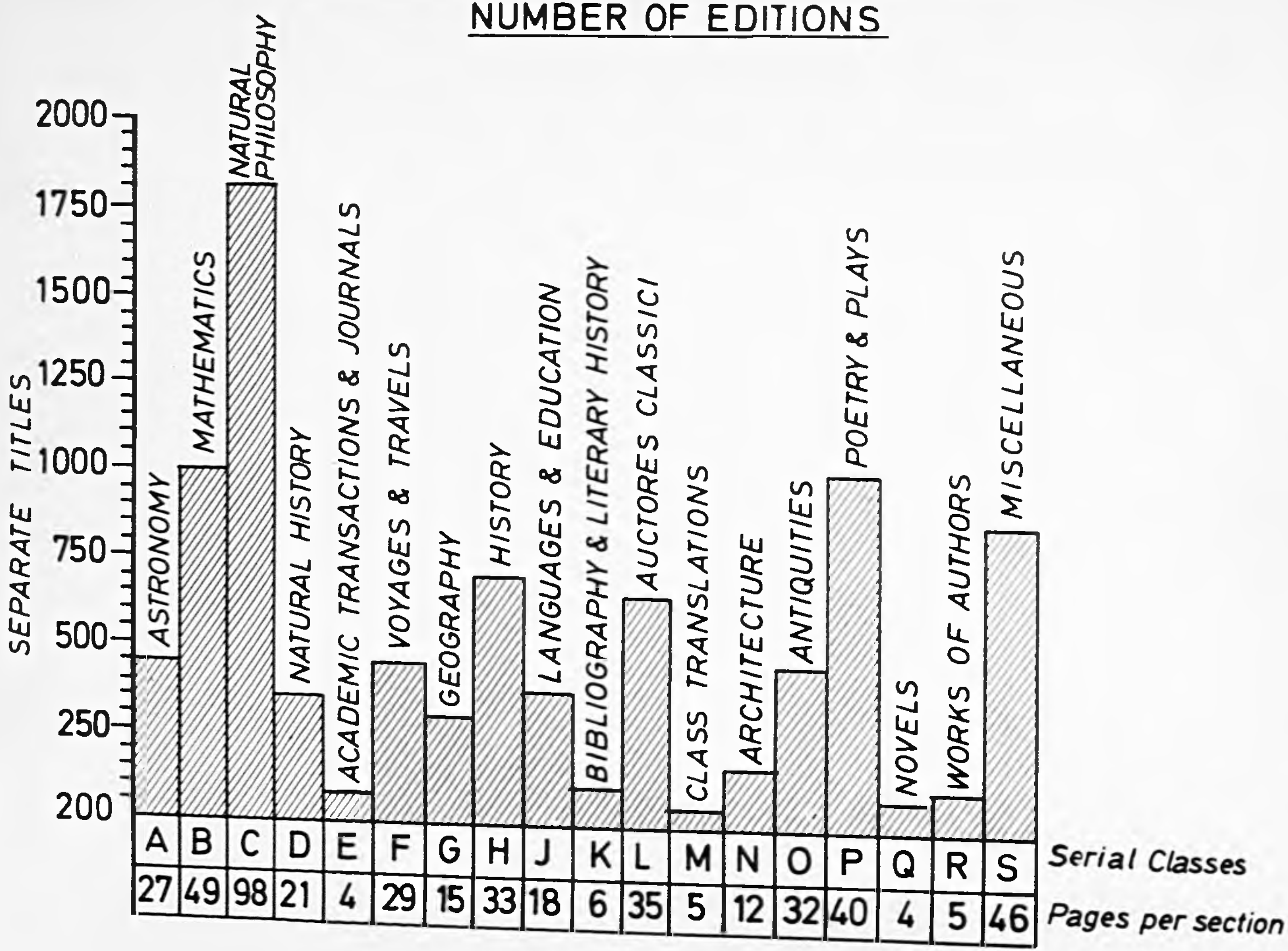

TABLE III

ANALYSIS OF CAVENDISH'S BRIVATE LIBRARY
NUMBER OF EDITIONS

references encountered in the whole catalogue.[1] Yet, it is difficult to offer any explanation of the meaning of these signs in relation to the general arrangement of his library, or to offer any hint on the method of storage.

A discussion of the reference marks with the Librarian of the Devonshire Collection at Chatsworth disclosed that he is of the opinion, that the catalogue mark, for example, Q,4-5, means section Q of the Cavendish Library, press or case number '4', and shelf, '5'. The letter signs, Adc, RKV, and so forth, are probably special identification marks which Cavendish adopted for his own private use, and they would appear on the spine of the books. Then, various pages in the Catalogue had paper strips pasted over one or both of their right hand columns, with fresh references inserted, which clearly looked like Cavendish's own marks. These alterations in storage references could have been made by reason of a re-arrangement of portions of his library, a task he was bound to undertake from time to time, as new editions were admitted to his library. In the mathematical class Cavendish has used abbreviations, such as Alg, Geom, Phy, Chy, Trig, Opt, to help identify quickly groups of book titles, recorded consecutively on the same subject matter.

If Cavendish has been responsible for making personal additions to the catalogue, other hands too have been at work writing up the individual titles. Originally each class began alphabetically, and titles were entered under their authors, but this procedure was eventually

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1. H.C.C., Poetry and Plays, Section P, pp.32-39.

abandoned, as fresh editions made it obsolete. Naudé had suggested that it would be preferable to reserve a special place for new acquisitions, sorting them into the general classification at the end of every six months. In this way the books would be dusted and handled twice a year. Even so, 'there are but few books', he says, 'but are reducible to some order, especially when one has many of them'.(1) The 'mixed books', according to him might be set apart at the end of each faculty as a miscellaneous class. While Cavendish did not adhere strictly to the letter, he did observe the spirit of Naudé's recommendations, because he had a miscellaneous assortment which he introduced as a separate, and large class at the end of his work of reference.

The catalogue of the Cavendish Library is now complete, and there is no doubt that Cavendish made daily use of it for personal consultation, as well as for the benefit of those engaged in scientific research.

To turn to the subject of storage, the problem had scarcely arisen before the seventeenth century, for the normal English private collection rarely amounted to more than a few score volumes, probably stored in an oak chest or laid flat on a table, or possibly kept on a shelf or two fastened to a wall. Where, however, a library of a large sort was kept in a room, rather than in a gallery, fixed wall shelving can perhaps be assumed.

But, towards the end of the seventeenth century, a new age had

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1. Irwin, Origins, p.136.

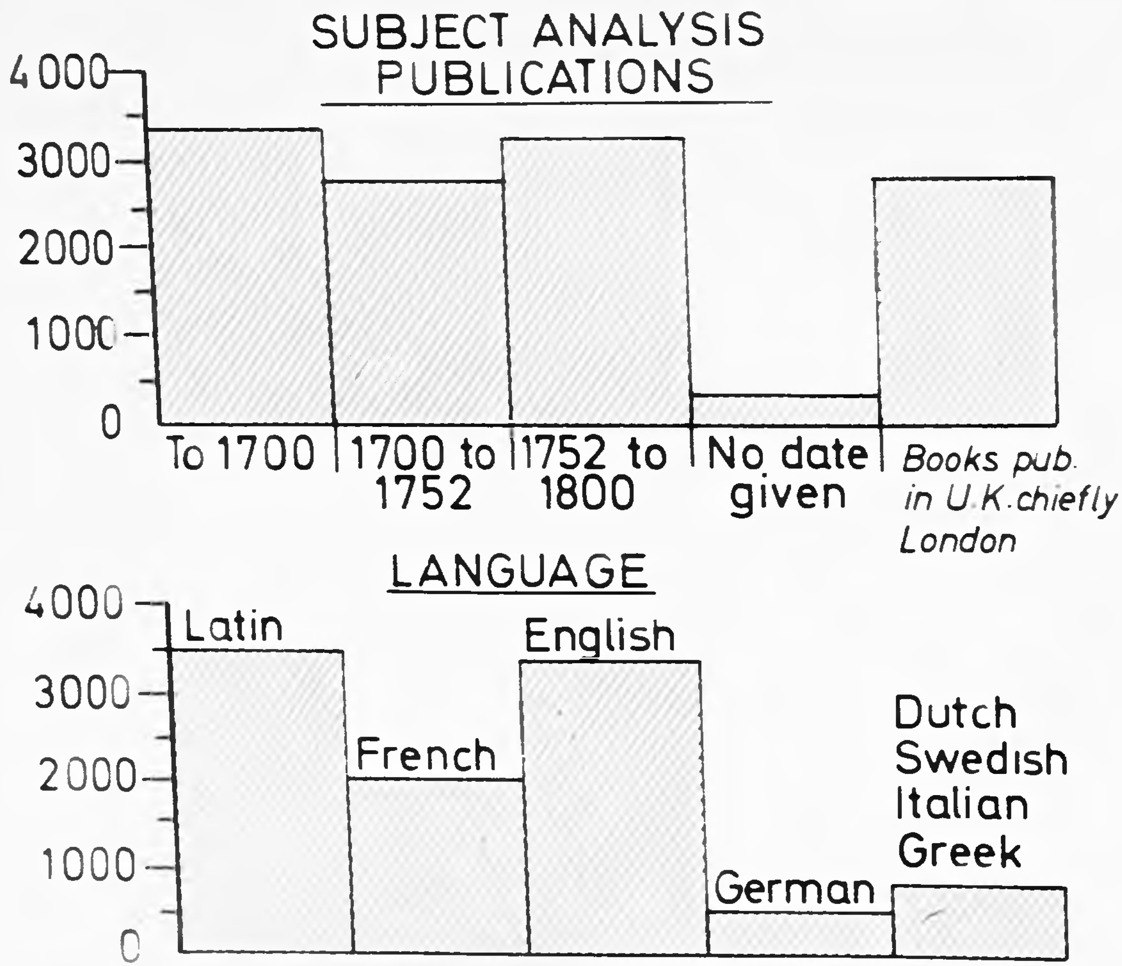
SUBJECT ANALYSIS
PUBLICATIONS
4000
3000
2000
1000
0
To 1700
1700 to 1752
1752 to 1800
No date given
Books pub. in U.K. chiefly London
LANGUAGE
4000
3000
2000
1000
0
Latin
French
English
German
Dutch
Swedish
Italian
Greek

TABLE IV

ANALYSIS OF CAVENDISH'S PRIVATE LIBRARY PUBLICATIONS AND LANGUAGE

begun, and is marked by possibly the most famous of English private libraries, which has survived to this day in its original form - the library of Samuel Pepys. The Pepysian library numbers about 3,000 volumes, arranged in cases of red oak,(1) the doors being fashioned with small panes of glass. The books are in double rows, the taller volumes at the back, and the shorter ones in front, so that every title is plainly visible; some very small volumes are placed on blocks to avoid irregular lines. Where the volumes are heavy and valuable, they would often be kept on sloping shelves, side up. In the case of a collection devoted to fine bindings with ornamental covers, such as those of Jean Grolier (1479-1565), the volumes would all lie flat on sloping shelves, but this collection was undoubtedly exceptional. The great collection of De Thou was the first large library to be shelved with the spines of the books facing outwards. In this way, the spine presented a useful face for identification marks, and it was Locke who not only had every volume press-marked on the inside cover, near his signature, but also had the marks pasted on the spine.(2)

The Library of Henry Cavendish displays the same quality of method and care, so marked a feature of the libraries of Locke and Mazarin, as each copy bore the imprint of its owner. The thousand or so books of Cavendish's library that were inspected revealed few signs of wear and tear as the result of age and use, though many of

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1. S.L.A., p.7.

2. S.L.A., p.9.

these volumes are now four hundred years old.

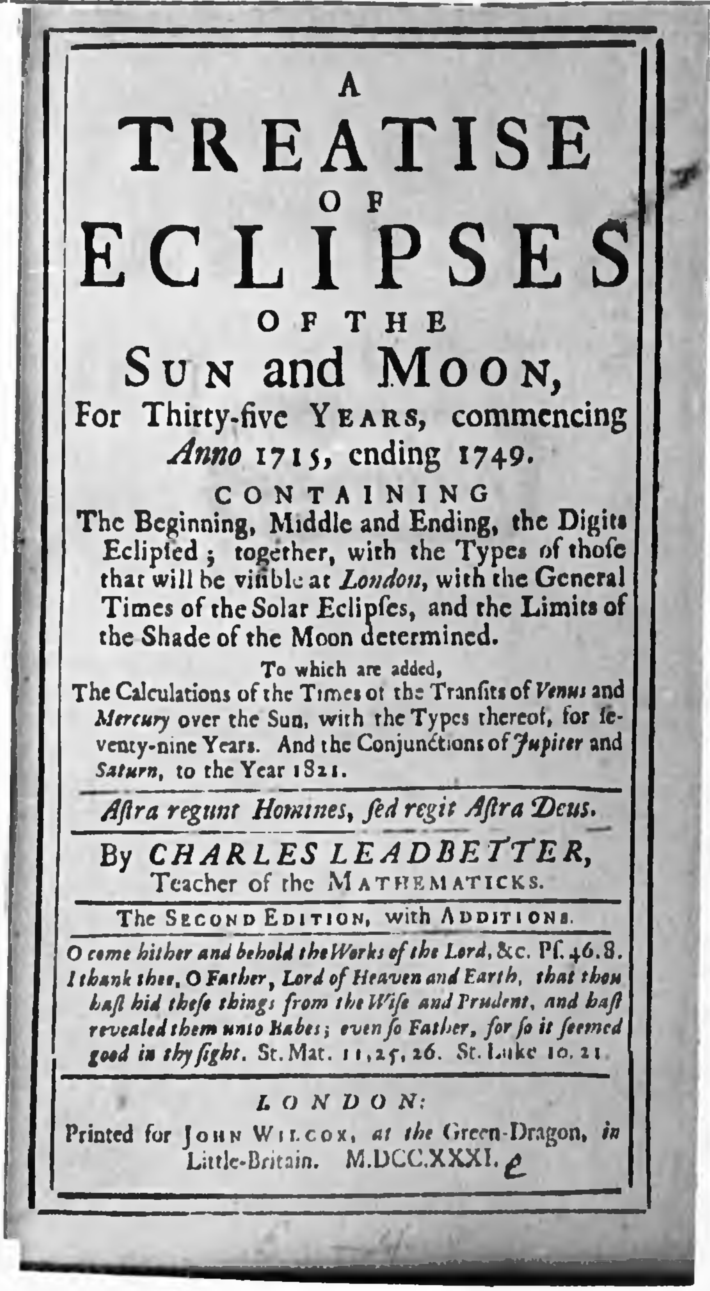
On the next page, Plate XIV is a reproduction of the inside title page of a book from the Cavendish Library. This volume, which is in good condition, is typical of the majority of books in his collection belonging to this and even to earlier periods, and to all appearances was in regular use. The letter and figure reference, E, 3-4, characteristic of the large assortment of combinations used, was always inscribed at the foot of the title page, in a hand-writing resembling that of Cavendish's own.

Another familiar mark was the small letter 'e', which also appeared at the foot of the title page, next to the press-marks, as for instance in the illustration. This sign denoted that Cavendish had actually 'examined' the book in question, presumably with careful thought, for it was not every book that attracted his close scrutiny. It was, however, noticeable that the 'e' mark was evident in works of wide and varied interests, in different languages too, showing his broad and contemporary outlook. Where an edition comprised several volumes the 'e' appeared only on the first volume.

In the map series, all the contents appear to have been 'examined' as indicated by the letter 'e', which is shown only, on the first page of a series. The counties of England, for example, may each be termed a series, and the small 'e' is given on the first map. Many of the English maps are dedicated to some distinguished nobleman belonging to the county or shire, and are formally worded in decorative lettering. One such example is a survey of S. Wales, and on the first sheet Cavendish has inscribed the following: 'Written by Bowen,

PLATE XIV

TITLE PAGE OF A BOOK FROM THE HENRY CAVENDISH LIBRARY



A
TREATISE
OF
ECLIPSES
OF THE
SUN and MOON,
For Thirty-five YEARS, commencing
Anno 1715, ending 1749.
CONTAINING
The Beginning, Middle and Ending, the Digits Eclipsed; together, with the Types of those that will be visible at *London*, with the General Times of the Solar Eclipses, and the Limits of the Shade of the Moon determined.
To which are added,
The Calculations of the Times of the Transits of *Venus* and *Mercury* over the Sun, with the Types thereof, for seventy-nine Years. And the Conjunctions of *Jupiter* and *Saturn*, to the Year 1821.

Astra regunt Homines, sed regit Astra Deus.

By *CHARLES LEADBETTER*,
Teacher of the MATHEMATICKS.

The SECOND EDITION, with ADDITIONS.

O come hither and behold the Works of the Lord, &c. Psl. 46.8.
I thank thee, O Father, Lord of Heaven and Earth, that thou hast hid these things from the Wise and Prudent, and hast revealed them unto Babes; even so Father, for so it seemed good in thy sight. St. Mat. 11, 25, 26. St. Luke 10. 21.

LONDON:
Printed for JOHN WILCOX, *at the* Green-Dragon, *in* Little-Britain. M.DCC.XXXI. e

This photograph, of the title page of a book from the Cavendish Library, illustrates the reference marks he made, for example the small'e' indicates that he has examined this volume.

Usually at the foot of each title page there appears, as in this case, the library reference, as here E.3-4.

6 sheets'. However, the fourth sheet is engrossed without any date, though probably 1765-1770, as follows:

SURVEY OF SOUTH WALES

IN SIX SHEETS

BY EMAN BOWEN

LONDON

TO HIS ROYAL HIGHNESS

GEORGE, PRINCE OF WALES

ELECTORAL PRINCE OF BRUNSWICK LUNENBURGH

DUKE OF CORNWALL AND EDENBURGH &C.

AND KNIGHT OF THE

MOST NOBLE ORDER OF THE GARTER

THIS MAP OF THAT PART OF YOUR HIGHNESS'S

PRINCIPALITY CALL'D

SOUTH WALES

IS MOST HUMBLY DEDICATED AND PRESENTED BY

MAY IT PLEASE YOUR ROYAL HIGHNESS

YOUR HIGHNESS'S MOST OBEDIENT & MOST

HUMBLE SERV^{t},

Eman Bowen.

All the engraved maps are from actual surveys undertaken by different persons, for example the Gloucester series shows that the county survey was completed by Isaac Taylor, Ross, 1777.

The Staffordshire survey, however, is marked thus, 1769 - finished 1775, by William Yates.

The maps invariably contain an humble inscription to the Lord-

Lieutenant of the County, or perhaps to the principal landowner, e.g. the Duke of Bedford. It was noticeable that the Bucks. series did not contain an 'e' sign.

The maps are all exquisitely engraved in colour, and the scale is a large one, so that detail can easily indicate villages, churches, gentlemen's seats, notable houses, farms, and even cottages. Tunnpike roads, and those intended to become so, are shown too, also inclosed roads, open roads over commons and downs, roads open on one side with a hedge on the other. Fields of battle, ancient encampments, are all indicated, while divisions of the hundreds are enclosed by dotted lines.

In fact, the detail is so clearly defined in these superb dimensional maps that tracing Cavendish's Journey of 1785, for example, in South Wales presented no great difficulty. The illustration on page 149 is of Plate XV of the South Wales series, and should be read alongside the text of this journey.(1)

Cavendish must, indeed, have been proud to possess such a valuable collection of maps, and enjoyed consulting them as he and Blagden planned their tours in England and on the Continent. While primarily engaged in scientific research, it must not be forgotten that Cavendish had proved himself to be a known traveller, and he could well have developed into a renowned explorer, so engaging was his curiosity in any form of discovery. There are many books of travel, of voyages and adventure, on his shelves, which captured his interest and imagination.

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1. Chatsworth MS. X(a)4, Journey 1785, p.30, - Appendix I.

PART OF MONMOUTH SHIRE
EXPLANATION
CARDIFF
Caerphilly
Aberdare
Llantrisent
Cowbridge
Bridgend
Llanelly
Abergavenny
Penderon
Capel Brithdir
Bettus Chapel

PLATE XV

THE MAP SERIES

The map opposite is a page from one of Cavendish's large volumes containing a series of maps of South Wales. This one, a portion of Glamorganshire, shows the Valley of the Taff, with the VAN at the top, and PONT-Y-TAAVE, , below, both of which are named in the Journey of 1785. The explanation in the bottom right-hand corner is a key to the many detailed references and features to be found on the face of the map. The scale of the original is 5 miles to 3"; the photograph is approximately 1/10 of the actual size.

There is an 'examined' copy of an account of the expedition of the British Fleet to Sicily, 1718, 1719, and 1720, under the command of Sir George Byng, Bart, afterwards, Viscount Torrington, [O, 4-5, 1739]. This book was written in English. There were eight volumes (7" x 4") [F, 3-3, 1731] on the voyages of Du P. Labât, En Espagne et en Italie, written in French. Again, also written in French, was a set of five volumes [F, 3-4, 1780] of the voyages of De Platrière

Lettres Ecrites de Suise, d'Italie,

De Sicile et de Malthe.

Roland de la Platriere

Platriere par M. X X X Avocat en Parlement, de plusieurs Academies de France, et des Arcades de Rome.

Cavendish has inscribed the name of the author in the position indicated above.

There was an interesting set of four volumes, entitled The Grand Tour, or, A Journey through the Netherlands, Germany, Italy and France, by Mr. Nugent, styled, Nugent's Grand Tour, 1778. It could well be that Cavendish and Blagden studied these volumes in preparation for their visits to Europe nearly ten years later. The books are attractively written in English, and the letter 'e' is exhibited on the inside of the first volume.

Cavendish's interests could turn westward, as well as eastward, with equal facility, as various editions appear of American life, one of which, written in English, is entitled, Notes on the State of Virginia - 1787. In history too, one noticed many interesting publications; a series of seven volumes [H.3-6 - 1788], written in French was entitled, De La Monarchie, Prussienne Sous Frederic le Grand, Mirabeau. Biographies, too, were not forgotten by Cavendish, and his library contained many, of which one was on the life of Sir T. More, A.D. 1716, and at the foot of the title page is written the following:-

'At the end are the love letters of Ann of Boleyn, and Hen.8'

Another set of two volumes [P.4-6, 1780] are the memoirs of the life of David Garrick Esq., written in English. The memoirs are interspersed with characters and anecdotes of his theatrical contemporaries, the whole forming an History of the Stage. The letter 'e' appears on Volume I.

It was also gratifying to observe a publication which encouraged the use of science for the benefit of humanity. This was, An Essay on Electricity, [B,3-3, 1785], explaining the theory and practice of that useful science, and the mode of applying it for medical purposes.

And as a last illustration of the varied assortment of literature to be found in the Cavendish Library was the following:

G. Cuvier

Éloges, Historiques

Précédes de L'Éloge de L'Auteur,

Par

M. Flourens.

Paris. E. Ducrucq, Libraire - Editeur.

On pages 139-159 there is an account of the great philosopher entitled, 'De Henri de Cavendish'.

It will be remembered that it was Cuvier who later in 1812, as Secretary of the French Academy, read an Éloge on Cavendish who was elected in his old age a member of the Institute.

Thus in perusing a selection of his books, one felt it a privilege to inspect examined copies embracing so wide a range of topics, and all bearing his name.

Most of the renowned owners of libraries had some distinguishing mark displayed on their books; for example Mazarin's books all bore his coat of arms, those of Locke his signature. Cavendish was satisfied to have his signature stamped in a convenient position, usually on the first available blank page, or failing this whereever it was possible. The form of the stamp is given in plate XVI which is a replica of his signature as it appears beneath his portrait in the frontispiece.

Not all famous libraries were treated by their owners with the respect that one anticipates from them. Austin Dobson relates that Goldsmith was not a book-lover, and did not hesitate to tear out half-a-dozen pages to save the labour of transcription, or to underscore passages with his thumb-nail.(1) Dr. Johnson though who loved his books, did not show the respect of a true book-lover. He did not hesitate to cut leaves with a greasy knife, or to read while he ate, 'and one knows how he ate', adds Dobson. He rarely failed to deface a borrowed book with marginalia; he rarely remembered to return it. Boswell wrote to Temple in 1763, that 'He has many good books, but

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1. S.L.A., p.10.

PLATE XVI

CAVENDISH'S SIGNATURE STAMP

The stamped signature of Henry Cavendish as it appears on the first convenient page of each volume in his Library.

they are all lying in confusion and dust'.(1)

Locke's library, and his catalogue, were masterly examples of orderliness and careful thought, and it appears that annotations, extracts, comments, prices, and desiderata were entered in his catalogue, which was an interleaved folio copy of Thomas Hyde's 1674 catalogue of the Bodleian.

Cavendish did not mark his catalogue at all, with the exception of the few additions already noted, and on the whole it is an attactive and meticulous work. He did, however, make comments and alterations in the books he examined. Whether all the annotations belong to him is, again, difficult to confirm. In the book illustrated in Plate XIV, the work had been studied carefully. Various illustrations are shown depicting the degrees of darkness of the 'sun' and 'moon'. Each drawing is called a 'type', and the circle represents a face divided into two segments, one black, and the other white. On one of the drawings Cavendish has made the following observation: 'The position of this type is wrong'.

It was surprising to find numerous small editions, measuring in size 3 inches by 6 inches, in their original covers. One such copy entitled 'Traitte de l'Aiman', and illustrated, was written in French, and published in Amsterdam, 1687. There were drawings of loadstones, and on an inside page, the following was written:

> 'It is observed that load stones ordinary strength consists in the proportion of matter it has equally distributed about ye pole, so that a stone six-foot diameter, if ye pole pass

1. S.L.A., p.9.

> thro' one side of it an inch deep, that stone will be no stronger than if it were but 2 inches diameter.'

There are two more comments following this one, but the writing is difficult to read, owing to discoloration of the paper and the ink. In any case, the writing of Cavendish, assuming this to be his, was at times hard to decipher.

Another interesting book on the 'Art of Numbering by Speaking Rods, vulgarly termed 'Nepeirs Bones', was corrected, presumably by Cavendish, to read 'Napier'. The volume was a small one, printed in London 1685, by T. B. for H. Sawbrigge at the Bible on Ludgate Hill. These old mathematical books are printed chiefly in Latin or French, and occasionally in Greek. There is a publication by René Descartes, a Musicae Compendium in Latin 1683. It is an enquiry into the principal phenomena of sounds and musical strings by Matthew Young, and is a signed autograph copy from the author. He adds,

> 'In the following discourse I have endeavoured to vindicate the 47th Prop B_2 of Newton's Principia from the objections which have been made against it, as it appears to me to be the only true principle on which the phenomena of the pulses of air can be explained ... &c. ...'

This is an 'examined' copy.

It is apparent from a close inspection of the catalogue, that Cavndish's scientific books were arranged chiefly in Sections A, B, C, D and E of his library, with press and shelf references such as 3-4, 3-9, 3-10, and so on. The cases were mainly of ten shelves high, and only rarely one noticed a reference indicating '11' or even '12' shelves.

Many of the books are old copies, and relate to the seventeenth century.[1] A book on the, 'Principles of Bridges', by Charles Hutton, Mathematician, Newcastle, 1772, was 'examined' by Cavendish, and on the page opposite the title, was written Dr. C. Hutton. Continued inspection revealed copy after copy of Cavendish's books which he had 'examined', while others he may have ignored, because in some instances the double pages were still intact. One curious copy bore the following words on the front page:

PASIQUE DES CORPS ANIMES

PARLE P.B. * * * correspondent de

l'academie ROYALE DES SCIENCES.

Cavendish recognizing what the asterisks represented supplied the omissions by adding the name Bertier above them. The reference number in the book was given as A, 3-3.

The Cavendish Library was a 'one man' library, and it is evident that this one man made considerable use of it, treating every volume with the care which it justly deserved. It contained a varied yet systematic collection of editions quite outside his own sphere of technical and professional interests. It was quite different from the haphazard accumulation of Dr. Johnson's library, about which as a result we know very little, even though it ranks as one of the great libraries of the country.

By contrast, there was the library of Edward Gibbon, about which we do know a good deal. Like that of Cavendish, all his 7,000 volumes were carefully and methodically acquired. 'I am not conscious,' he

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1. Blunderville, S.T.C., 3149.

says, 'of having ever bought a book from a motive of ostentation .., every volume, before it was deposited on the shelf, was either read or sufficiently examined'.(1) His great collection was gathered together with one purpose in mind, his 'magnum opus', and though he made use of famous libraries in Europe, the 'Decline and Fall' was chiefly indebted to the resources of his own library.

Perhaps the library of Henry Cavendish in its original state resembled more that of a 'Johnson', but after its arrangements, became a collection able to vie, in mass and orderliness, with that of a Gibbon, for both of these eminent men had books good and bad in their collections. The main criterion for inclusion, whether in religion or politics or the stage, was that they should be books which everyone was reading, and would in consequence stimulate discussion.

Cavendish possessed books on every conceivable subject, covering at least two hundred years of publications, for his library contains editions up to the close of the eighteenth century.

How many of these books did Cavendish inherit?

Did his library reflect the forward movement in habits of reading, from the fifteenth to the eighteenth century?

It is only possible to obtain a rough estimate of the strength of the library to which he succeeded, and by a reference to the analytical diagram Table IV it would be reasonable to assume that he inherited nearly half of his entire library.

With so wide a range of classes, eighteen in all, it is astounding

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1. Irwin, <u>Origins</u>, p.189.

TABLE V

AN ANALYSIS OF THE HENRY CAVENDISH CATALOGUE

CLASSIFICATION	Class Letter	No. of Pages	BOOKS Separate Editions	BOOKS Total Volumes	DATES OF PUBLICATION Before 1700	DATES OF PUBLICATION Between 1700-1752	DATES OF PUBLICATION After 1752	Published in U.K. London, &c.
ASTRONOMY	A	27	470	507	234	96	140	142
MATHEMATICS	B	49	1,010	1,064	453	284	273	361
NATURAL PHILOSOPHY	C	98	1,815	2,325	298	421	1,096	579
NATURAL HISTORY	D	21	395	476	148	112	135	145
ACADEMIC TRANSACTIONS AND JOURNALS	E	4	687	355	1	9	58	21
VOYAGES AND TRAVELS	F	29	473	756	114	109	250	232
GEOGRAPHY	G	15	308	391	80	88	140	87
HISTORY	H	33	731	1,096	301	269	161	274
LANGUAGES AND EDUCATION	J	18	377	433	242	81	54	86
BIBLIOGRAPHY AND LITERARY HISTORY	K	6	138	435	63	48	27	25
AUCTORES CLASSICI	L	35	657	712	497	121	39	106
CLASS TRANSLATIONS	M	5	54	122	22	23	9	26
ARCHITECTURE	N	12	177	199	103	62	12	45
ANTIQUITIES	O	32	451	519	254	133	64	105
POETRY AND PLAYS	P	40	1,054	1,099	235	334	485	298
NOVELS	Q	4	66	143	16	39	11	10
WORKS OF AUTHORS	R	5	70	143	26	35	9	31
MISCELLANEOUS	S	46	855	935	238	436	181	263
TOTALS		479	9,169	11,710	3,325	2,700	3,144	2,836
MAPS		20						
TOTAL		499						

to find so rich a choice of reading material, even from as few as the twenty percent of his library, which I have had the privilege to inspect. For example, from the Antiquities class alone, there were books on coins, money, exchange, weights and measures, medals, gems, the Peerage, genealogical tables, and one amazing literary treasure, 'The genealogy from Adam to these Times', 1736.(1) So one could continue enumerating exciting examples of this sort. It was, however, surprising to find that the 'Novels' were all French books, belonging to the early part of the eighteenth century, yet the 'Plays and Poetry', actually the second largest class in the catalogue, were later in date and published in English. There were many amusing and unusual titles among the editions, which were arranged systematically in the catalogue, beginning with the earlier publications. Works contemporary with the period were gradually finding their way into the Cavendish library, and so exhibiting proof that he was in tune with the times.

Then again, it is interesting to note that during this century politics began to take second place in men's interests to the issues raised by Addison and Steele. The Spectator and the Tatler, at this time, were concentrating on manners, ethics, and literature, their object being to 'enliven morality with wit, and to temper with with morality'. On a different plane, Edward Cave's Gentleman's Magazine, ran successfully from 1713 to 1754.

The trend, which began among men, found women of leisure developing a genuine habit for reading early in the century, while some fifty or

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1. H.C.C., Antiquities Section 0.29.

sixty years later the great majority of women were ardent readers of novels, and some were enjoying other types of books as well.

As a result of this new 'craze', the circulating library came into existence, and by the end of the eighteenth century it was an established institution working on lines similar to ours of the twentieth century. The reading habit had spread below stairs almost as rapidly as it did in the parlour, the boudoir, and the study. In fact, James Lackington, the London publisher, in 1791, made an entry in his diary, which confirms the continued demand for books. 'The sale of books in general has increased vastly with the last twenty years ... in short, all ranks and degrees now read.'(1)

Reading, therefore, had become an accepted part of life, and as a modern writer has said, 'I am mentally as much the books I have read as I am chemically the food I have eaten'.(2) The word books therefore means those which belong, not those which are borrowed.

Pause to reflect on this city of books, a priceless heritage of a celebrated philosopher, - Henry Cavendish. There are many he came by; others were gifts of authors and friends; some would be purchased because they appealed to him; countless he acquired to assist his researches; but what a collection that vies with the best! He lived with them, examined, read, studied, and even loaned them.

How much Cavendish must have cherished this Citadel of Books, pointing to the volumes on the shelves, and exclaiming as Dr. Johnson did, 'there are my friends'.

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1. S.L.A., p.13.

2. Irwin, Origins, p.245.

CHAPTER V

CHARACTERISTICS AND LATER YEARS

Cavendish's attachment to science was fanatical, and it has been the custom, even among his most ardent admirers, to regard him as a misanthrope.

But, surely, the truth would seem to be more complex than this. Scholars tend to be solitary creatures as Joseph Larmor declared in his preface to the Scientific Papers of Henry Cavendish, Vol. 1: 'The cultivation of the highest domains of physical science is rarely consistent with dispersal of interest in other directions. The tracking out of great discoveries which will be a possession to the human race for all times has indeed to be its own supreme intellectual satisfaction, and once an investigator has realized, in however modest a way, his capacity for such achievement, he can feel that he is serving humanity in the most perfect manner open to him by concentrating on that work, yet the temptation to continual postponement of ordinary social intercourse inevitably involves increasing isolation, and growing habits of solitude'.(1)

One of his biographers commented that, 'what was remarkable about Cavendish was not his psychoses, but the fact that they co-existed with intellectual ability of the highest order'.(2)

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1. <u>The Scientific Papers of the Honourable Henry Cavendish, F.R.S.</u>, Vol. I, <u>The Electrical Researches</u>, ed. James Clerk Maxwell, rev. Joseph Larmor (1921), p.ix.

2. W. R. Aykroyd, <u>Three Philosophers</u> (1935), p.76.

His detachment from society did not involve ostracism from mankind, it was just the intensive nature of his work that demanded it, and it is amazing to think that his health withstood the rigour of his daily activities. Apart from the following letter referring to an indisposition he occasionally suffered, there is reason to suppose that his pursuits were seldom interrupted.(1)

'16th March 1792

'Dear Sir,

I was very sorry yesterday to hear you were prevented coming amongst us by an attack of the gravel; ... I hope, however, the complaint is going off, as it was said you were better. That you may soon come amongst us is the sincere wish of all your friends, and of none more truly than of, Dear Sir,

Your most affectionate,

(signed) A. Dalrymple.'(2)

What, then, is the general picture of the man?

As might be imagined, no one ever succeeded in persuading Cavendish to sit for his portrait, but his picture, of which a reproduction appears as Plate I was constructed from surreptitious sketches made by the artist, W. Alexander, at a dinner of the Royal Society Club. The portrait is now in the Department of Prints and Drawings in the British Museum.(3)

In his manners, according to Dr. Thomas Young, Mr. Cavendish gave the impression of a 'quickness' and sensibility almost morbid,

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1. Sci. Pap., Vol. I, p.444.

2. Chatsworth MS. X(b)16.

3. Sci. Pap., Vol. I, p.ix.

united to a slight hesitation in speech, which seems to have depended more on the constitution of his mind than on any deficiency of his speech mechanism, and to an air of timidity and reserve, which sometimes afforded a contrast, almost ludicrous, to the sentiments of profound respect which were professed by those with whom he conversed. It is not impossible that he may have been indebted to his love of severe study, not only for the decided superiority of his faculties to those of the generality of mankind, but even for his exemption from absolute eccentricity of character. He was tall, and rather thin: his dress was singularly uniform, although sometimes neglected. His retired habits of life, and his disregard of popular opinion, appear to have lessened the notoriety which might otherwise have attached to his multiplied successes in science.'(1)

Numerous stories have been told of Cavendish's peculiarities, and one of these concerned a Dr. Ingenhousz, of Dutch nationality, who lived in England and was frequently to be seen in scientific circles. On one occasion when attending a conversazione at the home of Sir Joseph Banks, President of the Royal Society, he came with an Austrian visitor whom he attempted to introduce to Cavendish. Ingenhousz began by reciting all the titles and qualifications of his compatriot at great length. The stranger rising to the occasion, told Cavendish that his principal purpose in coming to London was to converse with him - one of the greatest ornaments of the age, and one of the most illustrious philosophers that ever existed. Cavendish stood silent,

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1. T. Young, 'Life of Cavendish', (From the Supplement to the Encyclopaedia Britannica, 1816-1824). Reprinted as an appendix to The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. I. (1921), p.444.

quite embarrassed, and spying an opening in the crowd fled from the house, sank into the darkest corner of his carriage and drove home.[1]

While Cavendish was ill at ease in the company of men, contact with women was quite intolerable to him. He shunned them as circumspectly as a fourth century hermit. He was a confirmed mysogynist, and to avoid chance encounters with housemaids, he had a back staircase built in his Clapham home, and should an unfortunate maid show herself, she was immediately dismissed. But, let it be added, there was an instance when he displayed true chivalry. A lady, who lived nearby, was being chased by an infuriated cow, whereupon Cavendish, who was taking one of his solitary walks, went to her assistance, and beat off the infuriated animal.[2]

The descriptions of Cavendish by Cuvier, Young, Thomson, and Wilson agree in representing him as living in London, and regularly attending the meetings of the Royal Society, but in other respects leading an isolated life, very much detached from the interests, whether social or scientific, of other men.[3] He had little intercourse with general society, or even with his own family, and saw only once a year the person whom he had made his principal heir, Lord George Cavendish.[4]

Though Cavendish had several houses in London, his principal

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1. Aykroyd, pp.75-76.
2. Berry, p.15.
3. <u>Sci. Pap.</u>, Vol. I, p.29.
4. Wilson, p.173.

residence, after his father died in 1783, was a commodious villa at Clapham Common. Most of the rooms were well stocked with apparatus for his experimental work, and what was intended to be a drawing room was converted into a laboratory. A forge stood in an adjoining room, while the upper apartments became an astronomical observatory. A large registering thermometer, of its owner's design formed a sort of landmark to the house; on the lawn was a wooden stage affording access to the top of a large tree which in the course of his meteorological or electrical researches he would occasionally ascend. As might be imagined there was little warmth and comfort to attract visitors to such a house, for his friends were few, and his ways were strange. He lived most abstemiously and seldom saw company. We are told if anyone dined with him his guest was invariably treated to a leg of mutton, and nothing else. It was said that when on one occasion three or four scientific men were to dine with him the housekeeper remarked that one leg would not suffice. 'Then get two', was the reply.[1] This appears to be the only record of any conversation he had with his housekeeper, as his usual practice was to order his meals by a note which he left on the table.

In spite of his peculiarities, Cavendish was greatly respected by his scientific friends, but he really had very few of them. Two must be mentioned specially. Dr. - later Sir Charles - Blagden (1748-1820), then Secretary of the Royal Society, who was also Cavendish's assistant, and the Rev. John Michell (1724-1793), formerly

1. Sci. Pap., Vol. II, p.4.

a Fellow of Queen's College, Cambridge, who afterwards became Rector of Thornhill, Yorkshire.(1) Blagden was a good scientist, without being a man of genius, as his writings display no originality, nor has he any place among discoverers of science.(2) His other close friend, Michell, was an accomplished mathematician and geologist, and whose life, like that of Cavendish's was outwardly uneventful. He was an excellent philosopher, and their friendship must have proved mutually helpful. Indeed, it was most likely that because of his relationship with Michell at Cambridge Cavendish was encouraged to pursue the study of geology, and his Journeys were just another illustration of his interest in that subject. Plate XVII represents Cavendish's conception of the solid geology of Britain accompanying which is a note of explanation. Plate XVIII is a map of the solid geology of England and Wales as it is known today.

Another friend who also served on the committee of the Royal Society with Cavendish and Michell was the Rev. Nevil Maskelyne, B.D., F.R.S., the Astronomer Royal. All three were collaborators in the investigations to determine the Density of the Earth.

The opening sentences of a letter from Maskelyne illustrate the warmth and respect in which Cavendish was held by his friends:

Letter to Henry Cavendish from Neville Maskelyne, dated January 5th, 1773, from Greenwich - re rules on attraction of hills.

'Greenwich Jan 5 1773

'Dear Sir,

Inclosed I return you your rules and directions for

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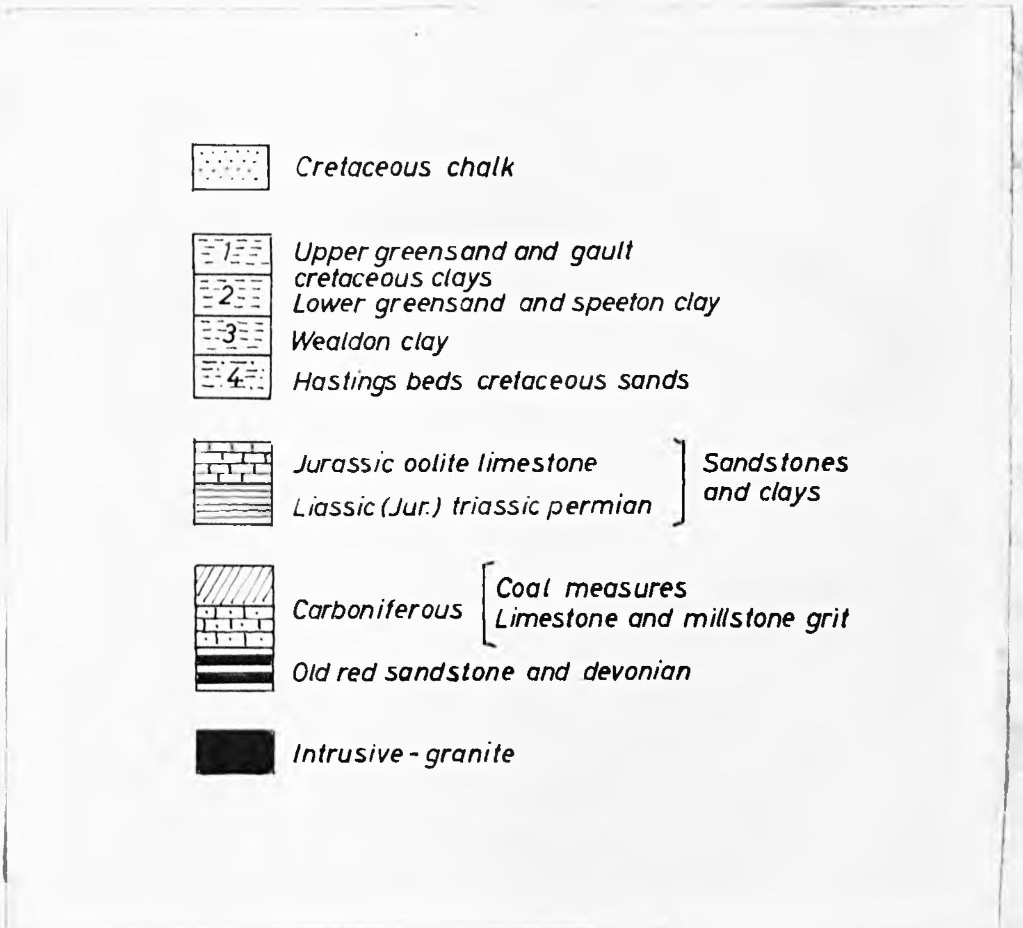
1. See Dramatis Personae - Appendix III.

2. Wilson, p.131.

SOLID GEOLOGY: ENGLAND AND WALES AFTER CAVENDISH

PLATE XVII

SOLID GEOLOGY MAP OF BRITAIN AFTER CAVENDISH WITH KEY



The Geology of England and Wales, according to Cavendish

Notes on the Map:

As far as possible the Geology of England and Wales, as it is described by Cavendish, has been correlated with the geology as it is known today, by grouping the strata named by Cavendish, into the correct rock series. Hence such features as the Alum Shales have not been recorded separately, but have been incorporated in with the Liassic, Triassic, and Permian, which are predominantly composed of various types of sandstones and clays, that form a large stratigraphic unit. Although they are an important local feature the Alum Shales are more appropriately mapped as part of the whole Permian succession. There has been some interpolation in the construction of the map, for instance in tracing the line of outcrop of the Jurassic or Yellow Limestone, which is a prominent feature over practically its whole outcrop.

The most complete description of local geology in the account concerns the South Eastern part of England, where the youngest rocks are found. The outcrop of chalk is well correlated too with that which occurs in Yorkshire and also in northern France. Particularly notable is the description of 'The Legs', the area enclosed by the North and South Downs, namely the Weald, or 'the Wilds'. Cavendish has made very good distinction between the different clays and sands of the Cretaceous and Jurassic rocks of this area. Thus the various names have been given in the key, and related to a number system on the map. There is a very good description of the landslip at Folkestone Warren, which is in fact due to sandstones slipping over clays that are rendered more mobile by water percolation between beds of different permeability.

Although no attempt is made at age dating by Cavendish, all the strata have been placed in the correct chronological order; where he is unsure of a particular stratigraphical succession, he still mentions the strata in question with the relevant country rocks.

Further elucidation of the correlation of the strata may be gained from the following short table:

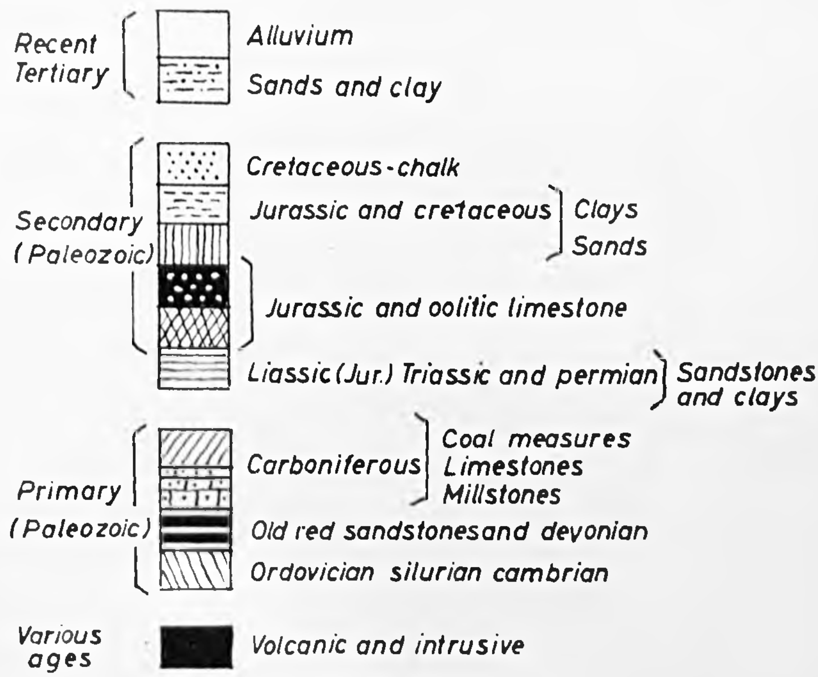
Rock Limestone	- Carboniferous Limestone
Yellow Limestone	- Jurassic Limestone
Killas	- Slates of the Old Red Sandstone and Devonian of Cornwall associated with granite bodies.
Red Rock	- Old Red Sandstone

Alum Rock, Fossil Salt, Blue Lyas - all part of the Liassic, Triassic and Permian succession.

SOLID GEOLOGY: ENGLAND AND WALES

PLATE XVIII

SOLID GEOLOGY MAP OF BRITAIN
WITH KEY



the choice of hills having a considerable attraction which I have taken the liberty to take a copy of. I think them well calculated to procure us the information that is wanted.

I am, Sir,

Your very humble servant,

N. Maskelyne.'(1)

The breadth of Cavendish's scientific interests was such that he could turn from one kind of research to another with ease, indeed it seems to have been his practice to keep several investigations running concurrently, although these were not invariably experimental, or concerned with a single department of science. By way of illustration of this it was during the time he was engaged on his inquiry into 'factitious airs' that he was also occupied with an examination of certain natural waters, made primarily with a view of throwing light upon the cause of the 'suspension [solution] of the calcareous earth which is separated from them by boiling'. At that period most districts in London were supplied by wells or springs; the water at Rathbone Place was formerly raised by an engine and served the immediate neighbourhood. Cavendish examined the water of Rathbone Place which had been selected for the purpose, and the results of his investigations were read to the Royal Society in a paper entitled 'Experiments on Rathbone-Place Water'.(2)

The question is often asked, why did Cavendish refrain from publishing so much of his works? This is not a question which can

1. Chatsworth MS. X(b)1.

2. Sci. Pap., Vol. II, pp.15, 102-111.

be answered satisfactorily. It may be, as many of his drafts would seem to imply, that literary composition was irksome to him. This was unfortunate no less for science than for his own reputation. Sir Edward Thorpe is of the opinion that the earlier publication of the cardinal discovery of the compound nature of water, for example, would possibly, although by no means certainly, have effected the speedier downfall of phlogistonism; it would at least have spared us what is known in the history of science as the Water Controversy, with its regrettable and unfounded aspersions on Cavendish's scientific character and moral worth.(1) It may be that he was not completely satisfied with certain aspects of his researches, but probably the real reason must be attributed to his morbid shyness and timidity.

In his dislike of notoriety, his taciturnity, and disinclination to publish, Cavendish, as in many other respects affords a striking contrast to his contemporary Priestley. It was characteristic of Priestley to write:

> 'When, for the sake of a little more reputation, men can keep brooding over a new fact, in the discovery of which they might, possibly, have very little real merit, till they think they can astonish the world with a system as complete as it is new, and give mankind a prodigious idea of their judgment and penetration; they are justly punished for their ingratitude to the fountain of all knowledge, and for their want of a genuine love of science and of mankind, in finding their boasted discoveries anticipated, and the field of honest fame pre-occupied by men, who from a natural ardour of mind, engage in philosophical pursuits, and with an ingenuous simplicity immediately communicate to others whatever occurs to them in their inquiries'.(2)

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1. Sci. Pap., Vol. II., p.6.
2. Sci. Pap., Vol. II, p.6.

This, most assuredly, must have been read by Cavendish, who was on good terms with Priestly and occasionally corresponded with him, but it is no less certain that he was entirely uninfluenced by it.

The correspondence of 1783, between Michell and Cavendish, indeed reveals a striking reference to the whole subject of publication. In preparation of Michell's paper of 1784, on 'weighing the Stars', Cavendish after receiving a draft of it, wrote that he was, 'glad you put your thoughts on this subject upon paper'. Michell, however, did not wish its contents to be disclosed if the paper was not read before the Society's recess.

Cavendish's response was to read Michell a lecture on the disadvantages of secrecy in scientific matters. While happy to receive the paper he was, 'sorry however that you wish to have the principle kept secret. The surest way of securing the merit to the author is to let it be known as soon as possible and those who act otherwise commonly find themselves forestalled by others ... On the whole I think that instead of you desiring me to keep the princ. of the paper secret you ought to wish me to show the paper to as many of your friends as are desirous of reading it'.

The advice is common sense. Yet it comes as a surprise in light of Cavendish's enormous reluctance to bring his own original researches to publication at all; the mystery of Cavendish's personality is only deepened.(1)

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1. R. McCormach, 'John Michell and Henry Cavendish: Weighing the Stars', <u>The British Journal for the History of Science</u>, Vol. 4, No. 14 (1968), p.147.

Cavendish was no less remarkable in the latter part of his life for the immense accumulation of his pecuniary property, than for his intellectual and scientific treasures. At some period subsequent to 1780 he became wealthy - how is not exactly known, but probably through bequests from relatives. Although he was as Biot expressed it, 'le plus riche de tous les savans et le plus savant de tous les riches', he was singularly indifferent to money and paid little interest or concern in spending it.(1)

There is a well-known story of his threatening to remove his money if his bankers, who were concerned at the amount lying idle in their hands, continued to bother him about it. Having with some difficulty obtained an interview with Cavendish, his banker informed him that he had a credit balance of some £80,000. To this, Cavendish replied that he did not wish to be 'plagued' about it, and if it was any trouble to the banker he would remove it. On being re-assured on that subject, the banker suggested, somewhat timidly, that some of this balance should be invested. 'Do so', was the reply, 'and don't come back here to plague me about it, or I will remove it.'(2)

Cavendish could be liberal at times, almost to the point of extravagance, when someone pressed a worthy object on his notice. He would request the subscription list, note the largest donation, and write a cheque for exactly that amount - a practice of which unscrupulous secretaries of charitable organisations learned to take advantage.(3) Similar acts of liberality are understood to have been

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1. <u>Sci. Pap.</u>, Vol. II, p.3.

2. Wilson, p.175.

3. Aykroyd, p.74.

performed by Cavendish on other occasions. According to Cuvier, 'il a soutenu et avancé plusieurs gens qui annoncaient des talens'. Who those parties were does not appear. The judgment, however, of a Fellow of the Royal Society, who had good opportunities for coming to a conclusion on this point, is, 'that Cavendish did some good in a very ungracious manner', and it could scarcely be expected, that one who took almost no care of his own property, should concern himself much about the prosperity of others. His famous answer to his bankers, already noted, is the best proof of his indifference to pecuniary affairs.[1]

Sir Edward Thorpe formed the opinion that, an impulsive generosity was wholly foreign to his disposition.[2] True, apparently, he made little use of his wealth, which steadily accumulated, until, at his death, he was found to be the largest holder of bank-stock in England and to possess upwards of a million in different public funds in addition to £50,000 in the hands of his bankers, a freehold estate of £8,000 a year besides canal and other personal property.[3]

Reference must, however, be made to his religious attitude, or as Wilson terms it, 'his irreligiousness', but immediately qualifies this by remarking that it may have been only apparent, because it was impossible to break through the silence, and measure his personal feelings.[4] One as reserved as Cavendish in ordinary affairs, was

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1. Wilson, pp.174-175.
2. Sci. Pap., Vol. I, p.3.
3. Sci. Pap., Vol. I, p.3.
4. Wilson, p.180.

likely to be especially uncommunicative on a subject touching any belief in his Maker. He did not give any indication or utterance on any creed or doctrine, and Wilson appears satisfied, after various investigations, that he did not make any confession of faith.(1)

Cavendish did not identify himself with the Church of England, or for that matter, any religious body, and he never attended a place of worship, though he was present at christenings of his cousins at Devonshire House, and at some other of the great houses of his relatives.

It is thus difficult to accept, on a question of religion, that Cavendish was 'nothing at all', yet it is vain to assert that we knew with any certainty Cavendish's views on spiritual things, or of his attitude to a future life. Wilson, however, does refer to a traditional belief that Cavendish not only favoured unitarian notions, but was decidedly Unitarian.(2)

The various accounts of Cavendish's death do not differ as far as essentials are concerned, but when he told his servant that he had 'something particular to engage his thoughts, and did not wish to be disturbed by any one', it was to insist that the closing hours of existence left to him should be solemn and silent, in preparation for the unseen world into which he knew he was passing.

This solitary eventless life came to an end, after a very short illness, on the 24th of February, 1810. He died, as he had lived,

1. Wilson, p.181.

2. Wilson, pp.181-182.

unattended and alone, and was buried in All Saints' Church, Derby, now Derby Cathedral, in the Devonshire vault, near the splendid tomb which his ancestress, the redoubtable Elizabeth Hardwick, the founder of his family, had built for herself.(1)

No tablet or other memorial of this celebrated man is to be found there, but his real memorials are the foundation of the Cavendish Society, of which the first President was the distinguished chemist, Thomas Graham, and, much later, of the Cavendish Professorship of Experimental Physics in the University of Cambridge.(2)

Almost the whole of his large fortune, apart from a legacy of £15,000 which he left to Blagden, was distributed among his relatives; the largest share went to Lord George Cavendish, the son of his first cousin.

It has often been lamented, even by his warmest admirers, that much as Cavendish effected for the promotion of physical science throughout his life, that he did not attempt to do still more after his death, by the appropriation of a small share of his immense and neglected wealth, to the perpetual encouragement of those subjects, which he had himself pursued with so much ardour. However, much this may be regretted, there is surely no reason to complain of his determination to leave his property to those whose relationship gave them a legal claim to it.(3) Evidently Cavendish considered that, in as much as he had received his fortune from his relations, he was in honour bound to secure its return to them.

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1. <u>Sci. Pap.</u>, Vol. II, p.4.
2. Berry, p.24.
3. Young, p.446.

Thomas Young, however, has this observation to make, that on many occasions the most successful cultivators of science are not always the most strenuous promoters of it in others. So often, 'ignorant persons', sensible of their own deficiencies, are disposed to overrate the value of education by bestowing more on the improvements of their own children than men of profounder learning, who may have felt the insufficiency of their own accomplishments for ensuring success in the world. Even if Cavendish had devoted some share of his property to the establishment of fellowships and professorships to induce men of talents to a more complete devotion of their lives to the pursuit of science, it is very doubtful whether he could have entertained a reasonable hope of benefiting his country by such an institution: for the highest motives that stimulate men to exertion are not those which are immediately connected with their pecuniary interests. We must hold out as incentives the possession of high celebrity and public respect; assured that they will be incomparably more effectual than any mercenary considerations,... Mr. Cavendish was indeed neither fond of giving nor of receiving praise; and he was little disposed to enliven the intervals of his serious studies by the promotion of social or convivial cheerfulness: but it would at all times be very easy for an individual, possessed of high rank and ample fortune, of correct taste and elegant manners, to confer so much dignity on science and literature by showing personal testimonies of respect to acknowledge merit, as greatly to excite the laborious student to the unremitting exertions of patient application, and to rouse the man of brilliant talent to the noblest flights of genius.(1)

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1. Young, pp.446-447.

The following quotations of some of Cavendish's more eminent contemporaries, who were well qualified to form an estimate of his disposition, will illustrate the greatness of the man.

Professor Playfair, of Edinburgh, visited London in 1782 and was frequently present at the meetings of the Royal Society Club. He says of Cavendish that, 'his knowledge is very extensive and very accurate; most of the members of the Royal Society seem to look up to him as to one possessed of talents confessedly superior; and, indeed, they have reason to do so, for Mr. Cavendish, so far as I could see, is the only one among them who joins together the knowledge of mathematics, chemistry, and experimental philosophy.'[1]

Sir Humphry Davy, in addition to the eloquent eulogium passed on Cavendish, soon after his death, has this to say - 'Cavendish was a great man, with extraordinary singularities. He was acute, sagacious and profound, and, I think, the most accomplished British Philosopher of his time'.[2]

The following account of Cavendish is from one of our most accomplished chemists, the Rev. Dr. J. F. H. Wollaston, 'When I was a very young man - a new Fellow of the Royal Society - I always looked upon it as a great honour to be noticed by Cavendish, and so did the other young members of the Society. We used to dine at the Crown and Anchor, and Cavendish often dined with us. He came slouching in, and hand behind his back, and taking off his hat (which by the bye he always hung up on one particular peg), he sat down without taking notice of

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1. Wilson, p.166.

2. Wilson, p.167.

anybody.'[1]

J. G. Children, Esq., was often in the company of Cavendish and thus refers to his interviews with him: 'I am now the Father of the Royal Society Club ... I recollect seeing Cavendish on one occasion talking very earnestly to Marsden, Davy, and Hatchett. I went up and joined the group, my eye caught that of Cavendish, and he instantly became silent: he did not say a word. The fact is he saw in me a strange face, and of a strange face he had a perfect horror. I don't think I had been introduced to him, but I was so afterwards, and then he behaved to me very courteously. He was an old man when I joined the Club, and was regarded by all as a great authority.'[2]

Is it possible, therefore, to estimate the qualities of a subject so complex as Cavendish? Wilson claims that an account of his life has necessarily assumed the character of a mosaic, made up of fragments furnished by different hands, thus leaving the individual with the means of drawing a likeness for himself. His own assessment of the character of the man appears to be that, 'morally it was a blank, and can be described only by a series of negations'.[3] The negations expressed as a succession of antitheses such as, 'He did not live; he did not hate', show a tendency to insularity.

It is acknowledged his circle of friends was small, but there is nothing either unusual or peculiar about this. What was more to

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1. Wilson, p.169.
2. Wilson, p.169.
3. Wilson, p.185.

the point was the affection and respect in which he was held in the Royal Society, at the soirées of Sir Joseph Banks, and among his scientific colleagues in this and other countries. All who knew him were sensible of striking dificiencies, but nevertheless this man was 'an intellectual head thinking, a pair of wonderfully acute eyes observing, and a pair of very skilful hands experimenting or recording.'[1] His isolation, one writer claims was spiritual,[2] and while he did not mix because he was conscious of his incompleteness socially, he circumspectly dwelt apart, preferring to serve mankind like a monk of La Trappe.

He was one of the unthanked benefactors of his race, who was patiently teaching and serving mankind, whilst they were shrinking from his coldness, or mocking the peculiarities of his domestic affairs. These trivialities, on which only the spirit of idle gossip could thrive, serve to emphasize the perfect consistency of a strongly developed will in all Cavendish's proceedings.

Cavendish did all things in the same spirit. Whenever he was to be seen he was rarely without some instrument whether it was a measuring rod, thermometer or barometer; if not in his grasp, at least near at hand.[3] Nor was this all: Cavendish followed strictly a daily routine as inflexible as the law which governs the hours of night and day. He wore the same costume continually regardless of changes in fashion; he hung his hat on the same peg, when he attended the

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1. Wilson, p.185.

2. McCormach, (J.M. and H.C.), p.130.

3. Wilson, pp.186-187.

Royal Society Club; he placed his walking stick in one of his boots, and always the same one, as they were placed in the same spot against the dining room door; he would never take a book from his library without giving a receipt, and when he rode out in his carriage, he measured the miles he travelled by a way-wiser attached to its wheels.

No matter what the ideal which Cavendish set before him, he adhered to it with undeviating consistency, and throughout his long life he never transgressed the laws under which he seems to have instinctively acted... Cavendo Tutus was the motto of his family, and seems ever to have been before him.[1]

'Whatever the sciences revealed to Mr. Cavendish,' says Cuvier, 'appeared always to exhibit something of the sublime and the marvellous; he weighed the world; he rendered the air navigable; he deprived water the quality of an element; and he denied to fire the character of a substance. The clearness of the evidence on which he established his discoveries, so new and so unexpected as they were is still more astonishing than the truths which he uncovered, and the works, in which he has made them public, are so many master-pieces of sagacity and of the methodical reasoning, each perfect as a whole and in its parts, and leaving nothing for any other hand to correct; but exciting more acclaim with each successive year that passes over them, and promising to carry down his name to a posterity far more distant than his rank and connections could ever have enabled him to attain without them.'[2]

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1. Wilson, pp.189-190.

2. Young, p.444.

'Such were the diversified labours of a philosopher, who possessed a clearness of comprehension and an acuteness of reasoning which had been the lot of very few of his predecessors since the days of Newton.'(1)

The preceding extracts, as appreciations of Cavendish, are from the writings of Cuvier, the author of his Éloge, from Young, who knew him during life, and from Wilson, whose Life of Cavendish still remains 'the locus classicus'. This chapter therefore, shall be concluded with an eloquent tribute to the character and achievements of Cavendish, as a man of science, by Sir. Humphry Davy (1778-1829), delivered in the theatre of the Royal Institution, a few weeks after his death.

He stated with perfect justice, 'It ought to be mentioned in estimating the character of Mr. Cavendish that his grand stimulus to exertion was evidently the love of truth and of knowledge: unambitious, unassuming, it was often with difficulty that he was persuaded to bring forward his important discoveries. He disliked notoriety; he was, as it were fearful of the voice of fame. His labours consequently are recorded with the greatest dignity and simplicity, and in the fewest possible words, without parade or apology; and it seemed as if in publication he was performing not what was a duty to himself, but what was a duty to the public.'(2)

Indeed as regards the style in which his memoirs are put together, Cavendish would seem to have been ever faithful to the injunction laid upon him by the original statues of the Royal Society,

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1. Young, p.443.

2. Sci. Pap., Vol. II, p.5.

and which remained in force long after he had passed away, viz.:- that in all reports of experiments to be brought into the Society, the matter of fact shall be barely stated, without any prefaces, apologies, or rhetorical flourishes.[1]

Henry Cavendish was a great man.

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1. _Sci. Pap._, Vol. II, p.6.

APPENDIX I.

NOTE ON EDITING

The spelling and numbering of the pages of the original manuscripts have been retained. Where insertions have occurred or alterations have been made, these are rendered as in the manuscript except for punctuation. Editorial insertions are given within square brackets. The insertions of commas and full stops have been kept to a minimum. Elucidations of place-names are supplied in the index and of unusual and technical terms in the glossary.

Computations and Observations in Journey 1785

(Chatsworth MS. X (a) 4)

[The first journey, undertaken by Henry Cavendish in July and August, 1785, was a tour of the industrial regions of South Wales and the Midlands.
The MS., in a scivener's hand corrected by Cavendish, consists of 17 double leaves 15" x $9\frac{1}{2}$", that is to say, a covering sheet and 62 numbered pages.]

[Page 1]

Sunday, July 17th. Just to the left of the Road between Woolverhampton and Thatcham, some of the Fossilwood Peat had been dug, and was then burning to all appearance for Manure.

Tuesday, July 19th.

In going down Nind-Lane, from Wortley Turnpike, we soon got to the end of the calcareous freestone, and came into the Stiff blue clay. The Farmers told us, that in digging, they first found pieces of blue limestone a little rounded, lying scattered irregularly in the blue clay, which they considered as an upper layer of the limestone beds, and called it the crop. Below the crop in digging they find successive layers of this Limestone, which, as they go lower, lies in more close compact beds, always with clays between, but where the Strata are very close, that clay is compacted into a hard Substance, almost like Slate. - In ascending from this blue clay up the Tortworth ridge, we soon got upon a Sort of Stone, looking like a gritty or coarse grained Limestone, which tried with an acid, was [Page 2] found to contain not much calcareous matter. The dip of this Stratum was highest towards the Freestone hills, and amounted in some parts to 40° or 50° to the horizon. In descending the Tortworth ridge from Wickwar towards Splats hill, we came toward the bottom of the same stiff blue clay, in which the blue Limestone was lying as about Nind. In the quarries here, the Limestone was lying in the form of flat Stones, some very thin, lying upon one another, with hard compacted blue clay between, having some what the resemblance of Slaty matter. Through some of the stones there ran veins of yellow matter seemingly mundic. The blue clay continued till we came near Hilsley, and there seemed to be nothing interposed between it and the beginning of the Freestone hills.

Wednesday July 20.

In making the Solution of Tin, Mr. Blagden used two parts of the Aqua fortis he had purchased to one part of Water. He drops the Tin in carefully, taking particular care, that the effervescence shall not be violent, otherwise a clear [Page 3] Solution is never obtained. - If any Straws or pieces of Wood are in the Liquor during the Solution, they are apt to make the mixture take fire, which entirely spoils it for dying, the Tin subsiding as a white powder: it also takes fire with the same effect, if the Solution be made too violently. The Aqua fortis is prepared by adding it to a small quantity of Common Salt; and the

Tin by being poured melted into cold Water, which divides it into thin irregular plates. No yellow fumes were perceived during the Solution, nor anything like the Smell of nitrous Air; the predominant smell was that of Aqua regia. We were told that where the Solution heated much, it yielded yellow fumes and became proportionably more turbid; and this was the case particularly when it took fire.- The Solution, if well made, would keep many days, and even some Weeks, if the Weather was cool: The Slower the Solution had been made, the longer it would keep; and when the Operation had been nicely performed, the Solution spoilt not by dropping any Sediment, but by loosing its yellowish, reddish or amber colour, and becoming [Page 47] pale and colourless. The powdered Cochineal was thrown in upon the Liquor in the boiler all at once, and floated on the Surface, where it was suffered to remain, without being stirred into the Liquor; the Solution (called Spirits) was then Sprinkled on the Surface of the Liquor at different Times, and in successive periods of the boiling, and the heat was urged at the same time till the Surface broke, that is, till it boiled up violently.- It appears that the cloths are dyed without such preparation with a mordant, as is described by Hellot, the Tartar or whatever else may be necessary to fix the colours, being put into the boiler with the dying drugs. In dying the Scarlet with grain, it is necessary that the cloths should not come into immediate contact with the copper boiler, other wise they are spotted. This is prevented by an osier frame in the boiler, cloths round the edges, etc. Alum entirely spoils the grain colours, turning the composition to a dirty crimson.- The cloths are never dyed crimson with Cochineal alone, but with Spirits in the Same manner as for Scarlet, but less composition, not much more than half, [Page 5] and then the proper hue is given by means of Archall, which brings it down to the crimson, from a Scarlet which is not very deep, or rather from a bright red. In dying Orage [Orange], they put the Turmeric and Tartar into the copper first, and when the Liquor was boiling (simmering) though not boiling hard, they throw in the powdered grain, and afterwards Sprinkled in the composition (Spirits) Successively, so that all the ingredients were in the furnace at the same Time.

Thursday July 21.

The fine and constant Spring called Kinner Well in the road from Mr. Hale's house to Monk's Mill, had been previously found to be $50^{1}/5$ by the Thermometer with a Sliding Scale. We now tried the temperature of a bucket of water, taken up briskly from the well at the Lower house Alderly. By the same Thermometer it appeared to be $50\frac{3}{4}$, but by a Thermometer with a fixed Scale (supposed to be adjusted for the diameter of the tube) it was only $50\frac{1}{4}$ consequently supposing this last the most accurate, Kinner Well is only $49\frac{3}{4}$, and the Lower house well is [Page 6] probably the same, as the water may have heated a little in coming up. We then measured the rope with the bucket of the Well at the Lower house, and found it to be nearly 107 feet. We then measured by the barometer the height of the Lower house well top (as before) above Kinner Well, and it came out [blank] feet, consequently they seem both to be nearly on the same level.

Friday July 22.

At Frombridge we were informed, that in order to draw Steel or Iron wire, after they had annealed it down to the proper temper, they found it necessary to rust the rods or large wires, by means of sour waters, that they might not heat too much in passing through the holes. They first rub off the ~~se~~ sc scales contracted in the annealing by means of a Mill, and then go to the operation for rusting, for which Sour Whey is much employed; still more to prevent the heating, they use much grease in the holes, which makes up into a sort of paste with the rust.

In making brass, they first divide their Copper, by dropping it melted into cold [Page 7] Water, which reduces the Metal into large irregular drops or lumps.- These are mixed up with about an equal weight of charcoal, but a much larger proportion of powder'd Lapis culaminaris, and the mixture is then put into a crucible (of Stourbridge Clay) so as to almost fill it, and then the crucible is put into a furnace, where the heat is immediately raised, so as speedily to reduce the Copper into fusion. In this state it remains 12. hours, and upon cooling the crucible a lump of brass is found at the bottom, about $^1/5$ of the quantity, of the Materials employed. In making both brass and iron to wire, they are obliged to anneal each drawing; but with the brass it is not necessary to rub off the outer coat, produced in the annealing, which must be done with the iron. In making iron wire, they Sometimes employ slitrods, but prefer certain rods made by hammering with irregularly lozenged Surfaces, from the Strokes of the hammer, as being of a more uniform texture, and drawing better.

In the Slitting mills, both rollers were both turned by rack work, moved by the same [Page 8] Axis. In the flatting mills, two rollers were turned by 2. separate waterwheels.

At the Tunnel cutting for the canal at Saperton, we observed that the freestone brought up was partly yellow & partly blue, the same piece of Stone being often tinged through of a blue colour, not exactly in the direction of the layers, but approaching to it. The different layers of freestone had in many places layers of clay interposed. The Shafts sunk down the Tunnel where, we thought, remarkably near one another: the deepest now made, is 35. yards; but near Saperton there are to be Shafts as deep as 60, we were told. The Tunnel itself was by estimation from 20. to 24. feet high; arched and walled with bricks: only about 40. yards are compleated.

At Stroud we were informed, that the old Canal had not yet paid any Dividend to the Priprietors, and that Scarcely anything but coals were brought up it, at the rate of 3^s/d a ton. The new cut extends from Stroud near 5 Miles to Chafford Prince, [Page 9] so as to be navigable; but no further as yet.

Saturday July 23.

At Stone Bench the head of Tide passed at 9^h. 50' A.M. by the watch last night at Alney, it came up nearly at the same time p.m. At Alney it made a good deal of noise before it came; at Stone Bench but little. The tide passed this evening at Newnham soon after 8. in the Evening. - It rose with great rapidity, and after the waves caused by the first coming, ~~it~~ had entirely subsided, perhaps half an hour or more after the first head, it seemed to rush up again with renewed violence, so as almost to form a head. We were told, that the tide, though earlier than we had expected it, did not come sooner than it ought: that in Spring tides, the interval between each tide, seldom exceeded $\frac{1}{4}$. of an hour, and that it was this Evening about one quarter of an hour later than it had been in the Morning. A person present said, that about 5. or 6. years ago, the Channel of the River, which used to run close to Newnham, had shifted to the other Side, and now ran equally close to Arlingham. [Page 10]

Monday July 25.

The furnace at Pentyrch not being in blast, we could only examine the forges. They are of 2 kinds, the Finery and the Chafery. In the Finery they make use of Charcoal only. A pig of iron is put on a hearth in the midst of a heap of burning Charcoal, and the blast of the bellows directed upon it, as it softens and partly melts, it runs down into the lowest hollow part of the hearth, the workmen stirring it all the while, till at length it is collected in the hollow as a soft tenacious lump, which can be taken up with the proper pincers. At the front of the hearth is a hole for the scoriae to run out. The lump while hot, is at the proper time taken up with a pair of large iron pincers, out of the Charcoal, and struck with iron rods all over the outside, to beat off all the Scales and adhering foulness which can be separated in that manner. It is than laid under the hammer, weighing 6. or 7. C^{t}. weight, the first strokes of which, besides making a large number of hot seales fly off to a distance, is to make a white hot [Page 11] fluid matter run out of different cracks of the Surface, some times in considerable quantities. From some of the cracks also a ~~brisk~~ bluish light flame issues, often to the height of 2. or 3. inches. This flame comes out without any strokes of the hammer, though more when the lump is under the hammer. This lump is then beaten with the hammers till it is reduced to an oblong form, ab^{t}. 20. inches long and 4. Inches thick, called half-blooms. These are then heated again in the same fire on the hearth where the pig is melting, and when white hot, are again brought under the hammer, and reduced, by beating in the middle, to a long bar, about [blank] inches in length, terminated at each end by a knob of 8, or 12. inches, being so much remaining of the original half-bloom. In this operation one end of the half-bloom is but little heated, as it sticks out of the fire, and affords a hold for the pincers to move it round in the fire, and at length to take it out. After these blooms are finished they are removed to the Chafery, where the knobs at the end are drawn out, and the Iron is fashioned into various utensils. All this is done with pitcoal; but only particular veins [Page 12] of it are fit for this purpose. The knob at the end is heated in a hearth like that of the finery, and when white hot is laid under the hammer, and beaten till it is drawn out even and similar to the original bar of the bloom, and it is found to be ~~Iron~~, in all respects equally good Iron.

The Scoriæ of different kinds are heated up again in the Charcoal fire with the pigs into those lumps, of which the half blooms are formed.

[In Cavendish's hand:-] To P.21*

At Newnham the Cliffs consist of a red Stone, partly calcareous, but leaving a good deal of undissolved matter, divided by thin Seams of whitish wax-coloured shivery Stony matter, which did not dissolve (in Aqua fortis) and appeared to be argillaceous.

When we got among the Hills about Pentyrch Works, they were found to consist of a reddish Lime Stone, laying in Layers which dip from S. to N. the whole Stratum very thick; the angle to the horizon at least 45°.- Proceeding northward we came to a blue shivery clay Stone, in some parts soft, deeper down very hard, in [Page 13] which both the Iron Stone and coal seem to lie; or at least. At Pentyrch Church the Lime Stone was as at the cliffs above the works; then we passed a Lane, and the first Stone, as we ascended again toward the Garth, contained no calcareous matter. In the Valley between the Garth and the hills of Pentyrch, were the Coal pits. In the Lane, ascending toward the Garth, where the first Stone not calcareous was found, the layer dipt very much, and apparently in the same direction as the Lime Stone of Pentyrch hill. In digging the Coalpits, they pass through nothing but the blue Shivery clay-Stone, which the lower they go, the harder it is, till near the coal it is quite a Stone; but on being brought up, and exposed to the Air, it presently shivers to pieces, and - moulders down.

On Caerfilly Common we had the calcareous hills to the S. The common itself consists chiefly of the blue shivery claystone, which also becomes harder the deeper they dig, till at length they come to a Seam of Iron stone, from 6. inches to a foot thick, with pellets [Page 14] or nodules, interspersed above and below the Seam. In other places of the Common, in digging through the blue clay, they come to coal. Under the Seam of Iron Stone, they have the same blue clay stone as above it. They have 5 different Seams of Coal with the blue Claystone interposed. The Seams of coal are from 2 to 4. feet thick each.

At the furnace we saw three different kinds of Iron, mottled, dark-grey, and bright-grey. Of these the mottled melts the easiest; bright-grey next easiest, dark-grey most difficult. The mottled will not make good tough Iron by itself, but either bright- or dark-grey will. Light-grey is always used by itself; but dark-grey is more frequently mixed with a little mottled, because it is very slavish to work, and of difficult fusion. The proportions are one ton of mottled to 3 of dark-grey. The mottled, on breaking, looks - more like light-grey, but has some white spots, especially toward the edge of the fracture. The general ground seems granulated, but the Spots look like crystallized plates broken edgewise. [Page 15] The light and dark-grey are both granulated, but the former exhibits finer grains in the fracture than the latter. In a Ton of pigs 28 lb. is allowed for sand; and then 4 Tons of pigs, make - 3 Ton of blooms 21. Ct.wt. to the Ton. To produce a Ton of Bar Iron, 21. Ct. of blooms is allowed, and 22. Ct. of half blooms. The whole produce from 4 Ton of pigs then is 3 Ton of Bars, 20 Ct.wt. to the Ton. The greatest advantage is to have the Iron bright-grey, shews that the proper proportion of ore to the charcoal in the furnace is used; if too little ore, it then becomes dark-grey, if too much, it becomes mottled, and when in excess, the furnace cools, and sometimes the mass congeals and spoils the furnace, so that they are obliged to take it down. Producing dark-grey, they call a low furnace, mottled and tending to congeal is raising the furnace high.

At Pentyrch they were putting a new hearth in the furnace. The hearth-part, which is the part in which the ultimate fusion of the metal is effected, is nearly Square, about 2 feet in length and breath, and perhaps 4. feet deep, built [Page 16] very solid. The hole for the blast was on the left hand wall, exactly in the middle between the back and the front, and about 18. inches from the bottom. The front is made by what they call a temp, which reaches from above to about 18. inches from the bottom; and the lower part of the outer front is a plate of Iron 2 inches thick, provided with a large notch in the top edge, and two arms on the right hand Side. This Iron plate is put close home to the left hand wall, but leaving space between it and the right hand wall, which in working is stopped up with Sand. The arms abovementioned reach to the right hand wall, into which they are fastened. Between them the poker is thrust, when it is necessary to stir the melted matters; and the furnace is tapped, to let off the melted metal, by removing the Sand which fills up the interstice between the right hand edge of the front plate and the right hand wall, close to the bottom; when the Metal discharges itself through a gutter made in Sand, into a Series of parallel Side gutters: the middle gutter and Metal congealed in it, being called the Sow, [Page 17] and those on the Sides each a pig. Immediately above this Square part, the furnace Spreads on each Side at an angle of between 30° and 40°. to the perpendicular, and after enlarging in this manner to a certain height, it again contracts to form the Mouth at the Top, by which the Furnace is fed. The parts that rise up immediately above the Square hearth, are called the <u>Bosses</u>. - When the Furnace is working, the whole load of Matter up to the Mouth is red hot, as we were told. After tapping the Furnace, they cease blowing some time, about half and hour, to get out the <u>Scoriae</u> and clean the hearth; after which the blast heing renewed, the Operation is found to have been in no respect injured by this cessation. Round the hearth they make what is called Air pipes, ~~between~~ forming a hollow communication, from the external Air at the Water wheels, about even with the bottom of the hearth, where there is one hole, to the Air in the casting house, where there is an other hole in the wall of the right hand side of the hearth above, level with the top of the cast Iron front plate. The use of these we could no otherwise learn, than that the Furnace would not [Page 18] work so well without them. Each hole, and we suppose for the whole length of the communication is about 2. Inches square. The hearth is built of a sort of Plumpudding Stones, of which we saw great numbers about Pentyrch loose in the channel of the Taaf.

Thursday July 28th.

Having heard that the blue Lyas Limestone was at Penarth point, we went thither. After passing the Salt meadows near Cardiff, we came to a hill which they call Lecquith; we found it lying in Strata nearly horizontal divided by thin Seams of blue indurated clay; the whole hill seemed composed of these alternate Seams, & probably contained as much Limestone as clay. When we came to Penarth Point, we found the cliff consisting of the red Clay stone, with Seams or veins of white clay stone, as at Newnham, above which the Lyas with its clay was laid, composing the upper part of the cliff. At the point some of the thin Seams between the red Stone, were of Gypsum of Alabaster. [Page 19]

Wednesday July 27th

Visited the Works at Mellengryffyth. The Forges, &c. seemed the same as at Pentyrch. For making the plate tin, the Iron is first drawn out into long and broad bars, which are then cut into Slips nearly of the breadth that the tin plate is to be. These are then drawn out between rollers. At last they come to be rolled 4 Sheets thick, and are then cut at the edges all the four sides of the Square, to be made Smooth, and then the 4. plates are separated from each other, which requires some force, as the cohesion is considerable. Each plate is next dipped Separately in Spirits of Salt, being previously bent in the middle, and laid in a kind of Oven, to be made red hot; they are then taken out, suffered to cool, then bent back as Smooth as they will readily become by the hand, and several of them being laid together, they are struck with great violence by a man on an iron Anvil. By this operation the general Scale or coat of rust, formed by the Spirit of Salt and the heating, is beaten off, and the plates rendered of an [Page 20] uniform though roughish Surface; in some places discoloured of bluish or yellowish brown, which we were told was not a Scale, and had no bad effect in the tinning. Each plate is next passed through a pair of rollers to make it Smooth and even, and it is then Steeped a proper time, half an hour more or less, in a sour Liquor, made of bran and water, fermented. From this Liquor it is put in common water, and is thence carried immediately to the melted tin, without being dried. The tin is melted in large boilers of a proper depth to take in the whole plate, and its Surface is covered with tallow or hogs Lard; but these being now dear, they were trying fish-oil, and found it answer. The iron plate is taken out and turned, and passed again into the Tin several times: so that the whole operation, till the surface be properly covered, takes up about half an hour. The tinned plates are then Scoured with bran, till they have acquired a proper polish. At the time the iron plates are steeped in the sour Liquor of fermented bran, they are well scoured with Sand, &c. so as to clean the Surface perfectly. [Page 21]

At this Work they make bolts for Ships by welding together the Shavings of the tin plates, by means of a hand hammer, and they consider the Iron as tougher than any Solid piece would be. The inside parts are not compacted into one mass, but only cohere, and they are thought less likely to break, than if they were one mass, besides that the iron would be much burnt before they could be so compacted.

* /In Cavendish's hand:-7

*/Scrivener's hand:-7 The Shape of the hearth at the finery is as follows: It consists of an oblong pit, formed of cast iron plates, about 2 inches thick. The pit is 2 feet 4 inches long, 1 foot 6 inches broad, and about 7. inches deep. In the front plate is a hole even with the bottom plate, which they tap by thrusting an iron into it, to let the Scoriae run off; and at the bottom of the front plate is a notch, lower than the under side of the bottom plate, through which an iron is thrust to heave up the bottom plate when necessary. The bottom plate does not come quite home to the front plate, for which no reason /Page 22/was assigned, but that it was unnecessary for it to be close; the distance was about 4. inches.

The weight of each lump, as it melts down from the pig, is about $\frac{3}{4}$ of an hundred. The pig rests upon the edge of the back plate, and the nozzle of the Bellows on the edge of one of the side plates, much nearer the back plate than the front plate, and just under the projecting end of the pig. As the pig melts, the matter collects at the bottom of the hearth, and does not come into liquid fusion, till it is among the cinders, or Scoriae, which the workmen consider not only as bringing it to the quality of tough wrought Iron, but even as necessary to melt it perfectly. After being stirred, and as it were kneaded some time with the Scoriae, it ceases to be in liquid fusion, and becomes that tenacious lump, which they take out with pincers to put under the hammer. An half bloom is commonly about 20. inches long and 4. inches thick. The Blooms are of uncertain length, according as they are drawn out into a longer or flat bar: the former is about 4, the latter only 2 feet, besides [Page 23] the knobs at the end, the longest of which is near a foot, and the Shortest about 7 or 8. inches. The firework Sparks fly off in all parts of the operations in the Finery.

In the Chafery the hearths have no front hole for the Scorio to run off by, but the refuse matter collects at the bottom into masses they call Mosses, which are taken out every 12, or 24. hours, when they make up the fire afresh. These in the Chafery hearth, worked with pitcoal, contain much iron, but are not found worth working over again, so that they are absolutely refuse, but when the Chafery hearth is worked with Charcoal, the Mosses contain no iron. The former ones are round Mosses, of the Size of a large Man's head, hollow in the middle, and open at top, very spongy and rusty. In the Chafery when they use Charcoal, it is commonly Small and dusty, which they call brain, and this workes up the Blooms, &c. with less loss.

Friday July 29th.

The Furnace at Pentyrch is 26 feet; but the Funnel reaches much above it, and other Furnaces [Page 24] are much higher. The bottom of the hearth is narrower, and proceeds upwards widening a little, so that the Temp-stone is supported by the inclining Sides. In wet weather they can use to work the furnace only one measure of the wet Charcoal to 6. of dry; but when the weather is dry, they can use 2. wet to 7. dry. In the forges they do not regard whether it be wet or not, and are frequently wetting it, to prevent the iron from cracking, from the difference of temperature between the parts of the Bloom out of the fire, and those in it.

At Merthyr a new Furnace with Machinery is just erected by the Messors. Humphries. The blast is given by means of a fire engine on the old construction, the cylinder 40. inchest diameter. At the further end of the beam, a piston was worked in a cylinder 6. feet in diameter, which forced the air into two cylinders, one in each side: from which went pipes that united in a reservoir, from which the blast was conveyed by proper pipes to the Furnaces. The covers of the Side cylinders were loaded with a weight equal [Page 25] to 4 inches of quicksilver. When these covers, which were mouveable within the Side cylinders, rose to a certain height, by the air forced in underneath them, they raised a frame which opened a valve, that afforded a discharge for the Superfluous Air from the middle cylinder in which the piston works. The Engineer, whose Name is Birch, Supposed that half the Air escaped this way; and it is intended to convert this Air to the working of a Forge. The piston of the middle cylinder, which was 6 feet in diameter, made a Stroke of 5 feet, 12 times in a minute. The pipe which let the Air into the Furnace, was fastened to the main pipe by flexible leather, so that it could be pushed in or out, and otherwise guided.

The Furnace was like Mr. Lewis's at Pentyrch; but the boshes reached up not more than 1/6 or 1/5 of the way from the hearth to the mouth where the Furnace is fed; and the width of this Furnace seemed much less in proportion to its height than Mr. Lewis's. The width was 12. feet the height 60. The air pipes extended round, under [Page 26] and up, in all directions, and are intended to prevent the Furnace from bursting, by the Air and Steam, when it comes to be heated. This Furnace had cracked toward the top, which was attributed by many to its having been heated too soon. They use 3 ton of Coak to make 1 ton of pig Iron, and the ore used, is entirely the Stone of the Surrounding hills. The casting we saw, consisted almost entirely of plates for the Anglesey Copper works. They were oblong, weighed nearly 1. Ct.wt. had 2. holes toward one of the long sides, and a protuberance between them, and were about $\frac{1}{2}$ an inch thick. The holes are intended as handles, and the protuberance to keep the plates apart, when they are laid in the Copper water. They were going to cast a hammer beam, that is, the ~~hand~~ axis by means of which the hammers in working are raised up.

There are several veins of coal in the neighbouring hills, with the blue clay above, beneath, and interposed. The bed of Iron ore, of which there is only one, lies underneath the coal. The veins often failed, and were found again at another level. The Seam of Iron ore is attended with [Page 27] pellets and nodules, as in the Caerfilly seam. They coak the coal by laying it in a large heap, several times broader than deep, and then light it at the top. When the flame has spread something more than half way over, which it does in 6, 9, or 12. hours according to the nature of the coal, they cover it up with ashes; but the heap or pile being hollow underneath, by a foundation of large coals laid upright and separate from each other, the fire spreads at bottom, after it is smothered on the upper surface, sufficiently to coak the whole heap. The ore is roasted in the same manner as lime is burned. Some of the kilns in which it was roasting afforded a smell of Sulphur; in others scarcely anything could be distinguished but the common smell of coal. - At the top of the furnace in which the ore was melting, though 60. feet above the hearth, the flame was very strong. Mr. Humphries prefers these high and comparatively narrow furnaces, because that construction makes a greater draught of air in the middle parts, and consequently a Stronger heat. [Page 28]

Friday July 29th 1785.

The Method of tapping at Mr. Humphries's Furnace, was exactly like that described by Mr. Lewis, by removing the Sand at the side of the front iron plate, close to the bottom of the hearth; except that in his Furnace, the interstice filled up with sand is at the left hand side of the hearth. As soon as all the Metal had run out, they began to clean the hearth, by removing the Scoræ and congealed matter with iron hooks and pincers, and the blast was suspended all this Time, perhaps a quarter of an hour, till the hearth was sufficiently freed of impurities. Mr. Humphries informed us, that the Materials, tho' much heated, and almost ready to melt in the body of the Furnace, do not really melt till they come under the blast; but immediately as they are acted upon by the Air, run down quite fluid. In consequence of the crack in the top of the Furnace, the flame forced itself out at the holes, that had been left as Air holes near the Top. [Page 29]

Saturday July 30th 1785.

Cyfarthfa

This morning we went to Carvartha Forges, Mr. Bacon's, now let to Mr. Tauper, about a mile from Merthyr. Here coak iron is reduced to malleable iron, without charcoal. The pigs are first melted down in a hearth (*) and stirred till they become a lump, as in the charcoal works; they are then put under the hammer hot, and reduced to flat plates in general about $\frac{1}{2}$ an inch thick, of an irregular shape, and rough cracked irregular edges. These plates are then broken under a hammer into pretty large lumps, which are laid in a heap, and kept moist by water dropping upon them. We found them blackish on the outside, with Spots of rust, and at the fractures of a granulated texture bright light colours, but also in places much rusted. The Small Stuff that was collected in the hearth, they washed with water, and then laid it by

(*) These hearths are nearly of the same form as those in the charcoal Works, but with some peculiarities, which the Agent told us were known only to the workmen.

[Page 30] Separate. Afterwards the broke lumps are put into cylindrical pots, made of refractory clay near a foot deep, with a certain proportion of the washed small stuff, which served as a flux. There is no other addition, and the Surface is not covered. The heat is not urged for the metal to melt, but so that the different pieces may be welded together, which happens by their Sinking down into a sort of mass, and contract so as to leave the Sides of the pot, which usually cracks, and is easily separated. This mass is then formed into a half-bloom, a bloom, &c. as in the common forges.

In proceeding up the Valley of the Taaf, toward the Van, the Strata were not much inclined. At first we had nothing but the same rock as about Merthyr, which seems a sort of Clay-stone, or at least is a hard Stone not calcareous. (Much of the Stone about Merthyr, of the same appearance nearly, is soft and crumbles.) Some Miles from Merthyr we got to Limestone, which composed several of the rising hills, and lasted for some miles but a few miles before we reached Pont-y-Taave. At the bottom of the Van, we came upon a [Page 31] Sort of Slaty rock, which lasted all up the Van, with some differences of appearance. Toward the Top of the higher hills on each side of the Valley of the Taaf, there were Strata of Stone of a different appearance, which Mr. Humphries said was Lime Stone, and this seemed to form the upper Strata of Stone on these hills.

Sunday July 31st 1785

On the road from Brecknock to Abergavenny, we had lime kilns on the right, near the top of the high hills on the S. side of the Usk. The Sugar loaf mountain seemed to be the same stone as about the Van. Many miles before we reached Monmouth, the Soil had the Same red appearance as about Newnham, and Chepstow.

Tuesday August 2nd. 1785.

In ascending Malvern hill at Wytch from Ledbury, we saw Lime Stone rising up along the hill, to the right, just at the foot of the down part, which they were burning into Lime. The highest point of the hill, is immediately above Malvern village. In ascending we saw [Page 32] rock projecting in several places, which was a sort of coarse Granite, below almost resembling a very fine plum-pudding Stone, but near the top composed of much finer parts or grains.

At Birmingham we were informed by Dr. Withering and Mr. Watt, that the part of the road through which we descended off the Licky on the Northside, when fresh cut, appeared evidently to be a granulated Quartz.

The Machine for twisting the handles of horse whips, is so constructed, that the bobbins can move only one way, as the Machine is turned backwards and forwards; but they slip over one another alternatively in succession.- When the bobbins rise up to a certain height, a catch is let loose, which suffers the thread to unwind from the bobbin half a revolution.

The great inconvenience complained of in the needle Manufactory, is their warping in hardening. In that case they must be made straight by a Stroke with the hammer; but this leaves an impression, and the needle is always the worse. [Page 33]

In the rolling plate Manufactory at Snow Hill a circular motion is given by means of the Steam-engine. A bar of iron is fastended to the beam of the Steam engine, and at its lower end turns a crank, which gives motion to a wheel, communicating with the rest of the Manchinery. In order to keep that in motion, when the crank is at its upper and lower points, it moves a wheel by rack-work, which makes its revolution in half the Time; and at one part of this wheel a heavy weight is fastened, which tends to accelerate motion most, when the crank is at the upper and lower points, and retard it, when the crank would give the quickest motion. It was invented, or at least the patent for it obtained, by a Mr. Picard, who has sold it to the present proprietor; but Mr. Watt claims the original

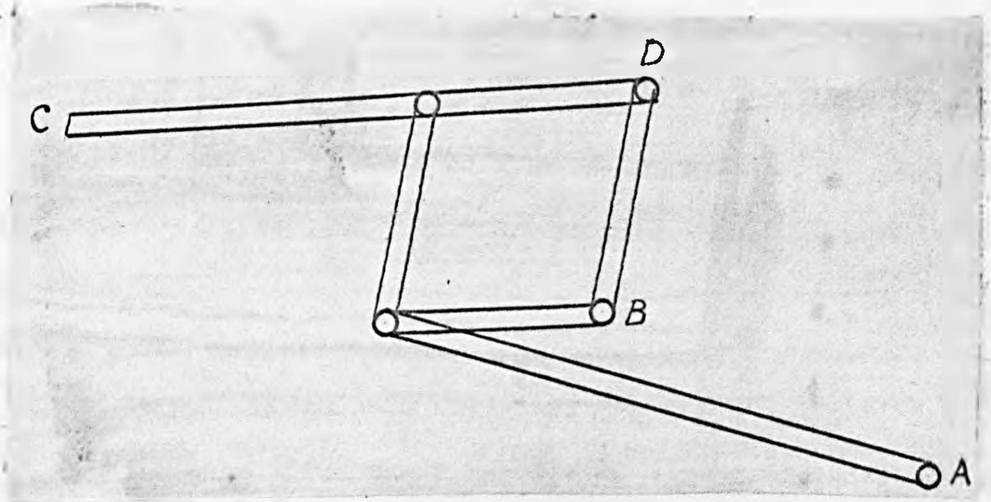
Idea. In order to make the Silvered plates draw, it is necessary to forge them, previously heated, before they are first put between the Rollers. In order to fix the plate of Silver on the plate of copper, they make the surfaces of both exceedingly clean, and then wet them [Page 34] with a solution of Borax. They are then put into the fire, and the workman watches the time, when the edges of the two plates in contact melts. Whenever that is observed, he takes them out of the fire, and they are found perfectly fixed to one another: not so however as to bear being rolled, till they have been again heated and forged with a hammer.

Wednesday August 3rd. 1785.

At Soho. The pieces of Steel which are inlaid into the Bath metal for buttons, are made of a steel very highly converted, so that it can be hardened by a very Slight heat. Some Steel is so converted, that it can be hardened with a heat Scarcely sufficient to make it slightly red hot; but that kind of Steel has not much Strength.

The fashionable excellence of gilt buttons is that they may look red, much like copper. For this purpose the gilt button scarce polished up, is dipped into a solution of some Salts, amounting as Mr. Watt Said, to a kind of Aqua Regia. It is then set on a part of a Stove, which seems to [Page 35] make it obscurely red hot, and then is thrown into cold water. Upon being afterwards burnished, it looks so like burnished copper, as not to be distinguished even by workmen, without applying Aqua fortis.- The very fine black polish is given to Silver by burnishing it with Haematites, nothing else will make it so perfect.- Filagree work is fastened in by Strewing Sodder with Arsenic over the Surface, and melting it with a Blow pipe, when it is absorbed at the parts in contact, without filling up the interstices meant to be left hollow.

Mr. Watt's new method of giving a circular motion by the Steam engine, is by making a Small wheel fastened at the bottom of the bar, Suspended to the beam of the Steam engine, pass round a larger wheel, without revolving at all on its own axis. The centers of these two wheels are connected by a lever, ~~and~~ keeping the Small one constantly at the circumference of the large one. The effect of this is, that the larger wheel performs always one revolution, and as much more as [Page 36] corresponds with the number of teeth in the Smaller wheel, while the latter is passing once round the circumference of the former.



This figure represents the manner of making a rod, moving by the beam of a Steam engine, perform its motion up and down vertically in a Streight Line, without the help of a circular arch and chains. CD ~~and D~~ is the Beam of the Steam engine, C. its center, A. a fixed point, and B the point which is to move vertically to a Straight line.

Mr. Watt mentioned, that having found that some Steam is condensed in the cylinder of [Page 37] the Steam engine, tho' surrounded with Steam, he made an experiment to discover what happened. He threw Steam into a Glass vessel close at top (*) and found that upon making the Vacuum some of the Steam condensed on the Sides of the Glass Vessel; and having heated the sides of this Vessel, so that none could condense upon them, he observed the condensation to take place, so as to render the Steam visible in the middle of the Glass vessel; that is, when the sides were much heated, no cloud was perceived; but as they cooled, a cloud began to appear at each Vacuum, in the middle of the glass vessel; and when any parts of its Sides were Sufficiently cooled, the Steam then condensed on that cooled part.

Mr. Watt thinks to have ascertained by experiment, that the less heat water is converted into Steam with, the more latent heat it requires to

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(*) By making it communicate with that part of the cylinder of this fire engine in which there is alternately Steam and Vacuum.

[Page 38] assume the elastic form; more even than the ~~sensille heat~~ differences of the Sensible heat: for instance, that water converted into Steam under a pressure that Suffers it to take that form at 100 , contains more heat, sensible and latent taken together, than when it is converted into - Steam under the whole pressure of the Atmosphere at 212°. He states the difference at 100. or more. Mr. Watt considers the heat of Steam at 212. both sensible and latent, as near 1160, - reckoning from 0 of Farenheits Scale; therefore the heat absorbed in the act of conversion from water into Steam, is 1160 - 212 = 948. He considers the Density of the Steam of boiling water at 212. to be 1800. less than that of water.

~~Bar. 29. 147. Therm. at 61½ at 11^h. 30'. P.M. Wednesday Aug. 3rd. Swan Inn, Birmingham, First Story~~. [Page 39]

Thursday August 4th 1785.

In the road between Wednesbury and Bilson, going from ~~Binn~~ Birmingham to Woolverhampton, we saw a coal pit hot and smoking, which not many months before, wer were told, had been burning. The Steam had the appearance of coming from the Top, but really came from the bottom, and continued transparent all the way up, being condensed, and so becoming visible, when it came near the top in contact with the cold air. Several other pits in that neighbourhood are in that Same State, Some of them throwing up fire or flame, which is visible at night many feet above the Top. The road here about is mended with a red Substance like potsherds, being the clayey matter about the pits, burned by this internal heat.

Between Woolverhampton and Shifnal, great part of the way we saw lying by the Side of the road for the purpose of mending it, both large and Small Stones of Granate, all rounded in the manner of pebbles, many of them seemed much to resemble the Granate we had found on Malvern hills. The red Soil continued with little [Page 40] interruption all the way to the wooden Bridge over the Severn.

The place where Mr. Wilkinson's Iron works are carried on, near Broseby, is called Willey.- His Iron is all made with coak, from ore and coal found on the Spot. The ore is of 2 kinds, called <u>pinny</u> and <u>flinty</u> ore: the latter harder than the former; but both he considers as a clay Stone, impregnated with Iron. Both ore and coal lie in clay, the former usually over the latter, when both are found together; but in some places, one in particular he mentioned, they interchange, the Seam of Iron ore running under the coal. Mr. Wilkinson described to us a fault in the Seam of coal near his Works, which he called a hog's back. It means an interruption in the Stratum of coal dipping according to the usual direction; but when the Stratum is found again, that part dipping in a contrary direction: So that if a Line were drawn from the bed on each Side of the fault according to the angle of inclination, the two lines would meet one another in an angle [Page 41] in the middle, raised above the surface of the earth. He said the regular and usual dipping of the Strata was a little to the Southward of East. He spoke of a place in Staffordshire, where after a fault the order of the Seams of coal was inverted, those lying undermost, which before the fault were uppermost. The Limestone he uses as a flux, is of a lightish colour, inclining to yellow, and has very distinct marks of extraneous fossils, Shells, coralls, &c.

He has two Steam engines, one for the blast, and the other to raise Water to work the hammers. The cylinder for forcing the Air into the reservoirs, is 72 inches in diameter. The piston in it, is worked up and down by the Beam of the Steam engine, and I believe he said makes a Stroke of $7\frac{1}{2}$ feet. From this cylinder pipes go into reservoirs made of brick, open at bottom, and surrounded with a column of water,(*) by the pressure of which it is meant, that the effort of the air to escape, Should be uniform. Out of the [Page 42] reservoirs, for there are two of them communicating together, pipes are led which convey the blast wherever it is wanted. The Air was let into the furnace in the same manner as at Merthyr. The furnace is 25. feet high, it was all flaming on top. He said the height of a Furnace should be determined by the nature of the ore, particularly its more easy or more difficult fusion. He is of opinion that the ore melts and runs down a considerable way above the point where the blast comes into the furnace. He said the blast might be suspended 16 or 18. hours, without Spoiling the Furnace.

In the Finery he had a current of water under the bottom plate of the hearth, but conceived it to be of no other use than to keep that plate from melting. The pig is here melted down with coak into a lump or loop, which is beat under the hammer into flat plates about an inch thick, with irregular edges. These are afterwards broken with a hammer into irregular pieces, and then picked, to Separate any metal which may not have [Page 43] been properly refined.

(*) The pressure of this, he said, was equivalent to 2. lb. on each Square inch.

These pieces, with the small bits broken of from them in the hammering, the latter previously washed, are put into an earthen pot, and kept in a fire, 3, or 4, or 5 hours, in the course of which Time they run together into a mass, tho' without coming into fusion, it is rather as a sort of welding. The pots soon break, and some fluid matter runs off, which is one Sort of finery cinders. When this lump is taken out of the fire in the pot, it is again hammered, and another quanitity of similar finery cinder is Separated from it. The Small Stuff or bits put into the pots with the large pieces, are ~~partly~~ what is broke off in hammering out the flat pieces or cakes; for the original lump does not bear the hammer like iron made of charcoal, but breaks and crumbles very much, thus forming the Small Stuff in question. Mr. Wilkinson employs 31. or 32 Ct.wt. of coak pigs, to make one Tone of Iron. The first refining reduces the quantity to abt. 25. Ct.wt. and the Second that from the pots, reduces the 25. Ct.wt. to 20. The pigs do not come into Nature, as the Term [Page 44] is, till they have discharged a large quantity of finery cinders: after which the mass puffs up and becomes Spongy, like Fermenting, and has then assumed the Nature of tough Iron, tho' still as yet but imperfectly.

The forged Iron Mr. Wilkinson here makes, is chiefly used for nails; it is not so malleable and tough as the Charcoal Iron made in England; but that Mr. Wilkinson imputes to the nature of the ore, and says, that this Coak Iron is better than it could be made by Charcoal with the Same ore; the reason he assigns is, that more of the original pig is worked away.

Friday August 5th 1785.

We went to Mr.Rathbone's Works, at Coalbrooke Dale, where the Iron Bridge was cast. They have two Furnaces, one a little below the other, ~~in a canal running off from the Severn.~~ The upper Furnace, the Smallest, is 25, or 26, feet high, and 12 feet wide at the Top of the boshes. It flamed at Top like the others we had seen. The blast was given by two cylinders, without [Page 45] any regulator, only a comparatively small box of Iron, into which the pipes from the two cylinders united. Hence a pipe conveyed the blast directly to the Furnace, and was furnished with flexible leather as usual. - All the motions were produced by water, raised by a Steam engine from the depth of 101. feet. The Engine was of Watt's construction: but in the little dish which sits upon the Collar in which the Shaft of the Piston works, the greatest part of the Liquid was water; but with some thickness of oil swimming upon the Top: and the Agent told us that a small quantity of water getting down into the Cylinder, did not injure the motion; but rather served to keep the piston tight and in good Order. When the Engine began to lift, it made a short pause, in the manner of the common Engine, and it worked remarkably slow 12. or 9. times in a minute. The Works extend near a quarter of a Mile, and the Same Water Serves all, Seeming to have about five Successive falls; then from a dam at the end of the works it is carried by a level to a pit under the Engine just 101. feet deep, whence it is raised by the [Page 46] Engine into the upper reservoir and so again makes the round of the Works. At the Furnace they employ three sorts of ore, called *white flats*, *pinny* and *ball*.

These lie intermixed with the coal in Strata of clay, and are found from 2 to 3 miles up the country. They have lately dug from near the Iron Bridge, a harder Sort of ore, which lies under the coal and all the other measures, and is supposed to be richer than the former ones. They had desisted from shingling at the forges for want of water, but were trying an experiment of working up the broken pots, kettles and other pieces of cast-Iron, by merely heating them with coal in the Shingling Furnace without pots. The Iron so made, did not prove very good, but was manufacturing into Stampers, for which purpose, they said, it was good enough. There was a Mill for boring Cylinders. A Square Iron box on a long Shaft of the same Metal, received an Iron wheel of near the diameter of the Cylinder to be cut. This Wheel had four pair of notches, each two near together; but each [Page 47] pair at intervals of a quarter of a circle from each other: Into one of each pair were fastened the 4. cutters employed, and the other of each pair received a piece of wood, of the same width as the cutters, so as to fit exact in the Cylinder, but rather behind the fore edge of the cutter, that it might only touch parts which had been cut. The use of these pieces of wood was, to make the Work to smooth, and prevent jarring.

About half a Mile below the Iron Bridge, is a Manufacture of Coal Tar, belonging to the Same Company. The Coal to be distilled, is put into chambers, built of fire brick, in the form of plates, and a fire is made under them, which drives the vapour through communication pipes of brick into a common gallery, or chimney, nearly horizontal, which is conveyed round, and terminates in a

Reservoir for the Tar or oil, over when the water swims. As the Tar accumulates, the Water is carried off, till the Reservoir is filled with Tar, when it is raised by a pump into another [Page 48] Reservoir, whence it is conveyed to the Alembic, where $\frac{1}{3}$ of it is distilled off, and what remains is thought Tar of the proper consistence. The matter distilled off is very pungent, and has been obtained of the colour of Mountain Wine, but they could not make it turn to any account, it was tried far Varnish without Success. The water Smells and tastes Strongly of hepar Sulphuris, and has besides a peculiar pungency which seemed to come from the oil; they had never ascertained the quantity of this water produced, and there was no appearance of its containing any volatile Alkali.

They also shewed us some Pitch, exactly like Lord Dundonalds. They said that they could not afford this Tar much cheaper than the foreign, on account of the great expense of casks for packing it up. It is used by the craft upon the Severn; many of the bargemen prefer it to every other kind, but others complain, that it being of a very penetrating nature, is too soon absorbed by the Wood and Oakum, and exposes the vessels to grow leaky. They do not Suppose any Tar comes [Page 49] over from the coal, till the Smoke is of a thick yellow colour, the first smoke is chiefly waters. The communication pipes or tunnels between the chambers containing the coal, and the great tunnel for the vapour to be condensed, are furnished with a damper, that is a plate which can be occasionally shut down, when they have occasion to open the door of the chamber. If this door and the damper were up together, the distilling coal would be likely to take fire, and probably blow up the chamber. No elastic fluid was observed to escape; nor have they any apparatus to let it out, if any such should be generated. The strate where they could be traced dipped down the River, inclining a little towards it. The hill a little above the Iron Bridge consisted almost entirely of Limestone, except a little towards the top, which was what they called dye earth, in which they observe no Iron stone or coal are ever found. This seems to be a clay laid on irregularly, so that the layers could scarcely be traced. In many places the separation between the layers of the Limestone [Page 50] were filled up with clay.

The part of the hill which had slid down into the Severn some years ago, appeared to consist of Soft clay, together with some masses which had a stony appearance, but which softened in water, and were found to be clay like the former. That clay and the dye-earth, were just of the colour of the Severn mud.

We returned to Mr. Wilkinsons Forges at Willey by Broseley, to see the operation of shingling. The pig of Iron is in the finery converted into tough Iron, after which it is stamped in a sort of Iron pan, and then broken. These broken pieces with the Small Stuff which comes off in stamping, is put into the pots of yellow burnt clay, perhaps 9 or 10. inches in diameter, nearly as much in height, and cylindrical. These are placed in a Wind furnace, made to hold 18. of them at a time in 4. rows: that is 6. in the row behind, 5. in the next row forward, 4. in the next, and 3 in the nearest. Large lumps of coal are [Page 51] put to the Side of each row, to prevent the flame from cutting off the Top of the pot, which it is apt to do. The fuel employed is raw coal. The fire in the Wind furnace was chiefly made at the Side upon a grate; but there was a large Space sideways with a solid floor, on which the pots stood, with a certain quantity of bright coal under them, and the funnel or chimney was continued up, still further sideways from behind the whole. They find a certain proportion of the Small Stuff absolutely necessary to the Success of the operation. They call it cinders, and conceive that it not only assists in welding the different pieces of Iron together, but likewise enters into the Composition, and feeding the Iron. Their idea is, that the more cinders can be brought to unite with the Iron, of the better quality it becomes. When the pots are put into the fire, which they call charging, - some of them crack very soon, others not till later, but all are cracked more or less during the operation, not so however but they adhere together, keeping in the Iron in a lump, till [Page 52] the workman at the end of the operation pulls them off from the lump with a hooked Iron, when they Separate very easily, and are brought off in several pieces.

Toward the end of the operation, a hole toward the lower part of the solid floor, ~~on which~~ of the furnace, on which the pots stand, is opened from the cinders and coal which before stepped it up, and then a quantity of liquid Scorae is seen running out for a considerable time, composed, as we were informed, partly of vitrified parts of the pot and coal, but partly also, perhaps principally, of matter which had run off from the Iron through the cracks in the pots. To facilitate the discharge of these Scorae, the floor is made inclining a little from all parts toward the abovementioned hole. When the Furnace is to be drawn, the Term for taking out the pots, which is from 3 to 4 hours after it was charged, they begin by examining the appearance of the pots, and judge that they are fit, by the whole appearing of an uniform white heat. They then [Page 53] pull off the pot in pieces, as before mentioned, leaving the Iron it contained in the form of a cylindrical lump, which they call a ball. At the Chafery then an other workman makes the end of an Iron bar white hot, and when the first brings the white hot ball under the hammer, the latter lays the hot end of the Iron bar upon it, which is welded to it by a few Strokes of the hammer, and then serves as a handle to turn and manage it. The hammer weighs about $6\frac{1}{4}$ Ct.wt. Its first effect is to strike off sparks, some of which fly to a great distance, and a few have the brilliant appearance of Steel dust in fire works. There comes besides a white flame from different parts of the mass, and at times a different flame from certain Spots, of a light bluish colour, like that from burning Sulphur. As the operation proceeded, some cinder ran down the Anvil, but in Small quantity, and as the ball cooled, it assumed under the hammer an oblong angular form, 2 feet, or 18. inches in length, and perhaps 3 or 4. in thickness, and is then called a half bloom; which is afterwards [Page 54] drawn out in the Chafery, into a bar with <u>Maggot</u> ends, answering to the Blooms of Glamorganshire, here called an ancony. Some of them however appear to be drawn out in the first instance into uniform bars. Formerly the Iron was made without this operation of shingling; but then it was of much worse quality. The shingling properly means, beating the ball with a hammer; that of putting the Iron into the pots to be heated, they call potting it.

By the Steam Engine at Rathbone's work, Coalbrook Dale, we saw a basket lying with several balls of fresh horse-dung: on enquiring the use, we were informed that they put it into the boiler of the Engine, when they observed any thing to leak out, and that it worked into the leak and stopped it. #

We were told here and in other places, that they distinguished the goodness of the Iron produced by the Scoriæ which come from the Furnace; those that are black [blank] rather Spongy, and not very perfectly vitrified, indicate the best and toughest Iron. When the [Page 55] Scoriæ comes out beautifully veined with white and blue, &c. such as we were shewn some at Willey Forge, the Iron is extremely bad. The general quality of the Iron produced at all these Forges, we were told was cold-short; it is the quality of the ore, or mine to produce such, and they say positively, that the same mine worked with charcoal, would make Iron still worse in this respect; but by the manner in which it crumbles in the operation of stamping, to produce the Small Stuff for the shingling pots, it appears clearly to be also in some degree at least, red-short. Even under the shingling hammer, a great deal Scales off, so that though it seems to be very strong in that State, yet it is not perfectly divested of its red-short quality. The breaking of the stamped Iron is effected by means of a strong iron plate, longer than broad, provided with ribs at proper intervals, set breastwise; the stamped cake being laid upon her ribs, the workman strikes it with a Sledge hammer on the part answering to the hollow, or interval between two ribs, when it commonly [Page 56] breaks off short, but sometimes only bends, and then must be laid upon the ribs with the convex Side uppermost, when it always gives way to the stroke of the Sledge.

About Bridgenorth on both sides of the Severn, we saw principally red rock, with a large proportion of Sand: and it seemed to lie in all directions, or consisted of no regular Strata, for the lines or cracks sometimes ran one way, and sometimes another, in pieces that were close together. The Terras-walk commands a remarkable Scene, from the Singular appearance of these rocks all around, but especially on the opposite side of the River Severn, the - Eastern, and from the fine view of the River underneath. The remains of the old Castle, battered by Oliver Cromwell, exhibit a remarkable instance of a leaning Tower, or ruin, which produces a fine effect. The Town is supplied with water from the Severn by means of wheel-work, turned by the current of the River, without any other fall than what is produced by stopping the current in that part and the height of great part [Page 57] the Town above the River, is very considerable. We were told they had no other water.

Saturday August 6th 1785.

In returning from Woolverhampton to Birmingham, about half way between Bilson and Wednesbury, we turned out of the way of the right 3 or 4. hundred yards to Bradley Furnace and Forges, lately constructed by Mr. Wilkinson. The road went close by the coal pit heath which has been burning many years. From some places close by the road, a strong flame was now issuing, and the earth seen through the crevices and apertures in many places was red hot or even white hot. All about the places actually burning, lay the cinders of old conflagrations, forming that reddish matter with which the road here is mended; and in many parts the ground had given way, forming hollows of greater or smaller diameter, and more or less deep, on the edges or brink of which the ground was broken into long cracks of different width, Some apparently [Page 58] very recent. The places from which the flame was now issuing, were not old pits, but apertures or cracks formed by the sinking down of the ground. About 3 years ago, the fire seemed approaching the Works at Bradley, and the ground became hot in many places; but it has been stopped by throwing upon the ground, at different times, considerable quantities of Water.

The Steam Engine at Bradley was upon Watt's construction, and made the blast by working the piston in a Single cylinder, whence the Air was conveyed to a Water-regulator, like that at Willey, but less. The Furnace here is 45. feet high, and 12. feet wide, at the Top of the boshes: flame issued from the Top of it. They use two kinds of ore, or mine, found on the Spot among the coal, Some above, some under, and some mined with it. They do not distinguish the two Sorts of Mine by different names, but use some of both, and find them both cold-short. They seem like the others a clay stone impregnated with Iron, some pieces richly, but others poorly. They do not here cast [Page 59] any large things immediately from the Furnace; but carry the pigs to a foundery where there are several hearths, with Machinery of cranes, &c. They bring the Streams from these Several hearths to join in one, when the piece to be cast requires so great a quantity of Metal. These hearths were all wind Furnaces, with the fire made at one side.

At Bradley we had a further account of the Finery hearth. The bottom plate from 18 inches to two feet square, Serves as the top to a cistern of water beneath the hearth, supplied with a small Stream of water, which runs in and out through the cistern. The Surface of the water is kept 3 or 4. inches below the bottom of the plate, which is interposed between it and the Metal in the [Page 60] hearth; that is, the bottom plate of the hearth: and its use is to keep that place cool, as they suppose. We observed that the shingling Furnace had a small pit at the hole through which the Scoriae are discharged, toward which pit the floor supporting the pots inclines on all Sides. The Steam Engine here worked with the rod of the piston quite dry, and made no pause at beginning to lift. We Saw a fly-wheel of Iron lately cast, and observed that the circumference was not continued, though the whole was cast at once, and the center and

Spokes were one: the Separation in the circumference was in the middle between each Spoke, and was left that it might not give way of itself in cooling, by the unequal contraction of the Spokes and circumference. At the edges of the Separation on each Side were holes, for joining them together by means of an Iron plate to which each edge was to be fastened: thus the whole was stronger than it would have been likely to be if a Single piece. [Page 61]

The rolling and Splitting Mill was worked with a Steam Engine, which communicated a circular Motion by means of a crank. There were two wheels of cast Iron turning on Separate axes, very near each other: each wheel having round its circumference a number of large holes, into which entered a large Iron pin, which passed through the hole or loop at the end of the rod. Thus the rod moved both these wheels round, keeping between them ~~which~~ & could thereby communicate movement to two different sets of Machinery. Each wheel turned the pinion of a large fly-wheel, by means of which the proper action of the crank was answered. The fly was not loaded on one Side. Each of these wheels was made to turn a rolling and a Splitting Mill; but one Set only was finished. The two cylinders of the Rolling Mill were inclined to each other, and adjusted to four gradations, so that the bar was rolled ~~for~~ 4 times with the Same heating. After being passed through the widest part, it was received by a workman on the opposite [Page 62] Side, and conveyed over again to the first workman, who then passed it through the Second gradation, and so on for the 3rd. and 4th. gradation, by which time it was reduced to a bar of considerable length, about ½ an inch thick, from a [blank] not more than a foot or 9 inches long, and perhaps 2. inches square. To make these, they hammer out a half bloom to the proper thickness, and then cut it into Such lengths, which they call, [blank] As soon as it had passed through the rollers, it went to the Slitting Mill without any other heating, and there cut into rods for nails.

Mr. Watt has contrived a Furnace to burn the Smoke, which he means to apply to the Steam Engine. The draught of Air is conducted backward.

Computations and Observations in Journey 1786.

(Chatsworth MS., X (a) 5)

[Cavendish made a brief excursion to the Alum Cliffs, near Whitby, to investigate the process for producing alum in commercial form.
The MS., consisting of 3 double leaves, 15" x 9½", that is to say, a covering sheet with 7 numbered pages, is written by a copyist, but Cavendish has corrected various mistakes of the writer.]

[Page 1]

Aug.t 22nd. 1786. The Cliffs near Mulgrave are every where covered with Sandstone, which we met with upon the Moors: under which is first a Stratum of what they call Dogger, being a Stone strongly impregnated with Iron, very hard, and under that the Shale, which is most clayey, and therefore yields most Alum at top, grows harder and less profitable to work as they descend, and by the depth of 30. Yards is no longer worth working. It seems to lie as a regular Stratum, without the trappings or faults found in many mines. It contains many Cornua Ammones, which are reduced in many places to Pyrites, and frequently form a kind of Nodule of that matter; likewise ~~Tu~~ Belemnites, but not so frequent. In many places it is so betuminious, as to stain the hand with a kind of Petroleum. At the Cliffs of Kettleness and Sand's End, the Strata dip towards Whitby but slightly.

The Alum Mine, or Rock, is dug down in Shelves which they call Desses, and along each Shelf or Dess is a gangway for a Wheel barrow. To calcine it they lay bundles of Brushwood [Page 2] at bottom, put on certain quantity of the Mine, and set it on fire. It soon kindles, and burns gently up to the Top, when more Mine is laid on, which kindles without any fresh wood; and thus heaps of 20 or 30. yards height are successively burnt. By the hurning it acquires a reddish Colour, being in general much loaded with Iron. Some parts bake very hard, others are more crumbley, and these last are more productive. The red pieces are thought to be too much calcined. The burnt Mine is gradually dug out from the great heap in which it was calcined, is wheeled in a barrow to the pits for Lix[sc]ivation. In these pits it is laid from 2. to 3 feet thick, and the Water conducted upon it by Pipes. The fresh Water goes first upon Mine which has had two Waters before, and after soaking about 2 Days, is let off into a Cistern, whence it is pumped up upon a quantity of Mine which has been soaked once before, ~~where it stays 2 or more Days~~ and after staying on this ab^t. a Day it is let off again into a Cistern, and pumped upon Mine which has not been soaked [Page 3] before, where it stays 2. or more Days, and then is ready for evaporation. This evaporation is performed in lead Cauldrons or pans. They begin by putting the mether liquor or Mothers into the pan, usually $\frac{2}{3}$, but sometimes more, and then filling to the proper quantity from the Alum liquor. As the evaporation goes on, more Alum liquor is let in, so that the pans may be kept at the proper height; and thus the evaporation is continued 24. hours. At the expiration of that period, usually in the Morning, the concentrated Liquor is let off into a Settler; a Solution of Potash or kelp being let in with it passing thro' the pan to keep it cool, while the Liquor is running off. In the Settler it remains [blank] hours, where it deposits a quantity of Sediment, called Slam. Thence all that will run off clear from the Sediment, is conducted into Coolers, where it remains 4. Days to crystalize. At the end of that Time what liquor remains, is scooped off into a receptacle, and is the Mothers, and the crystallized Salt is collected by scraping from the bottom and Side of the Cooler, and [Page 4] laid in a heap to be roached. - The roaching consists of putting a small quantity of Water to this rough Alum, and ~~hea~~ heating it in a Pan appropriated to that purpose, till it be melted, and then putting into a Cask, where it gradually congeals into a mass. In this Cask it stays [blank] days, and then the little Liquor which remains, is made to run off, and the Alum remains adhering to the Cask in a solid mass, hollow in the middle, into which great crystalline lumps are shot. They break up this Cask, take out the Mass of Alum, chip its sides and bottom, to get off bits of the wood of the Cask and other adhering impurities and then break it into pieces to be packed up for Sale.

The alkaline Liquor is made of 2 Tons of kelp to one of pot ash, or 1½ of Orkney kelp. They put water, that the Solution shall be 3 Dwts. to 3½. About 4. gallons of ley goes to 9. of the evaporated Alum liquor. The evaporated Liquor before the ley is at from 35. to 40 Dwts. The mixed Liquor in the Settler is about

29. Dwts. - It remains in the Settler from 2. to 3. hours.[Page 5]

The Alum in the roaching pan stays abt. 1. or 2. hours, till it boils up, and they keep sturring [sic] it; and if it stays longer it burns, and gets a black coat. It is scooped (scoped) out into a Trough from the roaching pan, and so conducted into the Cask. It stands in the Cask 15. Days before the Liquor is let off, and is scarcely cool till 12. or 13. Days. The Mothers are from 28. to 29. heavier than the Alum Liquor is at first in the Cooler, supposed from evaporation. When the Liquor is let out of the Settler into the Cooler, it is roused or sturred about with a pole with a small Tub at the End, and according to its weight, urine is put into it. When it comes into the Cooler, it weights from 28. to 29. Dwts. They put in Urine enough to reduce it to $27\frac{1}{2}$ Dwts. They are not particular whether the Urine is putrid or not. They said that horse and Cow Urine answer as well as ~~the~~ such human Urine, as ~~as~~ they get ~~that~~ which is most Sophisticated.

They said that the Alum might be made entirely of kelp liquor, without Urine. [Page 6]

The Mothers let fall an other Sediment; after it is got off the Coolers, called Stock Alum. This is very impure, and yet put into the boilers ~~is-Mothers~~ it makes The Liquor yield more Alum almost in proportion to its own weight, especially when mixed with the bottoms of Cask, (Tun bottoms.) They put it into the pans solid as it is. At 12. o'Clock at Night, the Liquor in the pan is boiled down to near half its depth, that the Slam may be deposited, perhaps 45. Dwts. and they gradually fill it up again to the Standard, at which they let it off - Without this the Slam would not be deposited, and the house would be dirty. Sometimes they carry this too far, and decompose some of the Alum with the Slam. If the Cooler is set to 24. or 25, the Alum crystallizes in great masses or Lumps: if too high, the Cooler forms a Magma, or thick hodge-podge, like Curds and Whay, and forms no Alum.

When the Liquor is too low, the great crystals formed are very impure, and turn yellow on keeping. [Page 7]

45. Cubic yards of raw Rock form 48. of calcined in the heap. These 48. fill a pit of 60. cubic Yards, and about a pit & $\frac{1}{4}$ upon an average form a Ton of Alum.

Journey in 1787

(Chatsworth MS.. X (a) 7)

/This first journey of 1787, starting from Kingsclere in Hampshire, took Cavendish to the South West Country, and is recorded under a single diary entry, dated July 15th, 1787. We are not to know, therefore, how long the tour occupied, yet he was back again to begin a second journey by the end of the month. The MS.;, consisting of 2 double leaves 13" x 8" width 8 numbered pages, is written by Cavendish, and contains many alterations. In the last paragraph of all there is a reference to a former journey, but no record of this is known./

/Page 1/

July 15 - 1787. Soon after leaving Kingsclere ascend a ridge of Chalk downs running nearly east and west which towards the left grow lower - but are higher to the right. Highclere is a few miles to the right. In some places between Whitchurch & Andover the Chalk is covered with a good deal of gravel but from Andover to Salisbury & so on to end of chalk country very little. From what seemed the highest part of the road between Andover and Salisbury the spire of the Cathedral appeared considerably above the distant hills. The Country from Salisbury to beyond Dorchester, though all chalk was fuller of ~~weed~~

wood & hedge rows than chalk countries usually are but scarce any streams in the valleys, except the Blandford & Dorchester rivers. Soon after leaving Dorchester began to ascend the chalk downs & continued ascending for 9 or 10 miles ~~when began~~ to see the country beyond the sea. There was a ridge of hills to the left ~~parallel~~ - running which are higher than rest of the Chalk hills & seemed ~~sep~~ in good measure separated from them by a velley though they seemed to join to them at the western ~~edg~~ extremity we were abreast at the highest part of this ridge 2 or 3 miles before ~~thepl~~ we came to the highest part of the road where we observed the barometer. It is this point whose elevation was found by level to be -

When we began to see the sea & distant country to west. Here we observed the barom/eter/ by which it seemed 643 feet above Bridport From hence a long hill seeming to extend from Charmouth to Axminster seemed elevated about 1' above level & therefore if its distance was 10 miles as should seem by map it should be /Page 2/ 68 above this place or 711 above Bridport. There was also a ridge of hills between us and sea running parallel to sea & separated from the hills we were upon by a valley though it seemed to join to them at the western extremity. The highest point of this ridge was abreast of us 2 or 3 miles before we came to this place & ~~from~~ at this place was elevated 9½' above horizon where if its distance was 8 miles it was 84 feet higher than us.

For some miles before we came to this place the road was mended with stone which the postboy said was taken from quarries lying near the above mentioned hills. It was a greyish colour very hard & proved to be intirely calcareous.

~~From~~ Just beyond this place the chalk hills broke down very fast but before we got ½ way down the Chalk ended & we seemed to cross a narrow band of whitish clay & immediately after began to see bits of stone& soon after some of the same stone in regular strata which were ~~inter~~ calcareous & seemingly of the same kind as those just mentioned & a continuation of the yellow limestone.

Some ~~way~~ miles beyond this the stone though to appearance much the same as this was found to be very Cherty having very little calcareous matter among it but I cannot say at what place the alteration took place.

[Page 3] Near the top of road between Charmouth and Lyme went to top of hill ~~&~~ which was about ½ a mile to right and observed the barom[eter] by which it seemed 550 above inn at Lyme & I suppose much the same above Bridport that is about 90 feet below our station on Chalk hills. The Chalk hills about that station ~~seen~~ observed from this place by level were nearly in the true horizon whence if they were 10 miles distant they were 53 higher than this place. The hill ~~which~~ between this place & Axminster which from Chalk downs appeared 1' above horizon from this place was elevated 44½ minutes.

Just by the place where we left the road was a kind of quarry by which it appeared that this part of the hill consisted ~~chiefly~~ of the above mentioned cherty matter mixed with sand or clay in the manner of a rubbish country.

From thence descended to Lyme. The Cliffs there were blue lyas between hard blue clay further to the east saw cliffs of yellow matter

& from the manner in which the strata appeared to dip supposed the blue matter to lie under the yellow but could not be certain.

About a mile to the westward of Lyme turned out of the road towards the ~~cliffs~~ sea. On a steep bank towards the sea saw the yellowish stone lying in strata consisting of strata or pavements [sic] of chert lying between other stone which seemed to be yellow limestone ~~but~~ upon trial it was found ~~either~~ that great part of that which I took for chert ~~appeared-to-be-~~ was limestone ~~Or-the-contrary-but-I do-not-remember-which~~. On the sea shore below these rocks we saw the blue clay & blue lyas so that here they evidently lay under the yellow limestone.

[Page 4] From hence to near Sidmouth the soil full of the cherty pebbles except in Valley of Ax where the soil was red. At Sidmouth the cliffs on each side were red but towards the top of the hill to the east the upper part of the cliff consisted of yellow matter lying over the red. This was at first supposed to be yellow limestone but on walking up the hill to examine it it was found to be chert pebbles & rubbish.

From hence to Exmouth & Dawlish red soil with very little intermission. Cliffs at Dawlish red rock & ~~seemed~~ continue so to near Torbay where they seemed to be rock limestone & by the direction of the Strata must lie under the red rock. The Strata of the cliffs at Dawlish dip very quick towards East and with some (I believe frequent) breaks in them.

The road from Dawlish to Bovey lay over little Hall down near the top & from thence ~~into valley of~~ down to the river Teign about a mile or 2 above the tide. The height of little Halldown came out 784 feet. The surface ~~seemed~~ was composed of chert & rubbish. On descending towards Teign we met with what we supposed to be rock Lymestone but a hard reddish stone which we took up as such proved to be not Calcareous.

Between great Halldown & Dartmoor is an intermediate range of hills & Bovey Heathfield is in a flat valley lying between Dartmoor & this intermediate range & extending to Teignmouth. In the southern part of this valley near Kingsteignton sand pits of white clay. In those we first saw on the east side of the road the clay was unmixed with black [Page 5] matter but in that we saw afterwards on the other side it was covered with a thick coat of black matter consisting of clay & particles of Bovey Coal. It seemed as if this stratum of white clay was continued all the way to Bovey.

The Bovey coal consists of several layers of coal between strata of greyish clay seemingly the white clay of Kingsteinton mixed with black particles. The pit is open to the clay & the lower part is drained by a water wheel & by that means can be worked only in winter Dr. Bl.[agden] in a former journey was informed that some time before they bored upwards of 16 feet below the bottom of the pit which is 79 feet below the surface they first found clay, then coal, then a bed of white clear loose sand about 6 feet thick, then clay & then a thin stratum of coal & as soon as they got [illegible] ~~the~~ that the water gushed up with violence.

The rock limestone at Chudleigh was to the right of our road here & that of the south Lane to our left & all the way from Bovey

Heathfield to Plymouth we were on Killas so that unless the stone near the Teign was rock limestone it must most likely be wanting in this part of the country.

From Ashburton went up to the point which from Lyme & other distant places seemed the highest part of Dartmoor being the most southern of 3 points called Hey Torr. Its height seemed 1485 above sea or 1304 above Ashburton. From this point a hill bearing pretty exactly west with a road on the left of it supposed the Tavistock road was elevated ~~39~~ 3 F 9/10 above horizon therefore if its distance was 11 miles was 1605 above sea. There was another ~~longer~~ longish ridge of a pretty uniform height the highest point of which that was visible to us bore W-30°N & was elevated 23' 3/10 above level therefore if its distance was also 11 miles its height above Sea was 1943.

[Page 6] In the way from Mr. Vivians to moor close to Hilsons house large rocks of a hard bluish stone with small grains like many of the Guernsea pebbles. Between Saltash & Leskeard the road went by a craggy hill consisting of the same kind of stone & in way from Wedgewoods Clay pits at St. Stephen to St. Austle saw many stones of the Same kind only ~~more approaching~~ in larger grains which the guide called Ironstone.

Cornwall consists chiefly of Killas the granite ~~occupying but a small part of excep~~ seldom appearing except on the high hills [hole] Caradon, the Cheese rings & Brown Willy & Row tor [Rough Tor] ~~there seems to be much~~ are granite & the ~~hill next the most mountainous app~~ country there has the most mountainous appearance of any part of Cornwall. Darnmath & Cairn Brae are also granite. The castle at Cairn Brae stands on projecting points of the granite rocks so as to seem founded on loose stones. St. Agnes is a detached hill and seems high. Between St. Austle & Truro & in many other places great quantities of lumps of white Quartz lie on the ground which from ~~the appearance at~~ what was seen at Tintagel we may conclude came from pavements in the Killas.

Observed barom./eter/between Camelford & David Stow in all prob./ability/the highest part of the road between Camelford & Launceston from which it is likely that its height was ~~about 1100~~ near 1100 feet above sea. From this place all the near hills dipt below horizon except Rowtor /Rough Tor/ & Brown Willey. The Cheese rings if I do not mistake were elevated very little above the horizon & the hills ~~about~~ supposed beyond Truro were very little depressed. If they were really beyond Truro they must have been at least 35 miles distant & must have been above 630 feet higher than this so that they must most likely have been some nearer range.

/Page 7/ The highest part of road between Barnstaple & Ilfracomb was 823 above ~~Barn~~ sea. The Eastern edge of the Exmore hills was very visible from thence & was much elevated above the horizon.

The highest part of the road between Linton & Porlock was 959 above sea it was not at the top of the hill but I believe not /illegible/ great deal below.

*~~At Cheddar Cliffs~~ the Strata of the rock limestone there were very visible & dipt very quick from Mendip. At the quarry by Cross inn the direction of the Strata was uncertain.

The road from Cross to Bristol runs through a gap in this ridge which seems continued ~~all the way~~ as far as the Channel at How rocks. This gap however is not so deep but what the road rises to a considerable height. Before you proceed far in this road you perceive that the ridge which ends so bold to the S.W. is not very broad but the ground soon descends again & forms a valley parallel to the ridge. The Soil in this valley seems to consist of ~~rubbish chiefly chiefly~~ limestone rubbish cemented by calcareous ~~there are~~ matter but amongst the matter [sic] thus cemented there are some parts not calcareous & ~~most of~~ the Calamine pits at Shiffham lie in this rubbish & from the situation I should suppose that those at Chewton & Harptree which are said to be the principal ones do so too.

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* Mendip ends with a very bold outline towards the S.W. or towards Bridgewater Cheddar is Chasm in this line

[Page 8] Broad Wells down is a ridge which may be considered as forming the other side of this valley the ascent to the down consists of this kind of rubbish but on the down itself where are many pits the soil seemed rock limestone. There were great quantities of columnar calcareous spar found about the pits most of these columns seemed to converge towards a center as if they hard [had] been formed within round cavities but some seemed to diverge as if they had been formed round a nucleus.

The rock limestone country seems to continue all the way from here to the hot Wells but Dundery down which is a little to the left of the road is yellow limestone.

Bath is on the blue clay the yellow limestone not beginning till you arise above almost all the houses.

The road from Bath to Devizes has been changed near last place so that I did not pass by the place where in a former journey I saw stone just below the Devizes but as the road there abouts is mended with yellow limestone that stone was most likely the same For several miles before we came to Devizes the Country was low & we saw no stone of any kind.

1787

(Chatsworth MS., X (a) 6)

[This tour, undertaken by Cavendish in July and August, 1787, followed closely in the previous one, covering much the same ground, but while this journey is largely concerned with tin mining operations, the former was entirely geological.
The MS.. is in the hand of a copyist, with corrections by Cavendish, and consists of 8 double leaves, 15" x 9½", that is to say, a cover and 30 numbered pages.]

[Page 1]

July 30th. 1787. Half way between Lestwithyel and St. Austle came to a low plain at St. Blasy, where was the first large Stream work. They had dug deep into the Earth, apparently 30. feet at least in some places, and were separating the Tin from useless rubbish by the running of Water. Just before we came into St. Austle, passed a Tin Mine on the right in the Common; many heaps of rubbish thrown up in a line, indicated the different shafts, which were pretty near each other. Polgooth Mine is about a mile and a half from St. Austle. Go a Mile or more on the road to Truro, and then turn down on the left to Polgooth, which is Situated in a narrow Valley, between two pretty steep hills, & has a small Water running Straight for the Sea. In Polgooth Mine, the load runs East & West, & is nearly vertical. We descended into it by Ladders, about 100. fathom deep, all the way through Slaty Stuff, called killas, which in different places dips in various directions. The Tin is in blackish or greyish grains, usually interspersed through Quartz, (Mr. Cavendish thinks chiefly Killas) which here seems rather crumbling, breaks [Page 2] readily. In general the Killas is also easily broken, but in some places they are obliged to blast it. The lead, or vein of Metal, lies much in the manner of the Lead Mine we saw in Derbyshire, only more upright, & the Sides are connected to the Killas, & run into it, so as to leave the Killas very irregular when it is broken out, not smooth as were the Sides in Derbyshire, - (Gregory's). They make floors in the same manner as there, by putting Strong blocks of Timber across the empty space, out of which the load has been taken; the ends of the Timbers having holes made for them in the Killas. Over these Timbers they lay Sticks to form a floor, & support the Deads. In this Mine, the level for the Water being to the E. they work up westward by stoops, that is, cutting the load as it were into long steps, carrying on the level of the floor as they proceed. In some places, the sides of the load incline to close with such force (to fill up the vacant Space left by taking out the ore) as to crush these large blocks of Timber. We saw places, where they were rent and split in different ways by the weight. To avoid the ill effect of this, they put the Shaft not [Page 3] in the load, but a little on one side, cutting Short Side passages to it, through the Killas. For raising the Water out of their works by the Steam Engine, they used forcing pumps instead of sucking pumps; the weight of the main rod was what forced up the water, and was more than sufficient, for they had a balance on the other side of the beam.* The main rod was confined in its place by boxes (Holes in frames of wood), So as to move perpendicularly. The forcing pistons were connected to it by off Sets, thus 

in sufficient number, according to the number of cisterns. The piston we saw, was 13 Inches in diameter. Round a groove in the middle of the piston, was put a quantity of tow, to fill up tight to the sides of the cylinder in which it worked and there was a contrivance by shifting a ring, which made one side of the groove to contract the breadth of the groove, as the two contracted in its bulk, that it might be always tight in the Cylinder. As the Steam Engine, left to itself, would have done much more work, than was required, they regulated it by a man constantly attending, who opened the valves at such intervals as were right. It was

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* It appeared afterwards that they had 3 sucking & 2 forcing pumps.

[Page 47] a 63. Inch cylinder, and made a long pause between each stroke. In winter it works as fast as it can. They had a smaller Engine on the work, as a temporary machine, to be worked only when the water was too much for this.

When the Tin ore is raised, they put it under Stampers, worked by a Water wheel. They are poles of wood, with the bottoms of Iron, and have pins in them, raised by the cogs of the wheel. The ore being put under, they break it by their weight; if there happens to be a hard Stone in the ore, the men break it with a pick ax[e] before they put it under the Stampers. There was a Stream of water passing through the ore, and a ~~greater~~ grate through which the ore was carried by the water when it was fine enough; all the coarser being retained, till by the continued action of the Stampers it was reduced to the proper fineness to pass through. The ore and the matter with which it was mixed, all came through together, no separation being here attempted. The Stuff that came through was so fine, as to look [Page 5] like mud, and was shovelled up as such. This mud is then carried to the buddle, which is a trough with a part at top little inclined, on which the Tin ore in the form of mud is put, and from it goes a part much more inclined, a stream of water - coming in upon the first part, carries the Tin mud gradually down, assisted by the stirring of the workmen, who beats it gently on the top part, and moves it about as it passes down the more inclined part also, (this Mr. Cavendish does not remember) by which, manneged with the proper address the richer part, being the heavier, rests higher up on the inclined plane, whilst the lighter is carried lower down; and when the buddle is sufficiently loaded, they draw lines of separation at different depths on this inclined plane, & keep the ore which rested at each height separate, in taking it off the buddle. That which rested lowest, is washed over again, and indeed the operation is repeated with all, till they are sufficiently pure. All the Tin ore, which contains Mundic, is roasted after it has been buddled, in a furnace, with a fire made at the back end, and the Smoke passing [Page 6] out by a Chimney in front. It ~~was~~ is made red hot; but they must take care not to melt it. This operation gives the Ore a brownish yellow colour. It is then buddled again to the proper fineness. The refuse of all buddlings, as a kind of Slime, is let out to persons to get what Tin they can, at a certain rate; which they do by washing it, upon an inclined plane, something like a buddle, on a large Scale, with a stream of water passing down. This inclined plane is made to turn over, and the Tin falls into a box placed just under the upper part of the inclined plane. It does not all fall by itself, but they throw water upon it to wash it down into the box. The Tin ore after it has been prepared, is in different States of fineness. Some as a Sand, other parts so fine, as just to cohere with water, other parts again so fine, that it may be moulded with water almost like clay; and the finest seems to be that which has undergone the roasting, which has a great degree of cohesion and may be very readily moulded as clay would be, and has the yellowish brown colour. They seem to call this fine part Slime Tin. Even the refuse of the refuse is washed over again, as long as it contains any Tin [Page 7] to pay the Labour.

From Polgooth Mine going down the Valley toward the Sea, we
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came to a large Steam work, about 2 Miles and a half from the Mine. They begain this lower down in the Valley, and have dug up the ground a great way from the place where they began. It is the low ground between the two hills above mentioned, and appears to consist chiefly of blue clay, which they dig through, & throw aside, to the depth of 30. or more feet, before they come to any Soil worth streaming for Tin. In this blue clay, & commonly very deep in it, they find
& commonly neither broken nor compressed & not up with clay
the nuts looking very fresh and sometimes Oyster shells over them; but the Captain observed that as they worked farther from the Sea,

they found less of the Oyster Shells than formerly; and that even the nuts were not so frequent. He said the nuts were often found in the sand or gravel, at the bottom of the blue clay, immediately over the Tin; but some he got for us, were several feet up in the blue clay. Toward the top of the blue clay, we saw several Trunks of Trees, all pretty much decayed. Under the blue clay was a layer of rubbish, consisting [Page 8] of Sand, gravel, and rounded pebbles, perhaps 5 feet thick, the bottom part of which for 2. or 3 feet was what they Streamed for the Tin. This was done by laying the matter on an inclined plane, with a stream of water passing over; they stirred the Stuff about in the water continually, so that the muddy or clayey part were quite carried off by the water, the Tin got to the bottom of the inclined plane, and the ~~layer~~ larger gravely or pebbly part rested above. This pebbly part they afterwards picked, throwing away those pebbles which contained no Tin, & preserving those pebbles which by their appearance promised to be worth working. Some of these pebbles are so rich, as to be worth Smelting immediately, but most must be stamped and buddled as the common ore.

As a vast quantity of rubbish, clay, &c. is to be removed, to get at the matter worth streaming for Tin, the labour of removing it is facilitated by carriages moving on a Stage overhead, & carrying the buckets loaded with the rubbish. They have poles of wood set upright in a row, in the direction of the length of the Stream work, and reaching rather higher than the upper Surface of the ground. These [Page 9] support frames of wood, running parallel to each other, at the distance of about 10. feet from one another. The frames have a groove in which runs the wheel of a carriage, consisting of an axle tree of the same length as the distance of the frames from each other & provided with a wheel at each end, moving in the groove of the frame, so that each pair of frames carries one of these machines. The carriage is drawn backward and forward by a windlass (called a Wem) moved by a horse at one end of the Stage, the rope moving the Carriage being passed through a pulley at the other end of the Stage, and one of the men below gave a signal by his voice when the direction was to be changed from forward to backward. The axis of the carriage had a rope wound round it, carrying a bucket; the rope being wound off the axis, most when the carriage was over the place where the men were ar work, the bucket was then lowest to be loaded, and as the carriage went back toward the Wem, the rope wound upon the axis, and so carried the bucket gradually upward, to pass clear of the rubbish. The bucket turned upon an axis, so that when they [Page 10] wanted to unload, they turned it over.

From Polgooth about 5 or 6. miles, nearly N. that is a mile beyond the Church of St. Stephens, we came to a place where the Growan clay is dug. After passing the slaty country, we came to a moor, where the moor Stone began to appear in detached lumps, mostly looking whitish, and seeming in various states of decomposition. Just before we came upon the Moor, the MoorStone which appeared, Tho' really granite, seemed to consist of flat plates, some thing resembling those of some kinds of the Killas. We found no Elvan or hard rock Stone between the Killas & the Moor-Stone. The clay itself lies in a lower part of the Moor, but not a deep sinking. Before washing, it evidently consists of bits of Quartz mixed in with the clay in large quantity, & many small shiny particles, being either minute bits of the Quartz, or white Mica. Mr. Wedgwood has pits here, for washing the clay, to separate all the Quartz. In some of this Clay bits of Cochle (Shörl) are found, which on account of their colour, Spoil that part for the making of Porcelain; and some of the Clay containing [Page 11] these black particles, is the toughest. In the direct way back to St. Austle, we passed large rocks of what they called ~~Ise~~ Ire [Iron] Stone, much resembling the rocks above Cornwood, but more Speckled.

August 1. went to Chacewater Mine. Observed in the plan of the Mine, that the lode which deviates sensibly from the perpendicular, has a layer of elvan upon its upper surface, which runs along with it throughout as far as it had been worked. The whole lode being in Killas, the killas joined to the elvan on one Side, but on the lower side of the lode, joined immediately to the Ore. They agreed that the layers of the killas ran in different directions, but near the lode generally inclined to the lode, and lay more horizontal than the lode, so as to run in the direction of cutting it on the under Surface as well as the upper. The lode is a mixture of Tin & Copper, often mingled together in the Same piece of ore; the Tin being the dark grey part, & the Copper of that kind, which is called yellow Copper ore. The Matrix consisted of Quartz and killas, with a mixture of elvan in some places. They break the ore to examine it, to separate [Page 12] the parts which are worth working for Tin from those which are to be worked for Copper; & the latter parts are then broke smaller, and the mere refuse being thrown aside, the good parts are put in a heap to be carried to the Smelting house. The parts which contain Tin enough to be worked for that Metal, are freed from Copper by roasting and washing; and the water of the washing being thereby impregnated with Copper, rusty Iron is put in to separate it. The smaller part of the Copper Ore is separated from its refuse by being shaken about in a Sieve under water; by which some of the dust goes off through the Sieve, and the larger refuse is found lying uppermost in the Sieve, the ore itself being collected at the bottom.

The windlass for raising the ore out of the deepest Shaft, was turned by a small Steam-Engine, working double, which was attended by a Man, who reversed the motion, when the bucket was at the top or bottom. The circular motion was communicated by the Planetarium, or revolvers, with a fly, and the direction was to be changed [Page 13] always in the middle of the Stroke [by opening the ~~different~~ valves so as to make the pressure act in the contrary direction]. The weight of the Rope of the bucket, was counterbalanced by a Rope with a weight which wound round two Spiral ~~forces~~ [fusees] joined to the axis of the windlass, so as to be on the widest part of the Spiral, & therefore act with the greatest advantage when the bucket was at top or bottom; and when the bucket was in the middle, the Rope was between the two ~~forces~~ [fusees] on the bare axis. At present they had lifting pumps, but intended to change them for forcing. They informed us, that in the pumps at Polgooth there were 3. lifting pumps joined to the main [rod] & two forcing pumps.

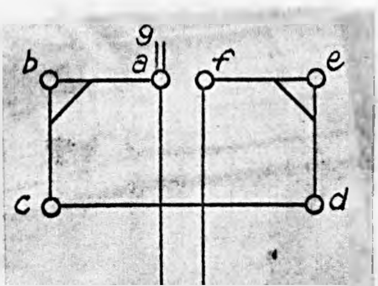
The elvan in this mine was of a yellowish colour, and appeared not of an uniform texture, but consisting of bits of Quartz interspersed in the yellowish matter. - At a small distance from Chacewater, on the S. side of the road, we saw the clay Supposed to be formed by the decomposition of elvan. It is whitish, tho' not without a tincture of yellowish brown, pretty strong in some places, & has a number of bits of Quartz in it, much like those we observed in [Page 14] the elvan. We were told that it formed a lode parallel to that of the Mine. This clay is used for making the Bricks of the fire engine, as it stands the fire well. The outside of the Brick is blackish, and looks vitrified, but the inside was white, with the texture of hard backed clay.

At Poldyce mine a new double Steam Engine of 58. Inches Cylinder is erected. It has no balance ~~holes~~ bobs but instead of, it works two rods, one descending perpendicular from the further end of the beam, as usual, the other fastened near the other end of the beam, toward the Cylinder, and descending obliquely, till it came below the Engine house, & had there a joint, which, by means of a lever with a fixed center, converted the oblique motion into a perpendicular one. Both of them worked lifting pumps, to carry off the water from the Mine. To save Timber in the beam, there were two smaller beams rising up obliquely - from the center of the great beam, from the upper ends of which Iron rods passed across from one to the other, connecting them together & each oblique beam was also connected to the [Page 15] great beam by similar Iron rods. In the boilers of these Engines the fire was made at one end, then passed through the middle, & then was returned all round the boiler, at its sides before it came to the Chimney. This Mine consists of a Tin lode and a Copper lode, the latter in some places double. The two lodes cut one an other at a small angle; and the two lodes having different inclinations, the line of intersection is not perpendicular to the horizon. Where the two lodes meet, the Tin and Copper are blended together, but the lode is poor. The Copper ore is of the yellow kind, both it and the Tin lay in a Matrix consisting principally of Quartz. The principal part of the lode passes through killas but under the killas is (growan) granite, into which the lode is also continued. This growan rises up from E. to W. in the direction that the lode runs so as to cut it nearly perpendicular to its plane Where the lode ~~rises~~ lies in, the growan, its Matrix, is almost entirely Quartz, which in some places is shot into crystals with the Tin in it. Toward the West end of this Mine, considerable quantities of Wolfram are found, crystallized in [Page 16] the Quartzose Matrix. At the same end of the Mine, there is also much Fluor Spar.

Near. St. Austle saw two houses for melting the Tin ore; one called a blowing furnace, for melting it with Charcoal, the other a Smelting house where culm only is used. The former was a small furnace with the Nozzles of two bellows (worked by a Water wheel) descending in the back part to the bottom close to the hearth. In it the Tin ore is put, with the due proportion of Charcoal, and a hole is left at the bottom in the front, through which the Tin runs as it melts. The Chimney opened into a large chamber, which they called the round house. This round house is furnished with holes, in which the people roasted potatoes, which was mentioned as a proof that there is no arsenic

limed
Sub~~stance~~; but it was said that something white condensed on the Skin of the potatoes. The Tin run down here was not in general sufficiently pure, but must be melted over again one or more times, and skimed, till it is freed from impurities. The Slogs also were melted over again, sometimes it was said as much as four times, and Some of the Slogs were [Page 17] Stamped, and then washed to separate the Tin. - The smelting furnace with culm was a long hearth, on the back of which the fuel was laid, and on the fore part the Tin ore: The flame of the fuel reverberated over the ore, passed up through a Chimney in front. At one side of the hearth was left a hole for feeding the furnace, and the other side was occasionally opened for the tapping. This is done every six hours, and the furnace is fed just so often. When they tap, the Slug and Metal both come out together, and the former is racked off. The hearth was made of Windsor bricks, cemented with Mr. Praid's clay, which is a brownish Sand apparently, with just clay enough to give it consistence; it was said to be excellent for the purpose. In the interstices between the bricks, is formed a dark shining substance in thin plates, a good deal resembling the sulphur Iron. It is the common Tin which they work in the reverberatory furnace, and the stream Tin in the blowing furnace, and they say none but the latter will make grain Tin. [Page 18]

bobs
August 2nd. 1787. Saw the T. ~~holes~~ at the Briggin Engine, Northdown Mines.



(ga) is the great descending rod connected with the beam of the Steam Engine. (abc) are two rods joined together, & turning on a center at (b). - (def) are two similar rods, turning on a center at (e), and connected with the former by the rod (cd). By the descent of the rod (ga) the rod (cd) is moved horizontally, and by that means lifts up the point (f) which raises an other set of pumps.

They were repairing the piston of the Steam Engine and we saw that they put a flat rope loosely platted or twisted into the groove of the piston, beat it down very hard by means of a Sledge hammer, & then put an Iron plate on the upper Surface of the piston. If the Engine was in full work, they were obliged to do this once a week, the rope wanting to be renewed so often. We were informed that as it was very difficult to regulate all the tiers of pumps even, and some had more leakage than others, it often happended [Page 19] that some of them sucked air, or, as they termed it, did not draw solid. The intermediate Cisterns usually contained as much Water as could be drawn up by 2. or 3 liftings of the pump. The motion of the beam of the Steam Engine was communicated to a distance by horizontal rods, which were a Set of rods joined together in a line, all the parts of which were suspended at an equal height - above the ground by pendulum rods of iron oscillating in forks of wood. The horizontal rods were so connected to the lever of the Engine house that they had less motion given to them than was communicated to the vertical rod, which deficiency was compensated by a similar inequality in the lever at their other end where they worked the pump. The rods only pulled and never pushed.

At ~~Huel~~ Wheal Virgin Mine is a lode of Elvan which dipping at a large angle to the N.E. cuts the lode of ore. We were told, that at the place of Intersection the lode was poorer, and had some Elvan mixed with it, but that the quantity of ore exceeded that of Elvan. Also that tho' it was poorer there in general, yet in some [Page 20] places it was richer in the elvan than in the killas, and that sometimes pools of ore were found in the elvan. We were likewise informed, that the lode of elvan was known to continue through the killas into the growan. The Elvans here consisted of yellowish ground, with bits of Quartz interspersed.

At the United Mines were observed a Wem (windlass) with a double fusee, the broad parts of each fusee lying together. The rope of one bucket wound up on one fusee, and that of the other bucket upon the other; and they were intended to counteract the weight of the rope in deep Shafts. With common Wems in deep Shafts, the weight of the rope was greater than that of the loaded bucket, so that they were obliged to put a drag to the Wem.

At Tresivane Mine we were informed that the depth of the killas was only from 10. to 16. fathoms in general, and that the lode then went into growan, in which it was continued. That the growan dipped from W. to E. but not at a very acute angle, and that the killas seemed uncertain on account of the irregularity in the dip of the [Page 21] upon it dipped much more. That in Sinking through the Killas Growan, they came to evident division separating one Sort of Growan from an other, and that these also dipped in the same direction. The Captain (Mitchell) added, that having observed this kind of division and the dip of it in one Shaft if another Shaft were Sunk at a certain distance to E. a Similar division of the Growan would be found in that Shaft, but as much lower down nearly as to answer to the before mentioned dip. He also said, that other cross cracks were found in the Growan, forming it into large heads of Stone; these seemed to be of the nature of fissures.

August 3. 1787. Ascended Cairn Brae which is composed of Moor-Stone, many of them lying in heaps at the top, & very large blocks. The Castle founded upon one of these heaps, so that one can see through between the Stones under its foundation.

At Cooks, Kitchen & Dolcooth Mines, the Copper ore, which was of various kinds, but seemed chiefly of the grey, had great quantities of red Ochre, or [Page 22] rather Haematites on the outside of the blocks, so that the workmen were quite red with it. This red matter did not penetrate into the Stone itself, but only covered the Surfaces of the blocks, as if it insinuated itself into the natural Crack and crevices of the lode. The two Mines were Separated by a lode of (Clay) Flookan, which kept the Water of one from entering into the other, provided the lode was not dug out too near to the Flookan.

On approaching Hayle Copper Smelting houses, which are said to be 10. Miles from Redruth, we passed by the Sand of a branch of the inlet of the Sea at St. Ives, & there saw many Shafts or pits, out of which a very shievery matter had been thrown, which looked blue in general, but the more decomposed parts assumed a whitish cast. The Copper works themselves are close to a stream running into St. Ives Bay, where the Tide rises near ten feet. The first part of the process is to roast the ore, by which, as Mr. Edwards, the Manger, said, most of the Arsenic, and a great deal of the Sulphur is expelled. It is done in a reverberatory furnace, with a strong red [Page 23] heat, but not such as to melt the Ore. We perceived a strong Smell of Arsenic. The Ore thus roasted is put into another reverberatory furnace, often mixed with some unroasted Ore, there brought into fusion, and ~~some~~ the Slag being raked out, the fluid part is run through gutters into a large cistern, placed nearly under the tapping hole of the furnace, filled with water, by which means it is reduced into small bits. These are put into an other reverberatory furnace, and roasted over again, after which they melt it, and run it out in forms into great lumps, which they called regulus. This Regulus was broken into pieces, & put into a reverberatory furnace, often with Some Scoriæ of other processes, & kept in a heat Short of Fusion for 18. hours, and then melted for 6. hours, which operation was repeated as many Times as was necessary, according to the nature of the ore, the Scoriæ or Slag being raked off at each operation. When no more of the previous calcination was thought necessary, they brought the regulus into fusion gradually in the furnaces and kept it to a certain [Page 24] number of hours, 6, 12, or more, then run it out, broke it, and melted it in the same manner over again, till it had acquired the proper degree of fineness. When the regulus was brought into that State, that it began to have something of a metalline appearance, but still without the true colour of Copper, being of a dark grey, they called it black Copper. The Scoriæ of the different processes contain Copper enough to be melted over again.

Japanning the Copper was said to be a great secret, & shewn to very few persons. The Copper was kept in fusion in a furnace close to the Japanning Apparatus, which consisted of a piece of Iron with two oblong holes in it, of the Size and Shape of japanned lumps as they come out, cut parallel in the iron, and pretty close to each other. A Stream of fluid like water passed briskly over these holes, or forms, and ran down into a kind of bucket underneath. The men ladled out the Copper from the furnace, and filled the forms with it, through the Stream of water; it made no explosion or [Page 25] ebullition, tho' one Saw the almost white hot metal in the forms under the water, and did not hiss much. When the Copper in the forms was cooled to a certain degree, but while it was still pretty luminous, the forms were turned over Sideways by a contrivance for that purpose, and the lumps of Copper dropped out into the bucket of Water underneath. These lumps were of the fine Copper, red on the outside, for which they were made to undergo this process. We were told that the fluid used was not pure water tho' very nearly so. We were also told that they used some lead toward the end of the process, to finish the purification of the Copper.

August 10th. 1787. The cliffs at Tintagel being killas, we observed in them knobs, and in some places a kind of pavement of pieces of Quartz, which Seems probable to have been the origins of the bits of Quartz which lay scattered on the ground in so many places as we passed along.

About Bridistow, between Launceston and Okehampton, are Several places where they get [Page 26] limestone. It lies in thin Strata, with similar Strata of hard slaty matter, which the workmen called the Shell. The beds of these were in many places alternate, but in other places there were two beds of Shell between the beds of limestone. Both were of a dark blue colour, and looked so much alike, that an unexperienced eye could not distinguish them, tho' the workmen do readily. On breaking, the limestone was harder than the Shell, had more the grain of Stone, and was not so much inclined to divide into plates. They said it made very good lime for building. Its fracture had not the appearance of rock limestone, but rather that of a clay Stone; it was every where surrounded with killas - country, and dipped from Dartmore at an angle perhaps of about 30°.

About Hatherleigh there is a band of remarkable red matter, which had much the appearance of red rock; the country on both sides of it was a yellow loam on the Surface, supported by killas, which in many places looked quite slaty. [Page 27]

At Barnstaple we ~~leart~~ learnt that there were two or three Spots in the Neighbourhood where they dig limestone, which, they said, was used for manure.

Near Ilfracomb, in the way to Comb Martin there were some lime kilns, and we were told that the limestone burnt in them was dug from the bottom of the cliffs. About half way between Comb Martin & Linton, we saw on the right some Shafts, which were said to be the remains of working for Lead, that had been now intermitted for some years. The country from Ilfracombe to Linton was killas all the way in many places quite slaty. Near Linton the hills began to grow red. The descent from Lintonto Limmouth is very red, and so is a hill terminating by a narrow edge near Limmouth bridge: whereas others of the hills have but a Small admixture of the red. As we advanced toward Porlock, the country became more generally red, and continued so all the way but there was no reason to think that we were off the killas country. The road from Porlock to Minehead, winding in the Vallies between hills, was all red, and in general the land seemed composed of rubbish matter, but in some places had an evident shivery appearance, as of bluish Slate. In going up the hill to the Church at Minehead, the Stone on [Page 28] the right hand bank, had evidently the ~~softness~~, texture and general appearance of red rock, lying in thick blocks, very different from killas. In an other part of the same hill the red stone was more in plates, and the hill at Dunster ~~Dmister~~ had the red stone lying intirely in the manner of plates. At the hill before we came to Watchet, the cliffs consisted first of red matter, apparently red rock, with some Stripes of the yellowish grey clay running through it. Beyond this the cliff was grey ~~whiteish~~ consisting of bands of the blue lyas & clay Stone **with thin Strata of** alabaster in some places. The separation of the two kinds of cliffs was nearly perpendicular, so that we could not there determine which sort of matter was uppermost, but further on we saw a part of the cliff, where the red rock lay evidently under the grey ~~white~~. The blue lyas Strata seemed to extend but very little way into the country for at a Small distance from the coast, the country looked very red. The Strata of the cliff here dipped so as to form a line inclining downwards in the direction up the Channel. – At Watchet the cliff consisted principally of the grey ~~whitish~~ matter, but intermixed with the red, and the grey ~~whitish~~ matter was principally claystone, with very little of the blue lyas in it. Here the Strata dipped inland from the Channel, and we had seen beds of blue lyas as we came down the [Page 29] hill into Watchet, so that the lyas seemed to lie chiefly in the upper part of the ~~whitish~~ grey matter. ~~Great part of the Lyas was almost as were as the claystone~~.*

From Watchet the country consisted of the same kind of red matter, apparently as before, and continued so to the copper mine, which is about 2 Miles before we reached Stowey, just before the road quitted Qantock Hills. There were several pits, the shallowest about 4 fathom deep, at which they are now working, and the deepest 70. or 80. fathoms, in a direction from the former toward the hill. The different Shafts were nearly parallel to the road. The ore is chiefly of the grey kind, with some blue, and is found in a Sandy matter, in lumps, of a loose texture. They dig through a loose red matter, which they call ~~Marl~~ Marl, & said the Vein of ore was not continued down into the red rock. Some of the red matter brought up from the deeper Shaft, was of a shivery texture, very soft & crumbling, and with the gloss of clayey matter; other parts were harder and more like the rock at ~~Dmister~~ Dunster, &c.

A few Miles before coming into Bridgewater, we Saw heaps of limestone lying to mend the road, of a pale blue colour, with calcareous Spar, and apparently rock lime Stone. Between 2 & 3 Miles

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* At Watchet they burn rock limestone for manure as the blue lyas lime does not fall to powder well in the air but as ~~told~~ I was [told] afterwards by Mr. Smeaton hardens by the rain.

[Page 30] from Bridgewater the road comes upon a ridge of yellow limestone, heaps of which we continued to see by the road side, till we came near Cross, where we say ~~brom~~ lime stone in the Mendip hills, having much the same appearance as the limestone lying on the road Side before we came into Bridgewater.

In some parts of the blue lyas ridge near Watchet, we saw a bluish matter in thin plates breaking out of the road side, & looking very much like Slate, supposed to be the light coloured clay which had taken that form.

An Undated Journey

(Chatsworth MS. X (a) 3)

[There is no indication given in the account when precisely this journey took place, while doubt exists, too, whether this excursion was actually undertaken by Cavendish. However, Blagden and Michell are both mentioned in the text, and there is every sign to suggest that. more than one person was engaged in the journey, and that it was attempted in the summer of 1788. It is not unlikely that Cavendish was responsible for the description of the journey. The MS., which is in a hand which might be Cavendish's, consists of 4 double leaves 13" x 8", with 14 numbered pages.]

[Page 1]

Summit of chalk hills is about 4 miles beyond Stevenage. Hence descend gradually but the chalk lasts certainly as far as Baldock & perhaps near Biggleswade. A little beyond Biggleswade to right are sand hills above Potton*

At Strangway hill 6 miles before Stilton ~~fine~~ extensive prospect of Peterborough &c

A few miles before Stilton road mended with yellow limestone mostly brought from Yaxley pit. From thence to Gunnerby hill beyond Grantham all calcareous country. In many parts of it road mended partly with pebbles said to be picked off the fields & chiefly jasper.

In some parts near as big [as] ones head.

About Gunnerby hill the limestone very brown

At Gunnerby hill descend into flatter country of reddish soil. Market place at Newark built of yellow picked stone. From Newark to near Doncaster soil ~~clayey &~~ commonly red & seemed chiefly clay frequently interspersed with a few pebbles & in some places particularly near Retford layers of pebbly gravel seen. Near Doncaster country grew sandy & soon after passing Doncaster on Ferry bridge road came to yellow limestone which continued to within

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*Pebbles with which road was mended at Bugden of different kinds chiefly jaspers.

[Page 2] 6 or 7 miles of Wakefield when we came to coal pits & found ourselves on a clayey sandstone the separation between this & limestone country being no ways marked which continued to Wakefield & Thornhill

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Receit for silver solders 6 of ☽ 4 of ♀ & 2 of zinc & to make it run freer - 1 part of 4 to 20 of ☽

To take off the silver from plated copper. Into strong oil ~~with~~ put a little nitre dissolved in a little water which enables it to dissolve the silver leaving the ♀ untouched if there be too much nitre it dissolve some of the but the silver soon precipitates it again & the silver is itself precipitated by diluting the solution.

From Thornhill through Wakefield Leeds & Austh[orpe] soil continued the s[am]e Between Aust[horpe] and Tadcaster on Bramham moor the yellow lime stone again appeared the separation ~~not well~~ marked This seemed to continue all the way to Tadcaster where arrived when dark Between Tad[caster] & York road flat in some ~~places~~ parts the road ~~was~~ seemed mended with some kind of quarry stone but in most places with pebbles. Between York & 10 mile stone road flat mostly mended with pebbles in some places perhaps with sandstone. After that ascended ridges of yellow limestone hills between which Castle Howard is situated. The yellow limestone continued to beyond Pickering after which came a sandstone like that near Thornhill but ~~much~~ harder & seemingly much less clayey the separation between these stones not observed but probably near the beginning of the moors this sandstone continued [Page 3] all the way to Mulgrave except where the shale appears.

In the whole passage by water from Staiths to Sands End the cliffs consisted of sand stone above & shale below. ~~In some places~~ The upper part of the shale only is good for alum the lower part is more of a clay stone in some places quite shivery so as to look like slate ~~in~~ others hard called blue scar which also proves shivery when broken or mouldering.

Near Staiths some marble lies near low water mark It is said to project up between fissures of the blue scar some pieces of it tried with aq[ua] fort[is] showed a considerable proportion of clay mixed with it. It works well & receives a tolerable polish Saw chimney pieces of it The shale dips a little to the S.E. but not considerably.

Uncertain what stone the top of the cliff at Scarborough Castle consists of but was supposed sandstone the middle was clay & the bottom sandstone but yet the same disposition of the strata seemed to continue to Red cliff and from thence to Filey brig except that from red cliff to Filey brig the strata dipt so that the upper strata of red cliff were even with the water at Filey brig & there is little doubt but the stone at Filey brig was yellow sandstone though not tried by acids. A little beyond this the yellow limestone sunk below the water & the cliff consisted intirely of red earth which continued apparently [Page 4] the same to near Speeton chalk cliff where it was examined & found to be a mixture of sand & clay thinly interspersed with pebbles of different kinds of hard stone but I believe no Jaspers. Blue clay then appeared but this red earth still seemed to continue over the clay & seemingly over the chalk. At the separation of the chalk & clay a narrow ravine ran up at first perpend[icular] to the coast but quickly bent to the right & became nearly parelled [sic] to the coast on the left of this ravine was chalk & on the right clay & the strata of chalk seemed to dip very fast in going from the coast & clay. In the beginning of the ravine also a thin interrupted stratum of stone appeared in the clay dipping also from the coast so that the clay seemed clearly to lie under the chalk but nothing seemed to show that any sand lay under the clay but as the ground in that part did not form fair cliffs that could not be determined with certainty.

neither whether the yellow limestone lay under the blue clay but as they both dipt in the same direction it must have done so without some /Page 5/ considerable irregularity in their direction.

The Yorkshire chalk is very hard & mixed with very few flints What there are of a whitish or greyish colour & softer than other flints The gravel on the Woulds consists almost intirely of rounded chalk. The chalk ends abruptly about 13 miles from York from thence to York only earth & pebbles to be seen & the same country seemed to continue to Easingwold but in going from York to thence it was dark about 2 or 3 miles beyond Easingwold road was mended with yellow limestone which however seemed not to have been dug very near but to have been brought from a ridge on the left hand ~~of~~ like those near Castle Howard & which seemed to be running that way.

At Leeming Lane ~~saw~~ they use a yellow ~~sandstone~~ sand stone for building Were told there that at a small distance towards Masham or to S.W. coal was found but fit only for burning lime that used for domestic purposes being brought from County of Durham. Met with no stone quarries till near Richmond where it is a hard sand & clay stone. We were there told that lead mines were found a few miles off in the hills & coal near /Page 6/ them but road too bad to fetch it from thence.

Soon after leaving Richmond came to the rock limestone which continued to the top of Stainmore where a black slaty stone called by Dr. B/lagden/ ragstone was found from thence to between Windermere & Kendal the prevailing stone was slate but with limestone in places.

About further end of Borradale hills seemed granite in most other parts. I believe slate wherever the strata of the slate were observed almost perpendicular. In returning from Buttermeer ~~both~~ the hill [sic] on both sides the valley had a regular slope covered with grass but excessively steep.

Between Windermeer & Kendal rock limestone begins & lasts all the way to Settle.

Near Ingleton to North are slate quarries said to form a narrow band Saw some about ~~one~~ a mile from Ing[leton] which was very good. The workmen told us that they found no alteration in the quality of the slate in digging deeper but that it changed as they went sideways Perpend[icular] to the ~~abyss~~ plane of the slate The slate seemed quite perpend. In following the slate toward Ingleborough they came at length to a hard rock~~y~~ stone called galliards. The highest part of the Ingleborough hill they said consist of a kind of grit stone but lower [Page 7] down both slate & limestone are found. About a mile to the southward of Ingleton & coal & there as well as above the town both limestone & grit are found. The limestone near the slate quarries dipt to the south of the last.

Examined the craggs above Settle which are rock limestone. The workmen knew of no chert in it nor could we see any but in some rubbish at the bottom of cliff saw some pebbles which I believe however were not chert. In these craggs were fissures one-on [sic] which was about 3 or 4 inches broad & extended from top of cliff to bottom in a remarkably straight great part of the substance with which it was filled up was crystallized & said by the workmen to be cawk.

Soon after leaving Settle the road was mended with a bluish substance resembling rock limestone but which was in reality a clay stone. In a quarry near ~~it said this~~ stone was found in alternate beds with yellow clay stone this substance continued some time but the yellow limestone gradually prevailed so that near Skipton & between that & Keighley it was all of that sort.

Some of the rocks near Ingleton were true grit stone like that in Derbyshire a good [example] of the same was found. soon after Settle to mend the road & some rocks of it further on towards Skipton.

From Keighley to Halifax ~~mostly by~~ road over high moors of same kind of sand or clay stone in one [Page 8] place about ½ way coal seemed to break out & just before we came to Halifax on north side of hill ~~further~~ as that furthest from Valley of Calder some extensive coal works & waggon ways. Between Halifax & Ealand edge stone approaches more to appearance of E[aland] e[dge]stone. On ascending the hill of Ealand edge which is high saw coal pits & [sic]bottom & the flagstone at top so that this stone seems interposed between the Thornhill & Halifax coal as Michell supposes. The best flag stone is got about a mile to the left of the road we went ~~& nearer the was~~ called long Ealand edge that which we passed being called over Ealand edge. Between that & Thornhill stone seemed of Thornhill kind but without any coal that we could see till near latter place.

The Liverpool & Leeds canal continued as far as Skipton the barges about 14 feet wide.

Michell considers the upper set of yellow limestone into 2 parts the upper consisting of the whitish yellow & blue stone & the lower of a brown stone containing fossil wood & shells of a different kind from those of the upper.

He supposes the lower set of yellow limestone to lie immediately over the coal country & says in one place they have dug through it directly to [Page 9] coal. Lead has been found [in] it. Small quantities of lead have also been found in coal.

Stone between Thornhill & Chesterfield of same kind as about Thornhill but I believe in most places harder & more sandy in some places between Sheffield & Chester[field] burn it for roads.

At Walkers furnace at Rotherham worked with charcoal could not see any of the plumbago or kish except a few particles adhering to the cast pigs informed us that we might see it at Smiths furnace at Chesterfield.

At the tin plate works there saw them pass the iron plates (single) through the cast iron rollers 11 times at one heating whereby they were reduced as well as I remember from ~~about $\frac{1}{2}$~~ upwards of one $\frac{1}{2}$ to about $\frac{1}{8}$ inch.

Tilt hammer at Sheffield went about 240 strokes in minute could not perceive any spring except what proceeded from the springing of hammer beam which was thick & not long & the elasticity of the wooden block & solid piece of iron let into it against which the tail of the hammer struck.

They straightened the small files there as Harrison did The large ones they can not do that way but heat them over again bend them so as to be ~~cro-~~ a little crooked the contrary way & again harden them as they suppose the bending in hardening to proceed [Page 10] from one side being harder than the other the steel of the hardest quality is supposed to become concave in hardening them they take care to dip them into the water perpendicularly & before they heat them cover them with a composition ~~as well as well as I remember chiefly salt~~ of salt & beer grounds.

Went to Smiths furnace the Griffin worked with coke were told by the master that when too much fuel was used the iron was Kishy in which case they laid on a greater proportion of ore & limestone. But they frequently chose to make it Kishy as then by melting old iron such as could not otherwise be used in a separate wind furnace & letting the Kishy iron into that the mixture made good iron and they were doing so when we were there. The Master did not know that any Kish ever came out distinct from the iron but the workmen said there did The master said he did not know that there was anything peculiar in his ore or manner of working but supposed that they must make Kishy iron wherever they endeavoured to make good cast iron.

In working a mine several gangs work at once on the same vein each gang consists of 8 me[a]n which work 2 at a time for 6 hours each & each gang work about 8 feet in height & a kind of floor called boning is laid for each gang on which they lay their refuse matter or deads but whether this is laid by the upper gang or by [Page 11] the lower & whether the upper gang begins first or the lower am not sure. Dr. Bl[agden] thinks the latter.

When a vein separates so as to form a small vein by the side of the other the stone which lies between them is called the rider. In many places as we went along the sides of the vein out of which the ore had been dug were sleek & this they called sleekers or slicken sides but the ore itself is frequently divided into 2 or more ~~divis~~ partitions the sides of which are sleeks. The explosion as they call it frequently takes place though the ore is confined by the boning from falling from any great height. It seemed as if the explosion did not very often take place even in places where the sides were sleek.

The ore is separated from its impurities by breaking it into bits & washing it in water in sieves ~~but~~ which means the ore chiefly falls to the bottom of the sieve but not so much so that what it is necessary to pick it also by hand The small stuff is clear by putting it by little & little into a ~~through with a~~ kind of trough which has a gentle inclination & through which a pretty brisk stream of water of very small depth runs by which means the impurities are carried to a greater distance while the ore settles nearer to the part where it is put in.

At the mine of Cankwell great quantities of Toad stone were dug up it was very black & is therefore [Page 12] there called black stone it [in] other places it is not so black Some parts had hollows in it others were very solid & some were speckled with spar in the mines it is certainly hard but when exposed to the air most parts even the most solid gradually moulder into a kind of clay in some places this operation goes on very slowly in others very fast.

There are parts of it which are almost as soft as clay in the mine particularly by lying between it & the limestone which have not at all the appearance of being burnt. The stratum is of very unequal thickness in some places they come to a marl where its thickness is so great as not to be known In other parts it is thin The fissures penetrate into it but are smaller than in the limestone & sometimes there is a little lead in them but trifling & it has hitherto been found true that a fissure with lead ore over this

Toadstone is found to be continued with similar lead ore under it.

At the quarries at Ashover the chert in the limestone formed pavements but interrupted there were several thin strata of limestone which appear/e/d like chert but which the workmen said were not.

The sands of Wooburn are full of thin pieces of purplish brown stone consisting of sand cemented by iron some very hard & the road is mended with them

/Page 13/

Strata which Michell dug through for coal

		Yard	feet	inch
1.	Stone of a clayey sand consistence			
2.	layers of different kinds of clayey & sandy stones called cushats (from the colour of wood pigeon) Galliards binds & seat earth	25		
3.	A bituminous earth which would just burn & retain/e/d its form nearly when burnt out			2
4.	Similar to No. 2	5		
5.	a very good coal			3
6.	Similar to No. 2	24		
7.	A very good coal		1	10
8.	Seat earth }	1	2	
9.	black slate }			
10.	Stone like No. 1	4		
11.	Coal very good			7
12	Stone containing one bed about a foot thick very hard other parts like No. 2 in these last was a band of mud about an inch thick called a dirt band	11		

13.	Alternate beds of iron ore & firm black shale ~~All these iron ores~~ & shale as well as No. 14 ~~& 15~~ contained great numbers of shells seemingly all of one species & bivalve	3		
14.	a very bituminous shale	1	2	

[Page 14]

15.	Stone coal of various qualities divided by a stony band some pyrites parts of the coal contained shells like No. 13 a piece of the coal had impressions on it of a bone and of the scales of fish		2	6
	Total	77		
16.	Seat earth	1		
17.	Coal		1	3
18.	Several sorts of earth & stone	20	1	6
19.	Coal		2	
20.	Several sorts of earth & stone	31	1	
21.	Coal		1	11
22.	Seat earth			9
23.	Coal & scale			10
24.	Blue metal	22		
25.	Supposed like No. 18	14		
26.	Coal		3	2
27.	Other matters	14		
28.	Coal		2	3
29.	Other substances	36		
30.	Coal		3	
	Total	221		

To No. 15 inclusively is from Mr. Michells own knowledge the rest from information

The former from 2 pits near Thornhill Church the rest from several within a circuit of 2 miles nearby.

Journey in 1793

(Chatsworth MS.. X (a) 2)

[This is largely a circular tour of the Midlands, undertaken by Cavendish, beginning at Uxbridge and returning to the London area. The journey occupies a week from 24th August to 1st September, and is chiefly geological, but Cavendish also records his observations on the extracting of lead from its ore.

The MS.. is in Cavendish's handwriting, and consists of 3 doubles leaves 13" x $8\frac{1}{4}$" with 12 numbered pages.]

[Page 1]

Journey in 1793

Aug 24 Between Uxbridge and Amersham at 19 or 20 [miles] saw bedded in a gravel pit stones seemingly of grey weather kind.

Wendover is ~~nearly~~ in valley between the chalk hills & nearly in a line with the edge of them till that little Chalk comes to clay the highest part of the road is a little before Wend[over] & except at Wend. ~~from thence to Aylesbury we descen~~ though the road on the whole descends there is ~~hill~~ no consid. descent between highest part [of] road & Ailesbury and there not much

Between Wend. & Ailsbury there is nothing which shows the nature of the soil.

A mile beyond Ailsbury saw a gravel pit consisting chiefly of flinty pebbles but mixed with others seemingly of same kind as No. 1 further on.

At $44\frac{1}{2}$ miles ascended a small continuous ridge of hills which extended seemingly from a few miles N. of Dunstable far to left of road where the yellow limestone began & continued without interruption to Banbury but between Winslow & Buck[ingham] the road was chiefly mended with gravel which in some places consisted of large nodules. About 2 miles before Buck. some of this was examined and was found to contain many flinty pebbles but much of it was of the kind No. 1 No. 2 is a bit of yellow limestone found at same place.

[Page 2] Beyond Buckingham little gravel was seen.

No. 3 is a bit of yellow limestone found 2 or 3 miles beyond Bucking[ham].

A little before Aynho much of the limestone had a dark bluish look approaching to iron stone.

No. 4 is taken from a pit where this was dug. In this pit was no appearance of flint or chert or any pavement between the strata of a different nature from the rest but it seemed as if most of the stone had this appearance on the inside though the outside was of a yellowish brown.

In the bottom beyond Aynho much of the limestone was of a dark greenish blue & it was the same at Banbury. No. 5 is a bit of this kind used for building the new church there but ~~between~~ on the higher ground between this bottom & Banbury it was of a dark brown kind as it was in most parts of the road between Buck. & Ban. except near Buck.

For some distance from Banbury the limestone was of a blue slaty colour aferwards it was more brown & between Byfield & Daventry was full of impressions.

No. 6 is of this kind.

Between Shuesborough & Southam the road lay below the hills the limestone still continued & was ~~bl~~ blue but seemed of a smoother texture than the other [Page 3] blue stone & seemed of same kind as that in Gloucestershire & Somersetshire.

For about 2 miles beyond Southam the yellow limestone appeared pretty evidently to continue but at about 4 mile the soil began to be red & continued so with small interruptions to Coventry & the road all the way was paved with pebbles I suppose Jaspers but did not examine any but except in one place saw nothing which had the appearance of red rock.

A little before Coventry & in another place a little after Coventry in the way to Atherston[e] saw soft whitish sandstone like that at Nottingham & Warwick.

Soon after leaving Coventry came to ~~the~~ Country full of coal works & from thence to Ashby though the coal country continued only 2 or 3 miles little red soil was seen. ~~Near the e just after the end of the coal country~~. In this was an appar[atus] for raising the coal by a small fire engine ~~turning~~ working very fast which by a clank turned a wheel & fly which moved the barrel which rope wound on & revolved in less time than the fly wheel.

~~Seen~~ Immed[iately] after leaving the coal country saw ~~a~~ stone [stone] lying in thick beds but yet of a schistous nature of a red colour only inclining to the blackish colour of ironstone which I at first supposed to be red rock but I believe without reason. It dipt quick to the West & therefore as this lay to the E. of the coal should seem to lie either under or among the coal & soon after [Page 4] leaving Nun Eaton saw much of the same which had not much of the red colour.

Between Atherstone & Ashby saw little red soil the road mended with pebbles.

From Ashby to Lound road a white sand but mended in some places with stone said to be Breedon limestone. At Lound are collieries & just beyond saw a pit where they were digging a softish white sand stone. About 2 miles to right of this is Breed[on] consisting of a steep seemingly insulated hill with quarries on the side & according to the information of the persons at the quarry consists of the same stone from the top to the bottom. At Melbon [Melbourne] are quarries of white sand stone used for grindstones & for building. About a mile to the right are quarries of limestone of same kind as Breedon stone.

A few miles beyond the Trent on left of road are quarries of Gypsum. It lies in a very red clay & the principal stratum seemed at least 6 feet thick but the surface seemed far from flat & there were some thin beds over this except this there was very little red soil between Ashby & Derby.

No. 7 is Breedon lime. No. 8 quarry near Lound.

No. 9 Melbon quarry stone. No. 10 Gypsum ~~accompding~~ & the clay accompanying it.

[Page 5] A little past Derby was red earth with stone in thick beds. No. 11 is ~~part~~ a piece of it & seems a kind of grit stone. The grit stone began ~~many~~ several miles before Wirksworth ~~by Wirk.~~ ~~the~~ The Valley of Wirk. is limestone & full of mines but the road & hill above [above it] it [is] grit & as far as I can perceive there is no Shale between but the stone by the road is of a schistous kind & so it was ~~a mil~~ in many places for a mile or more before No. 12 are 2 pieces of it.

No. 13 are 2 pieces of Toadstone one of hard & the other of the mouldering kind. No. 14[(1)] is a bit of Crystalline mat[ter] sticking to the grit stone at the top of Overton hill.

No. 14[(2)] is piece of ironstone at coal pit near Overton supposed such as might be worked as ore.

No. 15 matter collected in chimney of standing Cupola furnace.

No. 16 Slag at D°.

No. 17 Smut or matter where coal of pit near Overton comes to day ~~from~~

The regular manner of working in mines is by steps & the workmen in ~~upper step go for~~ each step makes a floor over them to lay their deads on & those on the upper step throw down ~~this at~~ the ore to those on the lower.

[Page 6]

4 29 [Aug. 29] At Stanage Cupola furnace Part of the slag is vitrified so as to flow out on opening the hole part is not when it is sufficiently done the slag is first let out at one hole & afterwards the lead. That which is vitrified & flows out is supposed to contain no lead & is thrown away. That which does not run out contains some & is worked over again in blast furnace. ~~Along with~~

~~the-lead-there-flows-out-some-sl~~/ag/. The lead is received in an iron vessel sufficient to hold ~~not-much~~ it but along with it there flows out some slag & as soon as the unvitrified slag in the furnace is raked out this is thrown into the furnace for the lead mixed with it to run out & ~~when-~~ the lead in the iron vessel is ladled out & cast in moulds ~~the-ore~~ As the slag which comes from the cupola furnace yields lead in the blast furnace it might be supposed that ore would yield more lead if worked in blast than cupola furnace but this is said not to be the case as more lead is evaporated in the former.

Watt has lately made an exper/iment/ for determining spe/cific/ gra/vity/ steam. the steam from boiler was received in a cylinder the piston of which was moved regularly by water & as soon as piston rose to top the commun/ication/ between boiler and cyl/inder/ was shut & a valve open/e/d for letting out the steam & was continued so till the ~~cyl~~ piston sunk to bottom & the fire was kept such ~~that~~ /Page 7/ that the ga/u/ge in the boiler shewed ~~shewed~~ that the domes/tic/ pressure of the steam in the boilder should be equal to that of atmosphere by this it appeared that the steam was 1876 times lighter than water.

Bo/u/lton says that common fire engine works best when load is 6 /= lbs./ an inch weight atm/ospheric/ is 15 /lb/ heat of hot well 152 but according to Mr. Lawson the friction may be reckon/e/d at 1 or 2£ so that the true load is 7 or 8£.

He says too that 1 cub. inc. water makes 1 cub. foot of steam & that this raises 1 cub. foot water 23 feet.

To P.10*

No. 18 is matter resembling charcoal found in a block of coal at fire engine at Overton.

In road to Mansfield) At Stretton coal country begins & lasts to within 3 or 4 miles of Mansfield. When soil consists of reddish sand & pebbles but just at Mansfield on descent of hill is stone seemingly of sandy or argillaceous kind & lower down at entrance of town is limestone. The Sandstone is to appearance of much the same kind as that in the coal country a specimen of which is in No. 19. so that it looks as if the sandy or argill[aceous] stone lay under the red earth & the limestone under that. The houses in ~~Newark-ar~~ Mansfield are [Page 8] built of whitish stone not calcareous found near the town.

On ascending the hill from Mansfield at first find stone of the red rock kind but not very red after that towards top of hill find red sand mixed with pebbles after which the road all the way to Newark is gravelly sometimes red & sometimes otherwise except in a few places where there appeard some of the argillacious sort of red rock.

From Newark to about ½ way to Lincoln the road ascends gently & is mended with gravel seemingly of the same kind as between Mansfield & Newark but ~~about 9 miles from Newark~~ thereabouts the appearance of the gravel changes & seems to consist partly of flints partly of jaspers & partly of such stones as No. 20 & at 9 miles from Newark yellow limestone was seen but that is the only place at which I saw it till near Lincoln. From thence to Linc[oln] the road gradually descends. Linc. stands in a ~~va-ley-it~~ gap in a ridge of yellow limestone hills not high but rising pretty bold.

(6) Sep. 1. In ascending hill from Lincoln about $\frac{1}{2}$ way up saw blue clay which seemed to run under the limestone. If so it must be clay lying between the beds of limestone as there was limestone below it.

[Page 9] All the road between Lincoln & Sleaford is on the limestone which to near Sl[eaford] was of the yellow kind except one place where it was white but near Sl. it was brownish. The road was nowhere mended with gravel nor did I see any pebbles except such as seemed fragments of limestone. Between Sl. & Bourn[e] the road was mended with limestone commonly brown but no gravel.

Between Bourn & Peterb[orough] road was in many places mended with gravel which in the first part seemed composed of jaspers but in the latter part of various kind & so it was between Peterb. & Aukenberry [Alconbury] hill.

From Biggleswade to within a mile of Baldock no chalk was seen but the road was mended with what seemed flint gravel.

Weight in pounds required to breaking wires of metal $\frac{1}{10}$ inch diam[eter] taken from Boulton

Gold - 500

iron - 450

Silver - 370

Brass - 360

red copper - 300

pewter - 49$\frac{1}{4}$

lead - 29$\frac{1}{4}$

/Page 10/

*from P.7

If steam is 1876 times ~~li-ht~~ lighter than water i cub. inc. water makes 1.085 cub. feet steam & therefore if there was no loss should raise (when barom/eter/ is at 30 inc.) ~~$30 \times \frac{10}{9}$~~ one cub. foot water to height of $30 \times \frac{10}{9} \times 1.085 = 36.2$ feet so that loss of force is about $\frac{4}{11}$ of the whole. N.B. if in saying it raises 1 cub. foot to 23 feet height he means that it will actually work a pump which raises that quantity of water the height of ~~36.2 feet~~ 23 feet must be increased by a $\frac{1\frac{1}{2}}{6}$ part so that the engine if no force was lost by the friction in the water pumps would raise 1 cub. foot to 23.0 ~~36.2~~ $\times \frac{5}{4} = 28.75$ feet & therefore loss of force would be only $\frac{1}{4.83}$ part of the whole.

/Page 11/

Examination of Specimens

No. 1 One piece of this was a well rounded pebble & was calcareous 22 grs. of it left ~~a very small~~ quant/ity/ of light resid/ue/ & 1 gra/m/ of sandy ~~or quartzy~~ matter.

The 2 other pieces had somewhat of the grey weather appearance & were not affected by Sp. S one easily rubbed down to powder and the other more difficultly.

No. ~~2~~ /26 of No. 2 left very little light sed/iment/ & only $\frac{1}{2}$ gr. of sandy matter.

No. 3 left very little light sediment & scarce any sandy matter.

The foregoing 3 pieces of calc/areous/ earth were of a close grain but with very ~~little shin~~ few shining particles in them.

No. 4 was very much mixed with ~~crystalline~~ shining matter

& some veins of ~~sp~~ sparry matter. The sparry matter left scarce any light sediment or sand ~~of sand~~ 19 of the grey contained about $\frac{1}{3}$ of sand & very little light sediment & 21 of the blue about the same.

No. 5 was of a greenish colour of a coarsish grain & soft. 9 of it left $3\frac{1}{4}$ of sediment which did not feel gritty & retained some of the greenish colour being digested with Sp[irits of] s[alts] all except $\frac{1}{2}$ gra[m] of gritty matter dissolved the solut[ion] was precip[itated] by vol[atile] sal[t of] Amm[onia] which made a bluish precip[itate] but this perhaps was*

24 ~~No. 4~~ of No. 6 left 7 of brown sediment which was not much gritty.

No. 9 being rubbed with water & washed appeard to contain 78 of fine yellow sand & 6 of clay.

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* not owing to the iron being mixed with anything for a mixture of old solut[ion] gr[een] vitr[iol] grown yellow with fresh made solut[ion] iron in Sp[irits of] s[alts] made a precip[itate] approaching to that colour but the solut[ion] green vitr[iol] alone made a brown precip[itate] & the solut[ion] iron in Sp. s. a whitish one.

[Page 12]

No. 8 contained but little clay it had not much yellow colour & the greater part of the sand was not fine. It contain a few thin flakes of shining matter I suppose Talc.

N.B. I believe that No. 8 & 9 must have been displaced &

that No. 8 must be the stone found at Melbon[sic].

No. 12 containd 8 of clay about as much of very fine sand or clay & 86 of moderately fine sand.

No. 19 containd 47 of clay & 111 of fine sand.

No. 11 is to appearance of the same nature as common gritstone only coloured a little red.

No. 20 were neither of them calcareous they seemed to be pretty much of the grey weather kind but both seem to have ~~consisted of a stone which was formed in thin plates~~ been formed in thin plates before they were rounded.

Blagden's Journey to France, 1787

(Chatsworth Ms.. X (a) 1)

[This is a short tour undertaken by Blagden in the vicinity of Calais and Boulogne, with a brief extension inland to the coal country. He was occupied chiefly in geological observations during the time from September 25th to October 15th. The Ms.., probably written by Blagden, comprises 2 double leaves 12½" x 8¼" with 5 numbered pages, and 3 unnumbered sheets which are here numbered 6, 7 and 8.]

[Page 1]

♂ Sept. 25 Embarked for Calais but wind being scanty went to Boulogne. Saw cape Blanc Nez near true chalk hills Then came to sand country with beds of stone the same as about Folkstone which continued to Grisnez after which began to see the cliffs with appearance of blue clay Went ashore at Boulogne & ♀ 26 went on Boulemberg. In ascending had first blue clay after getting above which began to meet with sand & stone in beds looking very silicious almost like chert but soft. Took specimen No. 1 This kind of sandy country continued all the way up Boulemberg Toward the top thought it was rather clayey Near bottom of hill a little way out of Boulogne found them burning lime stones taken out of the blue clay which were evidently a kind of blue lyas but of whitish grey colour They had the blue lyas grain but rather coarse. The guide confirmed that they made excellent lime for hardening under water. In descending from the Boulemberg soon came to a stone partly yellow and partly blue (blue in the inside) looking like yellow limestone but said not to be so somewhat harder. Took specimen No. 2. Returned to near Boulogne and there took road to Calais The 1st part was through a sandy country with some clay in places till ~~past Marq on ascending hill toward Duling~~ past Marquise when on ascending hill towards Dulinghen saw much stone & mounted the ridge perhaps 2 miles N. of Marquise

~~nothing [illegible] omitted~~

which seemed true yellow limestone & there saw lime [Page 2] kilns & took specimen No 3 This stone continued to near top of range going to Hautbuisson when the country changed insensibly to chalk before we got quite to the summit. The surface of the group was a sort of loam of reddish brown colour from the yellow limestone on to the chalk. From Hautbuisson which is about a mile on the summit of the chalk range the hills begin to descend & on the side of Calais came to gravel Country. ~~Lowland~~

In a line with the blue clay near Boulogne is a glass house at Arlinghem about 15 miles from coast. Saw them on the coast abreast of it burning kelp.

The glass house fewel is pit coal found in its neighbourhood.

4 29 The circle which Mr Cassini uses 12 inches diameter is invented by Chev. de Borda & made by a young artist Le Noir who is famous for dividing The strokes of the divisions are very large & there is a vernier for reading & by that I thought I could discover

that the divisions were unequal The circle is divided to every 10' which are divided into 20 parts or 30" by the vernier & perhaps the eye may estimate to a $\frac{1}{4}$ of that The telescopes have 1 inch aperture the ~~lower~~ upper but indifferent but the lower which is Co Collee very distinct.

☉ Sept. 30 From jettee head of Calais on French Coast toward Dunkirk saw excellently the effect of refraction a house lifted up with clear sky between it & the sea also 2 chimneys or roofs of huts lifted up still higher Should suppose elevation from 1 to 2' I am certain that [Page 3] the less the objects were elevated above the horizon the greater the interval of clear between them & the sea & that objects of a certain height permit no clear to be seen but could see nothing which looked like reflexion or inversion of the objects.

☽ Oct. 1. Observed that the French circle was difficult to manage that the threads were not in the focus of the object glass that the stand was very unsteady and the whole instrument tottering.

♃ 4 Oct. 4 The wind being only about 1 point to West of S & strong I observed that there was nothing of the white line between the distant objects & the horizon yet the distant objects seemed to be visible rather lower down than when that white line was seen. The hut was seen from the jettee to the bottom & the ground on which it stands whereas I could hardly see to the bottom of the house last ☉ on ☉ however there was a broad white line between what I saw & horizon also ☉ saw the tops only of the 2 huts lifted up [note on page 8 probably a continuation]

*P.5

☽ 8 Crossed the arm of the sea at Boulogne in a boat and went nearly south & at 2 miles came to a fishing village where is a little sandy cove. Found there some of the blue paving stone nearby broken in a heap with many petrifactions & bits of wood like charcoal in the stone Cliffs all the way the same sand with a little clay having beds of stone at top & blue clay underneath In some parts the blue [Page 4] clay is very black and seems to be what belongs to coal The cliffs to the South of this village seem to be of the same nature as likewise those of Grisnez Saw men at work here under the Cliff cutting out large pieces of stone fallen down The upper stratum of sand & clay is all of a yellow colour with beds of flattish stone which are also yellow on the outside but within have the peculiar blue of the Folkstone stone

+P.5

♂ Oct. 9 From Boulogne to St Omer After leaving Colemberg where is the whitish clay ascend chalk hills to towns of the Duc de Cray La Motte Boisdinghen & Chalk country Find that that that the range of hills which we saw from Mont Lambert are not yellow limestone but chalk the yellow limestone forming the lower risings before come to chalk It is said that they have dug for coal at Colemberg in vain

Oct. 10 Find that at St Omer they burn coal which they get from beyond ~~the~~ Lille At Mont Cassel burn some coal which comes from Armentieres which lies beyond ~~the-hill~~ Lille* So same as that at St Omers They have also coal from England by way of Dunkirk which notwithstanding the imposts comes cheaper Mont Cassel ~~is~~ consists of reddish sand & clay the clay at bottom & sand at top

Oct. 13 Mr. Mouran at Calais burns coal partly from England partly from Ardingheim Saw marble with him found at Ardingheim brownish smooth grain has often petrifactions Cornu Ammonis &c He said also that the yellow limestone near Marquise made

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* Therefore chalk range seems to pass to north of Armentieres which bears very little to S of E from Boulogne

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[Page 5] very good lime & that the limestone found in the clay near Boulogne he said in the road to Paris made lime that harden[e]d under water.

*from P.3 Oct. 8 Journey from Calais to Boulogne. Saw good pieces of yellow limestone lying at Hautbuisson for building said to come from near Leulinghen Set off from Hautbuisson at 0.35 & at 1.0 saw quarry of yellow limestone of which took specimen No 2 (No 1 is some of the building stone seeen at Hautbuisson) No 2 was intermixed with many petrifactions particularly toward the surface large smooth bivalves There seemed no material interruption between the chalk & yellow limestone a little descent perhaps & ground more coverd with mould which began to look richer above yellow limestone The yellow limestone soon began to change to blue & at 1;13 saw it lying in its natural situation in a cut of the road

+from P.4 Took specimens No 1. taken out of the cliffs a little N of the village which is 2 miles S of Boulogne along coast No 2 a bit of coal or wood taken out of one of the paving stones lying in a heap near the village No 3 the cap of one of those paving stones full of petrifactions No. 4 a bit of stone found on the cliffs

Examination of the stones

No. 2 Sept. 26 & No. 3 Oct. 6 both alike to appearance A bluish grey ~~shining~~ texture shining & approaching to that of rock limestone The greater part of both dissolved & the remainder was a fine sand

No. 1 Sept. 26 consisted of different substance cemented together part was a yellow earth part of it dissolved but the greater part seemed clay 2nd a compact shining & seemingly crystallized substance which formed the greatest part of the stone ~~3rd a few pebbels cemented in the stone not tried~~ which dissolved intirely & 3rd a few pebbles cemented in the stone & not tried

No. 3 Sept. 26 about 2 miles N of ~~Dulinghem~~ Marquise in ridge near Dulinghem A very close compact stone with a good deal of the shining fracture of rock limestone dissolved intirely

No. 1 Oct. 5 Consists of Ammonites much like Bath stone & No. 2 much of the same kind only more crumbly & the grains much smaller ~~& more crumbly~~

Oct. 8 No. 1 & 4 from cliffs 2 miles S of Boulogne Had the appearance of sand cemented by matter which in some places had a sparkling appearance the greater part of both dissolved The remainder of No. 1 was fine sand that of No. 1 rather coarser but mixed with a little clay No. 3 less of this dissolved than of 2 former the remainder was a coarse & unequally coarse sand mixed with some black particles

[Page 7] Oct. 9 between Colemberg & La Motte a close grain[e]d calcareous earth without any appearance of eggs or shining matter except a few small parts which for the most part had the appearance of shells It left a little residuum consisting of clay sand & hard ochry particles

/Page 8/ above the white lime & nothing of the ground whereas I now saw the very ground on which those huts stood but no white line

Oct. 15 From Jettee saw the hut all the way to the bottom though there was a broad white line on the English coast ~~therefore~~ at (low water)

Oct.

Dr. Bl/agden's/ Journey 1789

(Chatsworth MSS. X (a) 8)

/This journey was undertaken by Blagden in the Autumn of 1789. The itinerary extends beyond the Cities of Belgium to the valleys of the Meuse and the Rhine, and thence to the sight of the mountain ranges of West Germany. He hardly follows a prescribed route as his geological excursions take him hither and thither, but be takes the opportunity to note interests of an industrial nature.

The MSS. is written by Cavendish, and consists of 2 double leaves, 13" x 8" and one single leaf 6½" x 8" with 10 numbered pages./

/Page 1/

Dr. Bl/agden's/ Journey 1789

Sep. 20-26

Ostend, Bruges, Ghent, Brussels, Louvain, ~~St. Tron near this saw~~ (A little before St. Tron/d/ saw a bank with whitish matter like chalk found it chiefly clay but perhaps with some chalk intermixed)

26 St Tron. (from thence to Liege hilly with steep descent to Liege. The iron ore worked at Liege is chiefly collected in the small streams and is smelted with charcoal The coal pits are in general near the town & on N. side the river but on the hill as well as ~~by~~

~~the river~~ in the valley whence judge that they dip towards the river Went to coal pit They seem to pierce only through schistous stone & the same stone lies between the strata of stone of which there are many It is a schist which moulders in the air It is more or less between slate & coal colour with much iron crust in the cracks of it They bring their limestone from towards Namur & about 18 miles off in that direction have marble

27 About league from town begin to ascend & come upon schist of Auber forest which is nearly the same as that above coal only more black & seemingly with more iron As we ascend it dips towards valley of Meuse but toward the top lies in all directions according to the vallies. In some places the schist is Shivery in others almost in lumps like iron stone & probably lumps of this found in the streams may be used as ore On descending into valley in which [blank] is situated saw large masses of the paving stone which seemed to me to lie under the schist & in some places was composed of large crystals compostea together which I took to be quartz & feld spath

All the stone I saw about Spa Schistous & assured that no limestone nearer than several leagues towards Liege [Page 2] Some quartz mixed with the Schist which is partly in lumps & partly very shivery like chips of brown wood & moulders down fast No good slate under 2 or 3 leagues.

Sep 29

~~Road~~ In going from Spa To Aix ~~returned~~ went back by Liege road to about Franchimont then turned to right & soon after ascended ~~hill~~

a limestone hill & then came to slate This is the nearest limestone to Spa It is dark blue very hard smoothish fracture but rather coars/e/ No 1. It dipped there chiefly to S or SSE but that seems to depend much on the inclination of the hill After crossing valley of Verviers ascended a hill which is chiefly limestone of same kind as before In one place saw schist evidently over it. This is certain that we lose the schist & get the limestone in going northward & yet the strata rather dip to S. In proceeding from Verviers we continued some time on this limestone hill & then came immediately to chalk of which traces might be perceived at Verviers from the whitish flinty pebbles mixed with the soil At the top of the hill from Verviers passed a village & then continued on what seemed the rock limestone ridge rocks of it projecting out in many places as we went up the hill About a league forward on this ridge we came to the road from Liege & about a league before Harry /Henri/ Chapelle saw chalk From this ridge A see to the right what appears a continuation of the Spa hill or Ardern forest & to the left another ridge which we afterwards found to be sand On leaving HARRY /Henri/ Chapelle (which seems to be on this ridge) descended a hill with true chalk & flint Then soon saw sand then the dark rock limestone & then to mines of lapis calaminaris which seem to lie the rock limestone & the ridge of sand hills Was told by one of the workmen that the /Page 3/ limestone lies under the calamins The shaft where I was was 18 fathom deep The matrix seems to be a yellowish quartz stone like that of some copper mines Much iron mixed with it looking like red copper ore. From hence to Aix la Chapelle road sandy but dark before arrived there.

Ascended a little hill by Aix (Vogels Stand) it is a sand hill but with debris of many kinds of stones, chalk, what appeared to be fragments of yellow limestone, flints.

~~At~~ going out of the town by footpath to Bercheid saw some of the schistous rock which therefore appears to lie under the sand

Oct 1 Aix to Juliers road first sandy or loamy then ascended hill of shivery kind of Schist then on plain clayey loamy or sandy & before Juliers pebbly most of the pebbles sandstone but many of them almost Jasper like those of Nottinghamshire At Juliers are supplied with coal from between Aix & Maistricht A ~~worse~~ very good but a worse kind found nearer

From Juliers to Bergen country flat & pebbly

Oct 2) From Bergen to Koningsdorf country sand with pebbles Chiefly quartz & then came into valley of Rhine but before descending into it had view of mountains beyond the Rhine chiefly the range of Siegbergen From thence to Cologne along valley of Rhine country sandy with pebbles some of the dark blue seemingly Basalt The same kind of ~~country~~ road to Bonn [illegible] road on west side of Rhine.

Oct 3 Soon after leaving Bonn on W side of Rhine opposite to Konigswinter the mountainous passes of the Rhine begin & there the ridge of the Siegenberger ends in a very grand manner After passing this look up a valley & see the mountains [Page 5] all tumbled in heaps The bare rocks had a basaltic tendency but were perhaps more like some to be described hereafter Several of these rubbish mountains were conical About Millem the basaltic country begins. We see them by the side of the road as we pass very evident blackish with crystals as of Schörl with some glassy & whitish matter which I take to be Zeolite This kind of country continues about 2 miles About a league before Remigen is a fine quarry of this basaltes the pillars not very regular but the stone appears to be much fused When these basaltes no longer appear a schist appears forming a continuation of the same rocks This is much like that of the Arden forest assuming various appearances of greater or less compactness & greater or less thickness of beds as approaching more or less to the nature of Basalt See Specimen No 2.

Near Oberwinter before we arrived at Renmagen saw basaltes on opposite side of Rhine the Strata seemed bent as in Fingals cave but the pillars were not very regular It was curious to see how much the schist approached in many places to the basaltic form being in others very shivery & mouldering almost into clay

Between Renmagen & Andernach saw much schist having more or less of the ~~basaltic~~ volcanic appearance Andernach is placed just S end of the passes on the Rhine where the Country opens.

Oct 4 from Andernach to Montebauer) The valley of Rhine from Andernach to Coblentz is rich loam with gravel

[Page 5] The citadel of Coblentz stands on hill formed of schist of almost a volcanic appearance No 3 is specimen of Schist from Coblentz.

Cross the Rhine in road to Frankfort & ascend the hills which at first are schist with remote tendency to basalt As ascend higher meet with white gravel which seemed fragments of quartz & then came to ~~the~~ paving stone like that of the forest of Arden (Specimen No 4) which I judged to lie over the schist & is whitish & sandy but whether crystallized or aggregated I could not determine. Much iron ochre found incrustated & in some places the soil is of an Hæmatific redness As descend the hill to Montebauer again find the Schist

About $\frac{1}{2}$ way between Coblentz & Montebauer passed 2 conical hills well covered with wood but suspect that they are volcanic & that the basalt posts placed on side of road are brought from thence.

Oct 5 from Montebauer to Konigsberg) ~~Road-in~~ Country in general Schist Near Ober Brucken were basalt columns projecting out of the ground & soon after the schist became almost a true slate & about the same place was abundance of white gravel Then pass through Selters the water remarkably pungent & acidulated On hill near Etsche schist again turned to true ~~slate~~ blue slate (~~Oct-Seen-after~~ Oct. 6 between Konigstein & Francfort saw great blocks of white stone lying on ground ~~with~~ which I supposed quartz with stripes in it which seemed Schistous After that came to a salt work

Oct 7) Francfort to ~~Mayence~~) Between Francfort & Mayence see a ridge of hills on right leading towards Konigstein [Page 67] one point of which guessed to be at least 3000 feet high & another ridge to left which seemed to be on west side of Rhine beyond Worms Near Mayence road mended with a kind of yellow limestone not oolithotes but with small petrifactions.

Oct 8 On Rhine from Mayence to Brighen a pass of the Rhine between them.

Oct 9 to Coblentz) At Caub a little below Bacharach a quarry of slates & ~~most-of-the~~ The rocks on the river side were in general slaty the whole way.

Oct 10 to Cologne) A little below Andernach enter the pass among the hills which are close to the ~~hills~~ river on both sides & are composed of Schist in some places affording slate fit for roofs Some time after saw rocks on left which seemed basalt Some time after Schistous rock Below Lintz a fine basalt rock Below Remigen the Unhelstein a set set of basalt pillars projecting obliquely out of the water. Below Oberwinter to right had a vast ~~quarry~~ quantity of stone lay as rubbish on the side of a hill & told it was a quarry from which great quantities of stone had been sent to Holland This side of the hill seems to have its rubbish of joints of basaltes yet the side towards Bonn seemed afterwards to be nothing but slate

Oct 11 Saw lying on Quay at Cologne a sort of reddish flat paving or coping stone exactly like that found above Basle with shining particles of Mica in it but suppose this came from Mayence. Vast quantities also [Page 7] of the lava millstones

Oct 12 to Dusseldorf) along valley of Rhine see there lava millstones said to be brought from Siegenbergen

Oct 14 to Aix) From Duss[eldorf] to Juliers flat country.

Oct 16 to Maistricht) In one hour came to supposed yellow limestone much more like rocklimestone No 5 than usual but not unlike some of the Kentish limestone. In ½ hour more without any distinction of country except some small ravines came to chalk No 6 with abundance of flints scattered everywhere the Chalk ~~very~~ yellow but otherwise good & not hard At Gulphen the country still chalk but were building with a good yellow limestone No 7 like Bathstone said to be found about a league off to N.W. In approaching Maestricht descended steep hill with bare rocks of yellow limestone At Maestricht went into the subterranean passage where they now dig stone all yellow limestone very soft with petrifactions The temperature $44\frac{1}{3}^{\circ}$ or 44° outer air 53° water of 2 deep pumps at Maestricht 51° air at 49°

Oct 17 to Louvain) Road to Tongres seems to go over yellow limestone country but see no quarries of it At Tongres much sand well there 50° From Tongres go southerly by Cross road to mett that from St Tron to Liege. I have no doubt but the white bank which saw in going from Louvain to St Tron is chalk & a ~~projection from~~ continuation of that between Aix & Maestricht.

[Page 87] Oct 18 Louvain to Antwerp ~~Seen after~~ at leaving Louvain road is cut through a bank which consists of sand with beds of sand cemented by iron as at Wooburn.*

Oct 27 Brussels to Leuze) Suspect that between Hall & Enghien there is limestone under the surface as saw much lime on the fields In one place soil looked whitish as if chalky.

Oct 28 to Lisle) At Leuze burn much coal part from near Mons & part from other places As approached Fontenoy came to quarries of limestone of a deep brownish blue No 9 pretty hard close & compact but remarkable Schistous looking like slate seems as if it would take the least polish left a moderate quantity of sediment in solution but that piece which most of the slaty appearance left least.

No 10 is specimen of a stone used for building at Lisle hard of ~~bluish is reddish~~ purplish black colour close & compact but coarse grain without any tendency to polish Effervesces but not much dissolve

Oct 30 by Cassel to St Omer)

Nov 1 to Calais by Ardres) In hour came to chalk pits between St Omer & Recassy have a range of hills to right but at Ardres leave them on left.

*

*At Laken near Brussels use much of the limestone.

No 8 . ' , for building which is got about 5 leagues off It is of a blackish colour hard & full of shining parts ~~mostly fe~~ most of them flat fucets smells hepatic on breaking leaves but little sediment.

[Page 9] List of Specimens

No 1 from hill above Verviers One might distinguish in it 2 distinct substances One looked much like Jetty coal but was very hard This scarcely effervesced The other part was of the same colour with a ~~tight~~ close compact grain but without any shining This last dissolved almost intirely

No 2 Schist near Remigen of a basaltic colour rather gritty to knife but not much

No 3 Schist at Coblentz of a yellowish colour rather softer & less gritty than former

No 4 Paving stone ~~like that of forest of Arden~~ whitish doubtful whether crystallized or cemented sand but I think looks rather more like former

No 5 Between Aix & Maestricht limestone of a yellowish colour but much more like rock limestone than the yellow limestone usually is but perhaps not more so than some of that found in Kent

No 6 Nearer Maestricht Chalk yellow but true chalk & not hard

No 7 Building stone used at Gulphen nearer Maestricht much like Bath stone

No 8 Limestone used for building at Laken near Brussels got about 5 leagues off it is of a blackish colour hard & full of shining parts most of them [Page 10] flat facets smells hepatic on breaking leaves but little sediment.

No 9 From quarries near Fontenoy Of a deep brownish blue pretty hard but remarkably Schistous looking like slate left a moderate quantity of sediment but that which looked most slaty left least

No 10 Stone used for building at Lisle hard purplish black colour close & compact but coarse grain without any tendency to polish Effervesces but not much dissolves

Letter from the Rev. John Michell, Rector of Thornhill, Nr. Dewsbury, in Yorkshire, to Henry Cavendish, dated, Thornhill, 14th Aug. 1788.

(Chatsworth MS. X (b) 15)

[This letter could well be a corollary to the undated journey, and in it Michell emphatically corrects any misunderstanding in Blagden's observations with reference to the yellow limestone, and it will be noted too, that even Cavendish is implicated. The tour is accredited to Blagden, and conceivably undertaken by him in 1788. The M.S. consists of two double folios, 14" x 8¾", with 7 pages of writing.]

[Page 1]

Dear Sir

Some observations, as I returned from London, having occur'd to me with regard to the Northamptonshire, Lincolnshire, &c. yellow limestone (viz Dr. Blagden's, not my my yellow limestone) I take the liberty of communicating them to you, though perhaps hardly worth your attention; I could indeed have wished, I had been able to give them you with more precision. I lodged one night, in my road, at the Royal Oak, a new house built on Greetham Common about 7 or 8 years ago, 96 miles from London, which is in the midst of that set of strata, which constitute the yellow limestone; when walking in the Garden there, I unexpectedly found it to be upon clay, and

& enquiring of the Master of the house about it, I found, that he had been obliged to sink a ditch between three & four feet deep at one side of his Garden, as well as to make two or three drains of about the same depth to carry the water into it, in order to prevent it from being so swampy, as to be unfit for that purpose, & the water at that time stood some inches deep in some parts of this ditch, though it was in the most droughty part of that time, when everything about London was so much burnt up, which was also the case in a good measure, though not quite so much so, about Greetham. I the less expected to find things in this state, the land /Page 2/ hereabout not being low & having a moderate declivity, sufficient, I should have thought, if it had not been retain'd by the clayeyness of the soil, to have carried of the water, even of a wet season.

I also observed lying about two or three small heaps of pebbles, amongst which were some flints, & enquiring of the Master of the house, whence they came, he informed me that they were pick'd up from the plough'd fields, which consisted of the same clay with the Garden: they were lodged, as I understood amongst the clay, being found here & there in digging into it. It was not till after you & Dr. Blagden mention'd your having seen some specimens of chert, at some place on the coast, I think, amongst this set of strata, that I was aware, that any flints were ever found belonging to them, & the flints, I met with at Greetham common, must I suppose be of the same kind with those, you consider'd as chert, though I should rather consider them as flints; for though they are opak/qu/e & had nothing of that horny look, when broken, that the flints from the chalky countries have, yet they have more of the glassy texture & want that appearance of toughness, which the cherts in general have, so that I should not hesitate to call them flints rather than cherts, at the same time I can easily conceive, that our ideas of them may not so far coincide but that you might well enough look on them as belonging to the cherts: I however met with, amongst the rest, two or three flints, that everybody must look on as such, being, when broken, black & horny, & as perfect as the most perfect of the chalk country flints. They were also roundish like those & were covered with a dark brown coat, [Page 3] whereas the others had no coat, nor any appearance of ever having had one, that I could see, being rather angular, and somewhat irregularly shaped.

My Landlord also told me, he had been informed (for he had only kept the Inn a year or two himself) that, when the house was built, they had sunk a Well nine yards deep through this bed of clay, before they came to the stone; the clay may therefore, when compleat very possibly have been of still greater thickness, but I had no opportunity of learning any farther particulars about it. My Landlord also informed me, that he had been told, that in sinking the above Well, they had met with in the clay a few small stragling bits of coal, but nothing, as far as he could make out, from the vague account, he had been able to procure, & which came through three or four hands that seem'd to have any tendency towards a regular stratum; this story however seems to have induced the owner of the estate (Lord Winchelsea, I think) to try for coal somewhere there abouts; for he had had people to bore in search of it, & they had gone to the depth of 130 yards without any success, as I could easily conceive.

This clay did not seem to compose a very uniform stratum, not only consisting of harder & softer parts, but having likewise these flints & pebbles scatter'd through it, in such manner, if I conceived rightly of the matter, as to shew, that though they might perhaps have been formed in it originally, yet supposing this to be the case they must however have been somewhat disturbed from their places after their formation; though I neither saw nor could learn circumstances [Page 4] sufficient to form any probable guess concerning the way, in which these flints, as well as the other pebbles, which seem'd to contain sand & some iron in their composition, were formed, may I not however consider the circumstances & company, in which they are found as rather tending to strengthen my conjecture concerning the origin of flints in general?

Besides this bed of clay of the existence of which I was not aware, before my last return from town, there is another pretty considerable bed of clay (for I think it is not the same, appearing again at another place) which I have often taken notice of, that shews itself in the side of the hill immediately descending towards Grantham, on the East side of it: What is the thickness of this bed, I dont know, but, from what I have been able to learn concerning it, I should suppose it is not less than the other: there are also found in it, in one part of the stratum some cornua ammonis, & in another part some selenites; but these last I pay no great regard to, as they are frequently of a very modern origin, being commonly formed in clay, where some little vitriolic water o[o]zes or trickles out, provided there is a little calcareous matter likewise for it to unite with. There are a great many bricks & Tiles made out of this clay for the use of the town of Grantham, & I imagine, what might otherwise be very well, I think, supposed to be the case, that it is not an accidential mass of Clay in that place only, but part of a Stratum of some extent for I observed some other Brick Kilns, at a mile or two distance, on the side of a hill, at about the same level. Whether there may not [Page 5] be still more beds of clay in some other parts of this set of strata, I dont know, though from these instances & general analogy, it is not very unlikely there should. Almost immediately to the Westward on this side Grantham, we again have clay, which is continued to the top of Gunnerby hill, but which however must no doubt consist in great part of some kind of stone; for it could not otherwise rise so much, as it does, in so short a space, viz. about 70 or 80 yards perpendicular, I apprehend, in the distance of a little more than a mile: there is likewise another set of strata, which form another ridge of lower hills, three or four miles still nearer this way, about Foston: all these probably contain several beds of clay, & under these are found the Lyas, which consists of a great many alternate beds of clay & blue limestone.

I believe, I have formerly mention'd it to yourself & Dr. Blagden; but not recollecting whether I have before insisted so much upon it, as I might have done I shall take this opportunity, which the country I have just been mentioning, suggests, of observing, that to the Westward of all that edge of Dr. Blagden's yellow limestone, next our side of the sets of Strata, which run from North to South through the Island of Great Britain, as far as I am acquainted with them lies the Lyas at no very great distance, though indeed with two or three sets of Strata, viz. those of Gunnerby & Foston, between them: these run into Leicestershire to the South, & to where the Trent falls into the Humber & the upport part of the Humber to the North, the Lyas being the lowest of all these sets of Strata [Page 67 & all of them lying below the yellow limestone in order, but nowhere having any coal near them; whereas our yellow limestone has no Lyas any where under it or near it to the Westward of it, but, on the contrary, everywhere coal very near the Western edge of it all the way from Leicestershire by the edge of Nottinghamshire & Derbyshire, & a long way into Yorkshire, & how much farther I dont for certain know, & in many places, if not every where the coal is found under our yellow limestone, through which they sink in many places in order to come at it.

Since I began to write this letter I received from Mr. Beatson of Rotherham a parcel of the substance, he was mentioning to you: he sent by the person, who brought it to me, an apology for not haing sent it before, & saying at the same time that it was not yet so good a specimen, as he had wished to have sent. As it was directed to me, though it ought perhaps rather to be consider'd as your property, I have taken the liberty of reserving about half of it for myself, which however, if you want any more, than I have sent you, either to make experiments upon, or for any other purpose, I will send you, whenever you please. It seems to be in general a good deal harder than the black lead commonly used for pencils though some of the thin flakes seem to mark pretty well; probably the difference may be owing to too large a quantity of iron contained in it; for it appears by it's applying so very strongly as it does to the magnet to contain a great proportion of that metal. With best respects to yourself & due Comp^{s} to all friends, when you see them particularly those of the Crown & Anchor, & Cat & Bagpipes Clubs,

[Page 7]

I am, Dear Sir,

Your obed. humble Serv

Thornhill

J. Michell

14 Aug.st 1788

Letter from Henry Cavendish to the Rev. John Mitchell
(Chatsworth MS. undated and no reference but found with X (a) MSS.)

[Cavendish's reply bears no date, but it must be assumed that such an acknowledgement was written almost immediately, and on the most friendly terms, in which he gives credit to Blagden, in case their should be any misunderstanding. He therefore proceeds to confirm the yellow limestone view by recording part of their journey together of the previous year, but concedes to Michell that his yellow limestone is distinct from Blagden's. The journey referred to would be the first one in 1787. The MS. consists of 2 double folios, each measuring $12\frac{3}{4}$" x $8^{1}/10$", that is 8 single pages, of which only 6 contain writing.]

[Page 1]

I am much obliged to you and Mr. B[eatson] for the plumbago & to you for your letter.

I have ~~received~~ got some which I received from Wales part of which I think is purer than Mr. Beatson's. But the rest ~~is more~~ consists of ~~more sparkling~~ flakes of a more sparkling nature than Beatsons & less disposed to mark paper. I have also some which I received under the name of sulphur iron. ~~I do not know from what found~~ & which ~~has much~~ is much the same to appearance as the latter part of the Welch specimen. I analysed this & found it to contain more silicious earth than plumbago besides a good deal of iron not so much united ~~to the pl~~ in the state of plumbago but what it would dissolve in acids.

I suppose it must be the yellow limestone about Bridport in which Dr. Bl/agden/ told you we found chert. My-memory-is-by-no means-all too imperfect for me to attempt to describe its appearance appearance to you but whether it ought to be called flint or chert there is a remarkable quantity of it. How far it deserves that name I cannot say but to the best of my rembrance it was of a much coarser grain & had not at all the /Page 2/ appearance of flint but my memory is too imperfect for me to attempt to describe it to you. As the circumstances relating to it are rather remarkable I will mention what we saw of it last year.

On descending the chalk hills between Dorchester & Bridport by the time we got about ½ way to the bottom we found-true-limestone came to the yellow limestone which seemed separated from the chalk only by a thin stratum of clay of no great thickness a few miles further the stone though to appearance much the same was found to be of a silicious nature with very little calcareous matter in it. At Lyme the cliffs are blue clay ' blue Lyas but the top of the hill which we pass over immediately before we come to Lyme consists of gravel composed of this chert & about a mile to the west of Lyme was a hill with a the steep bank of-a-hill towards the sea about the foot of which was blue Lyas with yellow limestone a-mile-to-the west-of-Lyme-consisted-of-yellow-limestone over it mixed with veins of this chert so much like the limestone that one could hardly distinguish them by the eye but it must be observed that this as well as most /of/ the limestone we saw is of a hard compact &

rather brown kind. [Page 3] From hence to ~~near~~ Sidmouth the soil consisteth chiefly of this cherty gravel but the cliffs on each side of Sidmouth consisted of red rock (the sandy kind consisting of thick strata) ~~which~~ only on the east side they were covered ~~with~~ to a great thickness of the same chert gravel as the hill by Lyme. From hence we had red rock & red soil without any chert gravel to Hall down which is a hill extending from a little to the west of Exeter to near Teignmouth & the upper part of this hill consisted of above mentioned chert gravel ~~but the lower part I believe was red rock~~ so that it appears that the limestone of this country is very much mixed with bhert a great deal of which seems to have been reduced to gravel & deposited on strata of older formation & at a great distance from the limestone where it was formed & Besides Halldown the top of which is covered with this matter is I believe intirely separated from the rest of this country by a broad tract of the red rock country. In the cliffs between Minehead & Watchett I saw the red rock lying immediately under the blue lyas.

In digging the tunnel for the canal in Gloucestershire they have found one or more beds of clay between the strata of yellow [limestone] limestone & I believe the chalk is not free from them A little to the west of Dunstable considerable [Page 4] springs of water break out on the N.W. side of the chalk hills about the level of Dunstable. ~~I think it much most likely that~~ I believe you must be right in supposing your yellow limestone ~~as~~ to be separated quite distinct from the other ~~is that as well from the reasons you mention as that it seems separated from the other~~ From what I can learn ~~the~~

I believe N.W. edge of the other ~~lime seemed to run~~ after running from Gunnerby hill on the E side of the Trent & crossing the Humber & runs under the Yorkshire chalk & appears again about Castle Howards & so runs to Scarborough the chalk in that place lapping over or extending further west than the limestone.

Dr. Bl[agden] sent me ~~an~~ the miner[alogical] account of his Journey as far as Paris. From Dieppe where he landed to some miles beyond Rouen it was intirely chalk except the valley of the Seine. ~~He then see~~ He then came upon a pebbly gravelly soil which continued to a little beyond Lizieux where he met the yellow limestone so that he could not properly say where the chalk ended. From thence the yellow limestone continued to a little beyond Bayeux when on descending a hill ~~he found~~ he found the blue clay ~~appeared~~ before he got to the bottom & met a lime kiln where they were burning lime with coal brought from about 2 leagues to west. From thence to St. Lo [Page 5] the soil was at first clayey & afterwards in some places true slate. From between St. Lo & Cherbourg he passed 2 or 3 ridges of hills which were composed chiefly of what he calls silicious stone, but in one place slate & killas. The plain country between these ridges was yellow limestone & blue lyas. The latter they burnt for lime & found it excellent for hardening under water. Some bits of the silicious stone had the appearance of grains of quartz or sand cemented together but not intirely filled up with quartzy matter in other bits the grains were less distinguishable ~~so~~ that they approached more to the jaspar appearance. In his road from Cherbourg to Paris he went back the same way to between Lizieux & Rouen. At Evreux he again came upon the chalk which continued till he came into the valley of the Seine at Mante[s] where he found freestone much like some of the Bath stone but he did not perceive any separation between this & the chalk. On going down into the valley of Passy (between Evreux & Mante[s] he also found this kind of freestone.

The information he received at Paris is remarkable. At Minden the upper stratum consists of millstone like those of Picardy bedded in clay then some sand then the calcarious freestone of which Paris is built about 80 feet thick then a little sand & under that true chalk with fints in it. At Montmatre [Page 6] they have millstone & sand at top & under that alternate layers of Marl & Gipsum. He was much out of order with a fever & Rheumatism at Paris but on the 20 of last month which is the date of my last letter was much better & was setting out for Geneva.

(Chatsworth M.S., undated but after 1793 and
bearing no reference, is part of the
contents of the parcel marked Journeys
of H.C. in which MSS. X (a) are to be found)

[The following summary account could be described as a record of the geological observations of the Strata of England, made by Cavendish and Blagden while on their several excursions, often together, sometimes separately.

There is no direct indication to whom the compilation of this document may be ascribed, or of its date, but references occur to Michell, so that it is probably the work of Henry Cavendish and Blagden, and to places visited in 1793, so that it probably dates from after 1793.

The M.S. shows many corrections written on pieces of paper pasted here and there, which makes transcription difficult. Repetitions have been excluded from the transcription. There are in all 20 numbered pages, with 2 double sheets measuring 12 9/10" x 8 1/10", though one of these pages - page 11 - contains an extension at the top, measuring 6 4/10" x 7½", but no writing on the reverse side. The remaining pages are single leaves, chiefly 9¾" x 6½", with many corrections. The handwriting appears to be that of Henry Cavendish.

The letter 'S', denoting this Summary is used in the Index, Glossary, and Dramatis Personae for purposes of reference/

/Page 1/

The uppermost strata in the island are the chalk & the strata formed from its ruins & under that lies a thick stratum of clay & under that at least in most places is a stratum of sand. The chalk ~~formerly by originally~~ occasionally formed a band occupying all most all the S.E. part of the island ~~but at present it is almost all washed away towards the middle of the~~ On the E this band is bounded on the sea The Western edge of it begins at the N coast of Norfolk & runs by Newmarket Dunstable & Devizes & crosses the west road between Dorchester & Bridport but then instead of going straight to the sea turns sharp to the E & passes by Corf Castle & through the middle of the isle of Wight & from thence it should seem runs under the Channel to the French coast passes between Rouen & Lisieux.

To the S of London the band divides into 2 legs so as to leave a space between them consisting of the lower strata The ~~edge~~ boundary of the space between these legs extends from the sea between Dover & Folkestone & passes between Rochester & Maidstone to Madam scot hill Dorking Farnham Lewis & Beachy head.

In most places the edge of this band both on the western extremity & towards the country comprehended between the legs consists of steep chalk hills without any gravel over them but towards the middle of the band as near London for example the chalk is for the most part ~~almost all~~ intirely washed away & only the flints left which are rounded & broke into pebbles & sand & form the gravel of these countries [Page 2] so that as soon as we dig through the gravel we come to the stratum of clay which lies under the chalk but in general as we approach towards the edge of the band only part of the chalk is washed away so that ~~we fin~~ immediately under the gravel we find chalk & in general the pebbles of the gravel are less round & have more of the appearance of flints than near the middle of the band & near the edge of the band the soil consists in general of chalk hills without any gravel over them & ending steep & abrupt towards the edge ~~of the~~ For the most part also we find no flinty gravel now beyond the end of these hills ~~though their~~ & seldom far beyond them. The flints of the chalk line between the strata & ~~in~~ the upper strata seem to be thinner & to contain more flints between them than the lower. In some places perhaps all the lower strata are of a brownish colour & very thick and are in some places used as building stone. About Dunstable all the ~~chalk of~~ lower tiers of chalk that is all that below the high hills seems of a browner colour than the rest & to contain few or no flints but it is only one or 2 of the lowest strata which are used for building.

About London the chalk is all washed away & in general the uppermost stratum is gravel but in many places particularly the vallies & declivities of the hills the gravel is wanting & the stratum of clay which lies under the chalk comes to the clay. In most places the gravel is covered with a thin coat of brick earth but at Kensington gravel [Page 3] pits & I believe some other places the gravel is covered with a thick stratum of clay.

~~Hampstead High gate Harrow Norwood~~ &

The ~~gre~~ body of Hampstead Highgate Harrow Norwood & I believe almost the hills near London consist of the clay lying under the chalk but their tops consist of gravel or sand On Hampstead heath & I believe at Highgate the gravel is uppermost under that is sand & then comes the clay On Black heath this is also the case & more regularly except that there the chalk is not all washed away so that the chalk comes under the sand.

In many places near London wells are dug to the bottom of the blue clay. As soon as workmen judge by the appearance of the clay that they are near water they bore to the bottom on which the water gushes up with violence & brings up much sand with it which is a proof that a stratum of sand lies under this clay & ~~clay~~ the water must come from the country beyond the chalk hills where this stratum comes to clay & therefore the nearest place from which the water can come is the neighbourhodd of Godstone & Rygate.

In places ~~near the river~~ not much above the level of the river the water in these wells rises to the top & runs over but in high grounds it does not. There is another band of chalk in England which which is also bounded on the E by the sea & the [Page 5] western edge begins about Flamborough head & thence passes a little to the South of Malton from whence it should seem to pass to the NE. part of Lincolnshire & from thence to be lost in the fens but I am very little acquainted with its course in this country. ~~I have been told too that in this~~

~~From P.4~~ In Yorkshire at least in the road from Burlington to York this chalk is white but very hard & contains no flints ~~what~~

~~little~~ the few silicous stones which it does contain seeming to be a soft chert but in Lincolnshire I have been told that is very hard but contains flints & that there is much flinty gravel In the isle of Wight also & Purbeck it is hard but not so hard as that in Yorkshire & contains flints.

Though the communisation of this band of chalk with the southern band cannot be traced as lying under the sea they are in all probability parts of the same band for they both lie over the yellow limestone ~~with a stratum of blue clay under them & the Yorkshire as well as the Southern band~~ with a stratum of blue clay under them & the Yorkshire as well as the Southern band seems to have a bed of sand under the blue clay The most material objection is the want of flints in the Yorkshire chalk but this seems not very material as there ~~seems to be~~ are considerable varieties in different parts of the Southern band & if it is true that the Lincolnshire chalk contains flints would be intirely taken away as I imagine there can be no doubt of the Lincolnshire & Yorkshire chalk being part of the same band.

The Western edge of the ~~Yell~~ band of Yellow limestone begins near Scarborough & from thence runs to Malton & then runs under the chalk but rises again from under it near the Humber & runs [Page 5] at no great distance from the Trent on the east side of it to [Gunnerby] hill between Grantham & Newark. In then runs to Market Harborough & Edge hill to Landsdown & from thence to the Channel between Bridport & Sidmouth.

This limestone is soft & much of it is oolithous most of it is of a yellowish colour some of it is brown ~~A great~~ much of it is blue within side but then those stones which are blue within side are commonly yellow without & in Portland & Purbeck which seem certainly to be a continuation of the same band it is white.

This limestone is of various kinds some is oolithous & soft & of a pale yellow colour Some is of the same colour but much harder & of a close & compact grain though it appears rough on breaking some breaks with a smooth grain & is commonly ~~bluish on the~~ of a bluish colour on the inside & yellow on the outside This kind I have seen chiefly between Bridgewater & Wells & at the tunnel in the Gloucestershire canal & between Daventry & Southam & a great deal is of a dark ~~brown & often of a~~ bluish colour but with a coarse grain & a great deal of a dark brown colour & coarse grain & in Portland & purbeck it is of a coarse grain not oolithous & of a whitish colour without any tendency to yellow & of a less compact grain than most which I have seen except the oolithous kind of the foregoing kinds.

In some pieces ~~of the brown kind~~ I have seen veins of sparry matter but except in these veins few shining particles or [are] found but the limestone near Hythe ~~is of a~~ [Page 6] though doubtless part of the same band is of a closer & more shining grain than any other I have seen though I hardly suppose this would take any polish.

Excepting that near Bridport I have not observed any which contained any flints or other silicious stones in it ~~& on nor have I tried any~~ The few specimens too which I have tried left but little ~~which left much~~ silicious matter behind on dissolving them in acids but the stone near Bridport is mixed with a great deal of chert which frequently has such an appearance as not easily to be distinguished from the limestone & the limestone itself frequently contains much silicious matter. The Purbeck stone also frequently contains much silicious matter but whether it contains chert mixed among it I cannot tell. In some parts of the yellow limestone country the road is mended with gravel such of this gravel as I have examined consists partly of flints & partly of Jaspers both which I suppose must have been washed there from other places & partly of fragments of limestone some rounded into pebbles & some of irregular shapes.

Though there is sufficient proof that in general a stratum of sand is interposed between the blue clay ~~lave~~ below the chalk & the yellow limestone we do not always meet with it in travelling from the chalk to the limestone ~~In going from Dunstable~~ In the road to Northampton ~~Dunstable~~ from the foot of Dunstable hill to Wooburn the soil seems clay & just beyond that place we meet with a ridge of sand hills which I suppose is a continuation of the above mentioned stratum of sand & ~~it is~~ in this stratum are found beds of fullers earth & about Newport pannel [Pagnell] the yellow limestone is found The sands also at [Page 7] Potton near Biggleswade & at Shotover hill near Oxford are most likely of this kind But in the Buckingham road from the foot of the chalk hills near Wendover to the beginning of the yellow limestone at a few miles beyond Aylsbury the soil seems clayey without any sand In descending the chalk hills between Dorchester & Bridport before we get ½ way down the hill we seem to cross a narrow band of clay & immediately come on the yellow limestone & at the Devizes & all places I have seen between that & the above mentioned place we seem to come on the limestone almost immediately on leaving the chalk.

There seems great reason to think that in most places the softer strata where they come to clay are reduced in thickness & frequently intirely disappear owing I suppose partly to their being squeezed out by the incumbent weight & partly to their being washed out by water this is most likely the reason why we see so little clay at this hill & other places where we might expect to see it & shews the very imperfect knowledge of the strata which is to be acquired by merely examining the surface as is my case.

It should seem such accounts as I have seen [Page 8] of the strata found in digging for coal that in the coal countries the quantity of hardend clay or bind as they call it is much superior to that of the argillaceous sandstone but yet in such of these countries as I have travelled over we see little except this stone at the surface which is most likely owing to the above mentioned cause.

Between Hindon & Shaftesbury a large valley extends into the chalk hills to near Salisbury & at Fonthill & I believe most parts of this valley the yellow limestone is found but on each side of it are the chalk hills.

In the country included between the 2 legs of the chalk band the strata are rather different from what they are on the west side of the band for [blank] here the blue clay & sand lie under the chalk as on the other side but under this there comes sandstone of different kinds then a stone composed of sand & calcareous earth & then ~~the yellow~~ at least in some places a limestone which is most likely a continuation of the yellow limestone. In most places at no great distance from the chalk hills & parellel [sic] to them is a ridge of hills consisting of the 3 above mentioned kinds of stone & which have been called the stone hills & beyond these hills is ~~a count-what~~ a country the soil of which consists in general of a mixture [Page 9] of fine sand & clay & is the country which is commonly called the Wilds. It seems most likely however that this soil is not a continuation of any stratum lying under the yellow limestone but is a deposition made since the stone hills were formed.

The truth of the above mentioned order of the strata may be perceived by walking on the beach below the cliffs between the chalk hills and Folkstone. At the end of the chalk hills you see blue clay but on account of the inroads of the sea it is not easy se[e]ing whether it is continued under the chalk On walking towards Folkstone you see the sand lying under the clay & further on you see the sandstone lying under the sand. At Hythe the hill is composed of stone consisting of a mixture of sand & calcareous earth & as the strata dip towards the east we may conclude that this stone lies under the sandstone & a little further to the west is true limestone & under this there seems to lye blue clay. I believe however that ~~many~~ some of these strata and particularly the limestone are frequently wanting.

About Maidstone there is much of the mixed stone & sand between that & the chalk but though I have gone from thence over Cox heath to the foot of the stone hills I could not perceive any true limestone

In the Tunbridge road there is a little sand much sandstone & I believe a little mixed stone but I believe no true limestone. The limestone at Hythe & Ashford was a more ~~of a~~ shining appearance than any of the yellow limestone I have seen & ~~was sand~~ [Page 10] the beds are divided by thin beds of sand which I have no where observed in the true yellow limestone country

At Folkstone the cliffs are of sandstone & part of them is frequently falling or rather sinking into the ground for as between these cliffs & the beach there is a greal deal of broken ground consisting of their ruins theis falling cannot be owing to their being undermined by the sea but must be owing to the giving way of some soft ground which they rest upon accordingly among the ruins of the cliffs may be found patches of blue clay which must be the ground which they rested on & which gave way for it cannot be in this part there is no clay lying over the sandstone so that this clay could not come from anywhere else. This clay was [of] rather a stratified appearance & is mixed with sand but has not the appearance of being remarkably soft but almost any will become soft if springs of water rose through it.

It is uncertain what this stratum of clay is whether it is part of the stratum which lies under the limestone or whether it is not rather a stratum lying between the sandstone & mixed stone. If the former opinion is true it must I think at this place lye some hundred feet below the level of the sea so that one would hardly expect expect that it could either produce the effects or be forced up by the sinking of the cliff so that the latter opinion seems most likely especially as between Sandgate & Hythe that is between the sandstone & mixed stone there seems to be some traces of the blue clay.

At the S end of the isle of Wight & on the E. side of Portland there are similar sinkings of the cliff & which must have proceeded from the same cause. In the isle of Wight the cliffs consist of sandstone lying under the chalk as at Folkstone [Page 11] at Portland it is the yellow limestone resting on the blue clay.

Both the yellow limestone & chalk seem in some places to have thin layers of clay between them. In digging the ~~canal~~ tunnel for the Gloucestershire canal they have found one or more such & Mr. Michell mentioned to me one or 2 which he had met with in the yellow limestone in travelling on the north road & near Dunstable below the Chalk downs but above the lower tier of chalk considerable springs break out which must in all probability be owing to a stratum of clay being interposed between them & the circumstances of springs breaking out on so many different levels on the road to Dunstable & other parts of the chalk countries looks as if there were many such for if there were no beds of clay in the chalk it seems likely that at Market street & Luton & other such places no water should be found either till they got to the bottom of the chalk or till they came to the level of St. Albans or the other low levels at which the water breaks out [Page 11, continued]

On the blue Lyas

Under the yellow limestone lies a bed of blue clay mixed with thin layers of limestone hard & of a smooth compact texture but without any appearance of polish & of a brown colour frequently with a bluish tinge which is called the blue lyas & is excellent for water lime

There can be no doubt of this stratum lying under the limestone for the top of Landsdowne is yellow limestone but before we get to the bottom we meet the blue clay & if I am not mistaken find the Lyas in it. The top of the oliffs too a little to the west of Lyme consist of yellow limestone but the foot of them as well as I could ju/d/ge by viewing from the top consist of blue clay mixed with blue lyas many other proofs too might be produced

The yellow limestone as well as the chalk forms a regular band & the outline of it excepting an irregulum which will soon be taken notice of forms a pretty regular line & in general the strata are not much inclined to the horizon but the red rock & the lower strata are in general more inclined to the horizon & do not form a regular ~~bands~~ outline the coarse of one stratum being frequently interrupted by a lower stratum coming to the clay but for the most part the further we go to the W or N.W. the lower strata we meet with. In general too the lower are more inclined to the horizon than the upper.

On the red rock red schist & Jasper gravel

The red rock is a soft sandstone of the colour of red ochre found in general in very thick beds without many /Page 12/ cracks in them. The red schist lies in thin beds with a schistous appearance & seems argillaceous It is in general of the same colour as the other but frequently contains thin layers of a whitish colour The Jasper gravel is commonly also of the same colour but is sometimes of a yellowish colour

At the cliffs Between Minehead & Watchet we may see the red rock lying immediately under the blue Lyas What is the position of the red schist in respect of the red rock I cannot say but I believe the Jasper gravel where found lies over the red rock for On ascending the hill from Mansfield in the road to Newark we meet red rock & as soon as we get near the top we find this gravel There are some other circumstances also which seem to confirm this opinion. The ~~greatest quantity of~~ place where I have seen most of this gravel is Sherwood Forest. If I am not mistaken too there is a great [quantity] in the neighbourhood of Litchfield but I do not remember to have seen much in the West of England. As well as I remember there are Jasper pebbles thinly interspersed in the substance of the redrock at the Cliffs at Dawlish.

At Nottingham & Warwick & some places near Coventry is a soft sandstone of a whitish colour resembling the red rock except in colour but I am not acquainted with its position in respect of the other strata but as it lies in or in the neighbourhood of the red rock country I have mentioned it in this place

Antient yellow limestone

[Page 13] Mansfield. At Breedon also between Ashby Del Zouch & Derby there is an insulated hill consisting intirely of limestone which in all probability is part of this stratum but I do not know that it is found any where further to the S.W. From the position in which it is found at Mansfield there is great reason to think that it lies under the red rock

On the Coal Strata

These consist of strata of argillaceous stone mixed with strata of hardend clay shale & coal. At Ealand edge is found a hard sandstone used for the footpaths in London. This lies in the middle of the coal country & as Mitchell supposed lies between the coal of Thornhill & Halifax

On the Gritstone

This ~~is composed of~~ differs from other sandstones as it seems composed rather of small fragments of quartz than of sand I have seen it no where except in Derbyshire & between Halifax & Settle in Yorkshire but Whitehurst finds that or something of the kind between the coal & rock limestone at Colebrook dale

On the Shale

I have seen this only in Derbyshire

(from P.12) At Nottingham & Warwick & some places near Coventry is a soft sandstone of a whitish colour resembling the red rock except in colour but I am not acquainted with its position in respect of the other strata but as it lies ~~amongst~~ in or in the neighbourhood of the red country I have mentioned it in this place.

[Page 14] Of the rock limestone & Toadstone

The account of the Toadstone given at the mine at Overton does not quite agree with Whitehurst they say that it has hitherto been found true that when a vein with lead ore is found over it it is found continued with similar lead ore under it but they say that fissures penetrate into the Toadstone but are smaller than in the limestone & that sometimes there is a little lead found in them though trifling This it may be observed does not disagree with Whitehursts theory but if it is found true in other places as well as this it takes away his strongest argument in favour of it but the strongest argument against it is the mouldering nature of the Toadstone for thout it is very hard in the mine yet when exposed to the air most parts of it even the most solid gradually moulder into a kind of clay. In some places this operation goes on very slowly in others very fast There are parts of it which are almost as soft as clay in the mine particularly that which lies between the solid part & the limestone* This disposition to moulder agrees much better with the supposition that it is clay which has heated in its place ~~there~~ as suggested my Michell than with Whitehurst's supposition as we can hardly suppose that lava which had flowed in the manner which he supposes could moulder in the air.

I do not know that the Toadstone is found anywhere except in Derbyshire

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= This is what I was told at Overton but Whitehurst distinguishes this soft part from the Toadstone & considers it is as a different stratum It should seem too that some parts of the Toadstone are not at all disposed to moulder for at Castleton in the way to the Cavern we walk upon some which shews no signs of mouldering.

[Page 15] On the Slate & Killas

In general the substance called Killas in Cornwall is a schistous stone not very hard & not easily distinguishable by its look from the schistous stone of other strata there however are great varieties in it & in some places it is very hard & of a bluish colour but this is commonly called iron stone.

At Tintagel castle in Cornwall we may see pavements of quartz lying in the Killas & I believe it is the same near St. Anstle.

I cannot say anything as to the relative position of the slate & Killas but if one lies regularly over the other which I much doubt I should think the slate was uppermost for near Plymouth we find slate at a very small distance from the limestone. But the granite evidently lies under the killas for in some of the Cornish mines in which the surface is Killas the shafts are continued into the granite.

In Cornwall Is found a kind of stone called Elvin but this I believe is found only in fissures in the granite & Killas but I am not much acquainted with its appearance & I believe there is much variety in it /Page 16/

/Page 16/ On the Strata in the west of England

The whole of Cornwall & the western part of Devonshire is either Slate Killas or granite In Cornwall there are many places in which the granite comes to clay but much the greatest part is Killas. In Devonshire there is little if any granite except on Dartmoor which consists intirely of it but all round the foot is killas. In most parts of Cornwall it should seem that the strata of granite are not very much inclined to the horizon as I should conclude from what I was told of the line separating the granite & killas at these mines & I should suspect the same thing from the position of the stones at the Cheese rings but at Dartmoor there strata must be very much inclined for though the brow of this hill is granite & the descent steep yet the foot is killas.

At the foot of Dartmoor the stone is in general very hard & of the ironstone kind which looks as if that stone lay between the softer killas & the granite but I do not know whether this is the case in other places /Page 17/ ~~found slate almost close to the limestone which looks as if in that place the slat lay over the killas~~.

At /Bridistowe) betwean Launceston & Oakhampton is a quarry of lime-stone lying in beds of no great thickness between beds of argillacerous stone but I ~~do not~~ have not heard of limestone being found anywhere else in this country. The S coast of Devonshire from Plymouth to Teignmouth is rock limestone but ~~I cannot say how far it extends inland~~

~~but-not-so-far~~ except at Chudleigh it no where extends so far inland as the road from Exeter ~~except-at-Chudleigh~~ to Plymouth & none is found N of that so that in the northern part of Devonshire the rock limestone seems wanting & the coal is wanting in all parts for that in the S part we come immediately from rock limestone to red rock & in the N part we come immediately from Killas to red rock. On the S coast from Teignmouth to a little beyond Sidmouth is red rock & I suspect that all the country between Exeter and Axminster & from thence to the yellow limestone of Somersetshire is of that kind ~~but-I-suspect~~ On the N coast the killas continues as far East as Linton where the red rock begins & continues ~~as-far-as~~ to between Minehead & Watchett where the blue Lyas begins, but I believe the red rock does not extend far inland for I take Exmore to be Killas & I suspect Quantock hills to be so also. To P.18

[Page 18] The Western edge of the yellow limestone was before said to pass b~~y-Landsdown~~ near Bath but a little to the South of that is an irregularity caused by Mendip This is a ridge of rock limestone which begins near Wells & from thence extends to Bristol hot wells after which it bends ~~a-lit~~ towards the E & near Wootton under edge approaches near to the yellow limestone & there ends Between the Yellow limestone & this ridge is found red rock & coal as usual but on the other side instead of finding the strata inferior to the rock limestone we again find those superior to it. between Wells & Cross we have yellow limestone at Watchett we have blue lyas & between that & Minehead the red rock begins. Blue lyas is also found on the Welsh coast at Aberthan near Cardiff.

Between Wells & Cross the rock limestone ridge ends with steep hills of true rock limestone but except near the edge of the ridge seems to consist of the rubbish of limestone cemented by calcareous matter & it is in the fissures of this rubbish country that the Calamine is chiefly found.

[Page 19] It was before said that the yellow limestone about Bridport & Lyme contains much chert & accordingly there is much gravel compost & chert found in that neighbourhood ~~near Lyme there is a hill whose top~~ Between Lyme & Sidmouth the red rock country begins Sidmouth stands in a valley between 2 hills ~~the western one consists intirely of red rock & the eastern one~~ ending towards the sea with high cliffs The Western hill consists intirely of red rock & so does the lower part of the eastern but the top consists of chert gravel Halldown also consists of this kind of gravel though it is separated from the rest of this country by a considerable tract of red rock. To P. 20

[Page 20] On the Alum rock & fossil salt

Besides the foregoing there are 2 more strata to be taken notice of but which I have reserved to this place as I do not know where to place them The Alum rock as far as I know is found only in the N.E part of Yorkshire ~~Pickering in the road from York to Whitby stands on the yellow limestone & a few~~ In travelling from York to Whitby a few miles beyond Pickering we leave the yellow limestone & come to a pretty hard argillaceous sandstone as far as I could perceive without the intervention of any other strata It is very possible however that there may be clay & blue lyas between though I did not perceive This stone continues to near Whitby where the Alum rock is found ~~lying immediately under it This consists of~~

~~hardened-clay-interspersed-with-small-grains-of-pyrites-&-perhaps~~ immed[iately] under the sandstone lyes a bed of hard stone much impregnated with iron called Doggers & under this is the alum shale It is only ~~the~~ about 30 yards of the upper part which is worked for alum the lower part being thought not worth working. How deep the Stratum extends is not known The upper part consists of hardened clay mixed with small grains of pyrites & perhaps some other inflammable material as in some places it is so bituminous as to stain the hands with Petroleum The lower part of the rock also contains pyrites but perhaps they are only in detached lumps & not diffused through the mass in small grains as in the upper part.

I do not know the position of the fossil salt but as it is found in the neighbourhood of the redrock & coal it perhaps may lye between these strata.

APPENDIX II

GLOSSARY

The terms here listed are the more uncommon ones to be found in the Cavendish manuscripts which follow; while many of them are peculiar to the context in which they are found, others are well-known. Some of these belong specially to the processes of industry which Cavendish witnessed, having different shades of meaning in different localities, and he describes the terms and expressions in his customary clear style. Where an adequate explanation has been given in the manuscript, attention has been drawn to it. References to the text are indicated in the case of each term, with the same identification marks as those given in the index.

AIR PIPES, '85.17. Ventilating pipes.

Alabaster, '85.18. '87 (i) 28. see Gypsum.

Alembic, '85.48. An apparatus formerly used in distilling, consisting of a concurbit, or gourd-shaped vessel, and the cap or alembic proper, the back of which conveyed the products to the receiver.

Alum, '85.4. '86.1. [stock] '86.6. '88.3. 'S'.20. A well-known crystalline, astringent substance with a sweetish taste, a double sulphate of potassium and aluminium with water of crystallization. It is prepared in Great Britain at Whitby from Alum-slate - where it forms the cliffs for miles - and was once manufactured near Glasgow from bituminous alum-shale and slate-clay, obtained from old coal-pits.

Ammonites, '87 (i) 6. see also Belemnites and Cornua Ammonis. Name given to these fossils from their resemblance to the involuted horn of Jupiter. Ammon. once supposed to be coiled snakes petrified, and hence called snake-stones.

Ancony, '85.54. A bloom wrought in the figure of a flat iron bar ... with two square rough knobs, one at each end. In Glamorganshire they are called blooms. Drawn under the forge hammer into anconies, e.g. at Wilkinson's forge at Broseley. See text.

Annealed, '85.6. Loosely, to cool down from a great heat.

Aqua Fortis, '85.2, 3, 12, 35. '88.3. 1610. The early scientific, and still the popular name of Nitric acid - a powerful solvent and corrosive.

Aqua Regia, '85.3, 34. 1610. A mixture of nitric acid and hydrochloric acid, so called because it can dissolve the 'noble' metals, gold and platinum.

Archall, '85.5. A piece of ground left unworked - a mining term.

Argillaceous, '85.12. '93.7, 8. 'S'.12. Of the nature of clay; largely composed of clay [sandstone] 'S'.8, 20. [Stone] 'S'.13, 17.

BALL, '85.52, 54, 55. see Text.

Basalt, '89.3, 4, 5, 6, 9. A dark-coloured fine-grained rock occurring as a lava, or as an intrusion, often showing columnar structure, as at the Giants' causeway in Northern Ireland, and Fingal's Cave in the Hebrides.

Bath-Stone, Bl's, '87.6. Bl's, '89.7, 9. 'C'.5. A building stone quarried from the oolite formation near Bath.

Belemnites, '86.1. 1646. A fossil common in rocks of the secondary formation. [Cornua Ammonis] 'Ammon's Horn', which the fossil resembles - sometimes called thunderstone.

Bind, 'S'.8. see Hardened clay.

Bituminous, '86.1. Cf the nature of bitumen, originally a kind of mineral pitch found in Palestine and Babylon.

Bivales, '87 (i) 5. Having two valves; a two-hinged shell, e.g. a mussel.

Blooms and Half Blooms, '85.11, 12, 22, 23, 24, 30, 53, 54, 62. To hammer or squeeze the ball or lump of iron from the puddle furnace into a 'bloom'. See also ancony.

Black Lead, 'M'.6. See also plumbago - graphite or plumbago, material for pencils.

Black Stone, '88.12. See Text.

Blue Clay, see clay.

Blue Lyas, 'M'.5. 'C'.2, 3. 'S'.11. [see text] 12, 17, 18, 20.

Bobs, Balance, '87 (ii) 14. 1752. A beam in a pumping engine, a heavy lever ballasted at one end, and attached at the other to the pump rod.

Bobs, T., '87 (ii) 18. A balance bob on the beam of a Newcomen Engine. See Briggin Engine for illustration.

Bohing, '88.10. The process of levelling of a surface.

Boshes, '85.25, 44, 58. The plural form is due to the fact that blast furnaces were formerly of square section, and the 'boshes' were the four sloping walls of the lower portion.

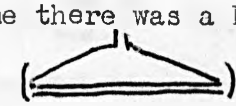
Bosses, '85.17. The enlarged part of a shaft on which a wheel is keyed, or at the end, where it is coupled to another.

Bovey Coal, '87 (ii) 5. A lignite or brown coal of Miocene Age, occurring in beds at Bovey and elsewhere.

Box, '87 (ii) 3, 6. The piston of a pump; the case containing the valve; also the upper part of a pump-stock.

Brick Earth, 'S'.2. Earth or clay suitable for making bricks.

Brick Kilns, 'M'.4. A kiln or furnace for burning bricks.

Briggin Engine, '87 (ii) 18. There was certainly a mine called Briggan, which may have been part of the North Downs mine, and presumably at this time there was a Newcomen Engine with a T bob on it, thus  The reference, therefore, is to the, and not to a Briggan Engine, meaning the engine at the Briggan Mine. Wheal Briggan, which lay to the North of the North Downs Mine, at one time formed part of the main concern. In 1754 there were two Newcomen fire engines at Northdowns, and five in 1787. Presumably therefore, at the time of the visit by Cavendish, one of these, on the Briggan section of the sett, was referred to as 'The Briggin Engine'. [Smiles, Lives of Boulton and Watt, 2nd Edit., p.260.]

Buddle, '87 (ii) 6. See Text. Strictly the buddle is an inclined shallow vat, either stationary, or revolving platform, upon which the ore is concentrated to be washed, by means of running water.

Burnished, '85.35. Made bright and shining; polished, as by friction.

CAKE, '85.55. See Text.

Calamine, 'S'.18. 1601. An ore of zinc in England and France, chiefly applies to the carbonate - $ZnCo_3$, often known as dry-bone.

Calamins, '89.3. [Pits], '87 (i) 7. See Calamine.

Calcareous, '85.12, 13, 30. [Freestone &] '85.1. '87 (i) 2, 4, 7. 'C'.2, 5. [Spar] '87 (ii) 29. '88.1. [Calumnar Cal. Spar] '87 (i) 8. '93.7. [Earth] 'S'.8, 9. [Matter] 'S'.18. 1677. Of the nature of lime - containing lime and limestone.

Calcination, '87 (ii) 23. [Calcine[d]] '86.1, 2. To reduce by fire to calx, [powder], or friable substance.

Cauk, Calk, '88.7. Barytes, Barium sulphate, also known as heavy Spar.
Caulk, The chief source of barium chemicals in industry.

Chafery, '85.10, 11, 23, 53, 54. [Metallurgy] A forge in which iron is re-heated. [1663. Fr. Chauferie]

Chalk, '87 (i) 1, 2. [Yorkshire] '88.5. '89.2. 'S'.1, 2, 3, 4, 6, 9, 11. [Hills] 'S'.1, 7, 8, 9. An opaque white soft earthy limestone which exists in deposits of vast extent and thickness in the South-East of England, and from high cliffs along the sea shore.

Charcoal '87 (ii) 16. '93.7. The black porous pulverizable substance consisting, where pure, wholly of carbon, obtained as the solid residue in the imperfect combustion of wood, bones, and other vegetable or animal matter.

Chert[y], '88.12. '93.2. Bl's, '87 (i) 2, 3, 4.Bl.'87.1. 'M'.2. 'C'.1, 2, 3. 'S'.4, 6, 19. 1679. A flint-like quartz, occurring in strata, hornstone. Also applied to various impure silicious rocks, including the Jaspers, hence cherty. [chert gravel] 'S'.19.

Cinders, '85.51. See Text.

Clay, [white] '87 (i) 4, 5. [yellowish grey], '87 (ii) 28. [Wedgwood's], '87 (i) 6. [refractory] '85.30. [claystone], '85.12, 13, 18, 58. '87 (ii) 28. '88.3, 7. [indurated or hardened], '85.18. '87 (i) 3, 8. Bl's, '87.1, 2, 3. '88.4. '87 (ii) 7, 28, 30. 'M'.1, 3, 4, 5. 'S'.8, 13. [clayeyness] 'M'.2. 'C'.3. 'S'.7. [blue], 'C'.2. 'S'.3, 4, 6, 8, 9, 10, 11. [see also Bind] [Mr. Praid's clay] see Dramatis Personae. A very stiff viscous earth found in many varieties in beds or other deposits near the surface of the ground, and at various depths below it. It forms with water a tenacious paste capable of being moulded into any shape, which hardens when dried, and forms the material of bricks, tiles, pottery, and 'earthenware' generally.

Coal Tar, '85.47. A thick black viscid liquid, which is one of the products of the destructive distillation of bituminous coal. It is an compound of many different substances chiefly hydro-carbons, and of its constituents are obtained paraffin, naptha, benzene, creosote, the aniline, or coal-tar colours, etc.

Cochineal, '85.4. Dried bodies of insect reared on Cactus in Mexico, West Indies, etc., - used for making scarlet dye and carmine.

Cockle, '87 (ii) 10. The English name of bivalve molluscs, common on sandy coasts, and much used for food. Formerly applied more vaguely, including other bivalves. [See also shŏrl].

Cold Short, '85.55, 58. See Text.

Coolers, '86.3, 5, 6. A vessel in which anything is cooled.

Copper Black, '87 (ii) 24. Unrefined copper after smelting.

Cornish Mines, 'S'.15. See Mines.

Cornua Ammonis, '86.1. Bl's, '87.4. 'M'.4. See Ammonities.

Crop, The, '85.1. See Text.

Culm, '87 (ii) 16, 17. A small, non-bituminous, free-burning coal, subject to much lower duty [imposts] than coal. Trades using it benefited. [SeeJohn, A. H., Ind. Rev. of S. Wales, p.115.]

Cushats, '88.13. See Text.

DEADS, See Text, '87 (ii) 2. '88.10. '93.5. Useless stone from a vein or working, usually stacked in abandoned workings, often on timber platforms, which are now dangerously unstable.

Desses, '86.1. 1552 - a dais, 1596 - desk. 1788. To dess up, to pile up neatly. [Provincialisms of E. Yorks., Marshall]. To arrange in a layer or layers; to pile up in layers. [1855. Robinson, Whitby Gloss. dess'd up, piled up].

Dirt Band, '88.13. See Text.

Dogger, '86.1. 'S'.20. A kind of ironstone - a stone strongly impregnated with iron. [see Text]

Drag, '87 (ii) 20. 'Put on the drag' - 'Put on the brakes' - to check [see Text]

Drawn Solid, '87 (ii) 19. When a pump sucks in air, it is said not to draw solid.

ELVAN, '87 (ii) 10, 11, 13, 14, 19, 20. [Elvin] 'S'.15. 1791. The Cornish for intrusive rocks of igneous origin, such as quartz-porphyry, whinstone, etc. [see Text]

Explosion, '88.11. [see Text].

FACETS, FLAT, Bl's, '89, 8, 9. One of the sides of a body that has numerous faces; originally one of the small cut and polished faces of a diamond, or other gem, but subsequently extended to a similar face in any natural or artificial body. In this case, flat.

Feldspar, Bl's, '89.1. A name given to a group of minerals, especially potassium aluminium silicate, usually white or flesh-coloured, occurring in crystals and in granite, and other primary rocks; used in ceramic and enamelling processes.

Filagree, '85.35. Ornamental work of fine gold or silver wire formed into delicate tracery; fine metal open work; anything delicate, light, showy, and frail.

Finery, '85.10, 12, 21, 23, 42, 43, 44, 50, 59. 1607. A hearth where cast iron is made malleable, or in which steel is made from pig-iron, also the action of refining iron.

Fissures, '87 (ii) 21. '88.3, 7, 12. 'S'.14, 18. Cracks or joints in the rocks, either open or filled with loose stones.

Flagstone, '88.8. A flag or flat stone suitable for paving, etc, hence often in plural meaning pavement - sandstone capable of being split up into flags.

Flatting Mills, '85.8. A mill for the process of rolling metal into plates.

Flint, '88.5. '93.1, 2, 8, 9. Bl's, '89.2, 3, 7. [Pebbles] '93.1. Bl's, '89.2. [Flinty] '85.40. 'M'.2, 3, 4. 'C'.1, 2, 5. 'S'.1, 2, 4, 6. [Gravel] 'S'.2. Hardstone of nearly pure silica, found in roundish nodules - hard ore.

Flookam, '87 (ii) 21. 1728. [Mining] A cross course or transverse vein composed of clay - also a sort of clayey substance, often found against the walls of a quartz reef and accompanying cross-spurs or slides.

Fluorspar, '87 (ii) 16. 1794. Native fluoride of calcium (CaF_2) found abundantly in Derbyshire, and often called Derbyshire spar. Widely used as a flux in blast furnaces, and as a source of fluorine in chemical industry, Also used for special glasses and ceramics.

Forms, '87 (ii) 24, 25. See Text.

Freestone, '85.1, 2. 'C'.5. Any fine-grained sandstone or limestone that can be cut or sawn easily - a slab of such stone. The reference, ('85.2.) in the Index of Placenames is probably to the hills composed of such stone.

French Circle, Bl's, '87.2, 3. [See Cassini, and Chev De Borda in Dramatis Personae.]

Fullers Earth, 'S'.6. A hydrous silicate of Alumina, used in cleansing cloth. In geology a group of strata characterized by the presence of this earth. There are extensive beds of this earth in the southern English counties, and the name has been given to a stage in the Middle Jurassic series.

Furnace [Blast] '93.6. 1697. That used in iron smelting. [Cupola]

'93.5, 6. A furnace for melting metals for casting. [Wind] '85.50, 51, 59. [Blowing] '87 (ii) 16, 17. A blast furnace e.g. used in glass-making. [Tapping] '85.16, 17, 28. [Charging] '85.51. Se Text. [Drawing] '85.51, 53. See Text.

Fusees, '87 (ii) 13, 20. [Fr. fusée] primarily, a spindle of tow, hence used for spindle. A conical pulley or wheel on which the rope was wound. In a watch or clock it is the wheel on which the chain is wound, and by which the power of the mainspring is equalized.

GALLIARDS, '88.6, 13. Hard rocking stone.

Granite, '87 (i) 6. '87 (ii) 15. '88.6. 'S'.15, 16. 1646. A granular crystalline rock, consisting of quartz, ortho close, feldspar and mica, and usually light grey, white or light red in colour.

Gravel, '88.5. 'C'.3, 4. 'S'.1, 2, 3, 6, 19. [Flinty] 'S'.2, 4. 'S'.2, 4. A material consisting of coarse and water-worn stones of various sizes, often with a slight intermixture of clay, much used for laying roads and paths.

Greyish, '87 (i) 5. Somewhat grey.

Grindstones, '93.4. A millstone. A disc of stone of considerable thickness, revolving on an axle, and used for grinding, sharpening or polishing.

Gritstone, '88.6, 7. '93.5. Coarse sandstone, especially of the kinds used for millstones and grindstones. The loose stones near the summit [of Ingleborough] the people call greet-stones. [1761. Nat. Hist. in Ann. Reg. 100/2]

Growan, '87 (ii) 15, 20, 21. [Clay] '87 (ii) 10. 1753. Granite or moorstone - a soft decomposed granite, overlying the veins of tin in Cornwall - often mixed with clay.

Gypsum, or Alabaster, '85.18. '87 (i) 28. '93.4. 'C'.6. 1646. Hydrous Calcium Sulphate - the mineral from which plaster of Paris is made. See also Selenites.

HÆMATITES, '85.35. '87 (i) 22. '87 (ii) 21. Bl's, '89.5. A blood-like stone - a widely distributed iron ore, recurring in crystalline, massive or granular forms; in colour red, reddish-brown, or blackish with a red streak.

Hardstone, '88.4. See Text.

Heat, '85.38. [sensible - latent] In physics, the heat, required to convert a solid into liquid or vapour, or a liquid into vapour; which as it does not raise the temperature and so become sensible to the touch as warmth, was regarded as being absorbed, and remaining latent in the resulting liquid or vapour.

Hellot (Mordant), '85.4. See Mordant.

Hepar Sulphuris, '85.48. Hepar is an old name for a metallic sulphide, having a reddish-brown or liver-colour, formerly called hepars, or livers of sulphur. The name commonly given in homeopathy to calcium sulphide.

Hepatic (Shells), Bl's, '89.8, 9. Of or pertaining to the liver.

Hog's Back, '85.40. A seam of coal. See Text.

Hydrochloric Acid, see Spirits of Salts.

INTERSTICES, '87 (ii) 17. Minute spaces between things or the parts of a body; a narrow opening, chink or crevice.

Iron, '85.14, 15. Mottled, Dark-grey, Bright-grey [see Text]

Ironstone, '85.13. '87 (i) 6. '87 (ii) 11. Bl's, '89.1. 'S'.15, 16. Iron ore containing mixtures of silica, clay, etc.

JAPANNING, '87 (ii) 24. See Text.

Jaspers, '88.1, 4. '93, 3, 8, 9. Bl's, '89.3. [Quartz] 'C'.5. 'S'.6. [Gravel] 11, 12. [Pebbles] 'S'.12. A kind of precious stone. Now, an opaque crypto-crystalline variety of quartz of various colours, usually red, yellow or brown, due mostly to the presence of iron oxide.

Jettee, Bl's, '87.2, 3. A term employed to denote any structure which projects abruptly from a landline into the water.

KELP, '86, 3, 4, 5, 6. Bl's, '87.2. [Orkney] '86.4. Solution of potash [of unknown origin] Collective name for large sea-weeds which are burnt for the sake of the substance found in the ashes.

Killas, '87 (i) 5, 6. '87 (ii) 1, 2, 10, 11, 15, 20, 26, 27, 28. 'C'.5. 'S'.15, 16, 17. 1674. Cornish clay-slate. Geologically the clay slate of Cornwall of Devonian Age, which rests on the granite.

Kish, '88.9, 10. A form of impure graphite which separates from certain kinds of iron in process of melting.

Knobs, '87 (ii) 25. See Text. [See Ancony]

LAPIS CULAMINARIS, '85.7. Bl's, '89.2. Calamine [Min.] an ore of zinc.

Lava, 'S'.14. A stream of molten rock issuing from the crater of a volcano, or from the fissures in the earth. The substance that results from the cooling of the molten rock.

Lead ore, 'S'.14. The most important of all the ores of lead is the sulphide, also known as galena.

Ley, '86.4. [Lee] Sediment, e.g. from wine.

Lime, [with coal] 'C'. 4. [Kiln] 'C'. 4. Ordinary lime, or quick-lime, is manufactured on a large scale by burning chalk or limestone. The operation is conducted in brickwork kilns, the lumps of limestone being mixed with coal, or other combustible material.

Limestone [Rock], '87 (i) 4, 5, 7, 8. '88.6. Bl's, '87.6. 'S'.13, 14, 17, 18. [Kentish] Bl's, '89.7. '93.2, 7, 8, 9. Bl's, '89.1, 2, 8, 9. Bl's, '87.1. '88.1, 2, 7. 'C'.3. 'S'.5, 6, 10, 13, 14, 15, 17. [Breedon] '93.4. [Blue] M.5. [True] 'S'.9. Limestone is one of the various forms in which calcium carbonate (carbonate of lime) occurs naturally. Limestone belongs to what are termed the sedimentary rocks, and for the most part owes its origin to the deposition of the remains of sea organisms on old ocean beds. In many cases well-preserved marine shells and skeletons of marine organisms are found embedded in the limestone (fossils). Limestones are very common, and form enormous rock masses on the surface of the earth. Varieties of limestone are: (1) chalk, a white earthy rock, which occurs in thick beds in the south of England, and (2) oolite or roestone, a white or yellow granular rock mass, which forms part of the Jurassic beds of the Midlands, and eastern portions of England. See also yellow limestone.

Lixiviation, '86.2. Purification, filtering, leaching.

Load [Lode], '87 (ii) 1, 11, 14, 15, 19, 21, 22, 23. 1602. A vein of metal ore. See Text.

Lozenged Surfaces, '85.7. A lozenged shaped facet of a precious stone - resembling a rhombus.

Lyas, see Blue Lyas.

MAGGOT ENDS, '85.54. See Text.

Magma, '86.6. 1681. Any crude mixture or organic matters in the state of a thin paste. The dregs that remain from a semi-liquid substance after the liquid part has been removed by pressure or evaporation. 1856. Like curds and whey. See Text.

Marble, '88.3. Bl's, '87.4. Bl's, '89.1. In the geological sense it is strictly a limestone which has been re-crystallized by the subsequent application of heat and pressure. Commercially the word 'marble' is applied to any limestone which will take a polish.

Marl, '87 (ii) 29. 'C'.6. A kind of soil consisting principally of clay mixed with carbonate of lime, forming a loose unconsolidated mass, valuable as a fertilizer. Also, marl-stone, argillaceous and ferruginous limestone, which lies between the upper and lower Lias of England.

Matrix /Quartz and Killas/, '87 (ii) 11, 15, 16. Bl's, '89.3.
1641. The earth or strong matter, the matrix in which an ore is found. An embedding or enclosing mass, especially the rock-mass surrounding metal, fossils, gems and the like. /See gangue - the waste minerals found with the ore./

Metalline, '87 (ii)24. adj. of metal.

Mica, '87 (ii) 10. Bl's, '89.6. A small plate of Talc, Selenite, or other glistening crystalline substance found in granite and other rocks.

Millstone, 'C'.5, 6. A stone used for grinding grain.

Mine, '85.58. '88.5. Sorts of ore.

Milnes, '87 (ii). Polgooth, 1, 7, 10. Chace Water, 11, 13. Poldyce, 14. Northdown, 18. Wheal Virgin, 19. United, 20. Tresivane, 20. Cook's Kitchin, 21. Gregory's, (Derby), 2. Dolcooth, 21. '88.11, Cankwell, (Derby). Cockwell, at Mill Town, Nr. Ashover, Derbys. /See J. Farey Senr. Survey of Derbys. Vol. I, p.256./

Moorstone, '87 (ii) 10, 21. 1698. A slab of granite found chiefly in Cornwall. See Text.

Mordant, '85.4. 1791. In dyeing, a substance used for dixing colouring matters on stuffs.

Mosses, '85.23. Refute matter ... which collects at the bottom of the Chafery.

Mothers, '86.3, 5, 6. 1611. Liquid left after crystallization, e.g. sea-salt: Mother liquor - water. The mother liquor of the rock-allum is called 'tun-liquor'. /1853, Ure. Dict. Arts., I, 57/. After the 16th C. applied chiefly to the scum rising to the surface of fermenting liquors.

Mountain Wine, '85.48. A variety of Malaga wine, made from grapes grown on the mountains.

Mundic, '85.2. '87 (ii) 5. 1671. Cornish miners' name for pyrites.

NITROUS AIR, '85.3. 1784. An epithet applied to the air, on the supposition that it was charged with particles of nitre.

Nodule, '86.1. [Min. and Geol.] A small rounded lump of some mineral or earthy substance.

Nuts, '87 (ii) 7. Small lumps of a mineral, e.g. coal.

OAKUM, '85.48. The coarse part of the flax separated in hackling. Loose fibre obtained by untwisting and picking old rope, and used especially in caulking.

Ochre [Red], '87 (ii) 21. [Hard], Bl's, '87.7. [Iron], Bl's, '89.5. A native earth, or class of earths, consisting of a mixture of hydrated oxide of iron, with varying proportions of clay in impalpable sub-division, varying in colour from light-yellow to deep orange or brown.

Off-sets, '87 (ii) 3. See Text.

Oolithous, Bl's, '89.6. 'S'.5. A species of limestone composed of globules clustered together, commonly cemented by calcium carbonate. What is known as the oolite, or oölitic series of rocks in geology consists of a series of strata comprehending a number of oölitic limestones, calcareous sandstones, marl, etc. which underlie the cretaceous strata and rest on the Lyas.

Ore, '85.40, 46. [White flats, pinny, flinty and ball] '87 (ii) 11. [Yellow Copper ore] 'S'.14. [Lead]. The valuable mineral from which a metal can be extracted. Flinty, is derived from flint; hard stone of nearly pure silica found in roundish nodules. In Derbyshire the word ore refers only to lead ore, galena.

Osier Frame, '85.4. See Text.

PAVEMENT or PAVING STONE, '87 (i) 3, 6. '87 (ii) 25. '93.2. [Blue] Bl's, '87.3. Bl's, '89.1, 5. 'S'.15. A piece of paved work, a paved surface. Stone prepared for paving. See also Flagstone.

Pebbles, '88.1, 2, 7. 'M'.2, 3, 4. 'C'.4. 'S'.1, 2, 6. Stones worn and rounded by natural action.

Petrifactions, 'Bl's, '87.3, 4, 5. Bl's,'89.6, 7. relics of the past, e.g. fossils, remains.

Petroleum, '86.1. 'S'.20. A mineral oil, varying from light yellow to dark brown, or black, occurring in rocks or on the surface of water in various parts of the world.

Pig, '85.12, 17, 29, 43, 59. '88.9. 1805. The side gutter for the molten iron. Applied to the moulds or channels in a pig bar.

Pitch [Lord Dundonald's] '85.48. See under Lord Dundonald Dramatis Personae.

Planetarium or [Revolvers] '87 (ii) 12. 1713. A model representing the planetary system [an orrery, named after Charles Boyle, Earl of Orrery,, for whom one was made]. It is a piece of mechanism devised to represent the motions of the planets about the sun, by means of clockwork.

The word is used here to represent a similar kind of mechanical motion.

Plumbago, '88.9. 'M'.6. 'C'.1. A species of lead ore. [Min.] Black lead or graphite; one of the allotropic forms of carbon; used for pencils, also mixed with clay, for making crucibles, and for many other purposes. The term plumbago is largely used in the arts, especially in mining. See also Black Lead.

Plum Pudding Stones, '85.18, 32. [Geol.] A term applied originally to a conglomerate of flint pebbles embedded in a siliceo-calcareous matrix, now applied loosely to any conglomerate.

Potsherds, '85.39. Now somewhat archaic. A fragment of a broken earthenware pot ; a broken piece of earthenware.

Potting, '85.54, 60. See Text.

Praid's, Mr, Clay, '87 (ii) 17. See Dramatis Personae.

Pumps, '87 (ii) 3. [Forcing and Sucking] Now a generic term for a great variety of machines, or mechanical devices for the moving or raising of liquids, and are so named according to their principle, e.g. a force pump or a suction pump.

Pyrites, '86.1. '88.14. 'S'.20. [Latin, Firestone], The double sulphide of copper and iron. [Cu_2S. Fe_2S_3]

QUARTZ [Granulated] '85.32. [White] '87 (i) 6. '87 (ii) 1, 10, 11, 13, 15, 20, 25. [Quartoze, Adj.] '87 (ii) 16. Bl's, '89.1, 2, 3, 5. 'S'.13, 15. A widely diffused mineral, massive or crystallizing in hexagonal prisms.

RAGSTONE, '88.6. A black slaty stone - a large coarse roofing slate. Name given in various parts of England to certain kinds of stone, chiefly hard coarse texture, and breaking up in flat pieces, several inches thick.

Racked, '87 (ii) 17. Drawn off or emptied by racking. See Text.

Refraction, Bl's, '87.2. Dispersion - the effect of the atmosphere in making terrestrial objects appear higher than they are.

Red Ochre, 'S'.11. See Ochre in Text.

Red Schist, 'S'.11, 12. See Schist.

Red Short, '85.55. Of iron, brittle while in a red-hot condition owing to excess of sulphur in the metal.

Red Rock, '87 (i) 3, 4. '87 (ii) 28, 29. '93, 2, 3, 8. 'C'.3. 'S'.11. [explanation] 12, 17, 18, 19.

Red Soil, '93.3, 4, 5. '88.1. Sandy or clayey soil of a reddish colour.

Regulus, '87 (ii) 23, 24. The purer or metallic part of a mineral which sinks to the bottom of a crucible or furnace, and is thus separated from the remaining matter. A product of the smelting of various ores such as copper, lead and silver, consisting of metal in a still impure state. See Text.

Reverberatory, Furnace, '87 (ii) 17, 22, 23. A furnace kiln etc., so constructed that the flame is forced back upon the substance exposed to it. The furnace has a shallow hearth, and low arched roof from which the heat contained in the products of combustion is reflected or 'reverberated' on to the charge.

Revolvers, '87 (ii) 12. 1769. To move round again, in various senses. See Text.

Rider, '88.11. A stone lying between a small vein which has separated from the larger one, and lives by the side of it. The stone which is in the middle is called the 'rider'. Also known as a 'horse'.

Roached, '86.4, 5. See Text.

Roasting and Washing Copper, '87 (ii) 12. See Text.

Rolling Mill, '85.61. A mill or powerful machine in or by which metal etc. is rolled out or flattened.

Rubbish, '87 (i) 3, 4, 8. 'S'.18. Any dross or rubble.

SANDSTONE, '88.3. /Yellow/ 5. /Whitish/ '93.3, 4, 7. /Clayey/ '88.2. 'S'.8, 9, 10, 12, 13. A rock composed of consolidated sand.

Scar Blue, '88.3. A rock, crag.

Schist, Bl's, '89.1, 2, 3, 4, 5, 6, 9. /Schistous/ Bl's, '89.1, 3, 5, 6. '93.3, 4, 5. 'S'.12. /Stone/ 'S'.15. 1793. A crystalline rock whose component minerals are arranged in a more or less parallel form.

Scooped, '86.6. To hollow out with a scoop. To form a concavity or depression in.

Scoriae, '85.10, 12, 21, 22, 23, 28, 52, 54, 55, 60. '87 (ii) 23, 24. The slag or dross remaining after the smelting out of a metal from its ore.

Seat Earth, '88.13, 14. One of the various names applied to the bed underlying a coal seam.

Selenites, 'M'.4. A transparent variety of Gypsum. Stucco, Plaster of Paris ($CaSo_4 . 2H_2O$) [Webels Technical Dict. Ger./Eng. 1930, p.558] See also Gypsum.

Settler, '86, 3, 4. 1674. A pan or vat into which a liquor is run off to 'settle' or 'deposit' - a sediment.

Shale, '86.1. '88.3, 13, 'S'.13. Very fine grained laminated sedimentary rock consisting of consolidated mud or clay. Hard slaty matter.

Shell, '87 (ii) 26. See Text.

Shingling, '85.50. [Furnace] '85.46, 50, 54, 55, 60. To subject the puddled ball to pressure and blows from a hammer, so as to expel impurities. Hence shingler, one who, or a machine which, shingles puddled iron. To distinguish between good and bad quality iron.

Shörl, '87 (ii) 10. Bits of cockle. See Cockle.

Silicious, Bl's, '87.1. 'C'.1, 2, 5. 'S'.4, 6. Of the nature of Silica - an important mineral substance [the double oxide of silicon] which in the form of quartz enters into the composition of many rocks.

Skim[m]ed, '87 (ii) 16. Cleared of impurities by skimming.

Slag, '87 (ii) 17, 23. '93.6. The waste material produced during smelting, e.g. lead ore. A rough clinker like lump of lava [vitrified] A vitreous substance, composed of earthy or refuse matter which is separated from metals in the process of smelting [unvitrified]

Slam, '86.3, 6. Sediment. Refuse matter separated from Alum in its preparation.

Slate, '88.6, 7. Bl's, '89.2, 5, 6, 8. 'C'.5. 'S'.15, 16. An argillaceous rock of sedimentary origin, the different varieties of which have the common property of splitting readily into thin plates.

Sleek, '88.11. [Sleekery or Slickensides]. These are the sides or partitions, into which the ore is divided. Slickensides - the shiny, grooved surfaces produced by movements of the strata along geological faults. Sometimes still in a state of stress, and liable to explode on being disturbed by mining.

Slime Tin, '87 (ii) 6. Finely crushed or powdered metallic ore in the form of mud.

Slips, '85.19. 1640. A semi-liquid material, made of finely ground clay or flint, etc. Mixed with water to about the consistency of cream, and used for making, cementing, coating, or decorating pottery, etc.

Slit-Rods, '85.7. 1522. To cut [iron] into rods, or [wood] into thin deals. 1611. Divided by slitting.

Slitting Mills, '85.7, 61, 62. [Metallurgy] A mill or machine by which iron bars or plates are slit into nail-rods.

Slogs, '87 (ii) 16. See Text.

Smelting House, '87 (ii) 16, 17. The place for extracting the lead metal from the ore.

Sodder, '85.35. Dialect for solder.

Sow, '85.16. One of the larger channels, or the main channel, in the hearth of an iron-smelting furnace, serving as a feeder to the smaller channels, or 'pigs'. 1843. The middle gutter for molten iron.

Spar, '88.12. A collective term for the crystalline minerals found with lead ore; variously applied to fluorspar, barytes (heavy spar), calcite (calc-spar).

Spirits, '85.4, 5. 1700. Frequently plural, especially in later use. 1875. Dyeing. Any of various solutions used as mordants.

Spirits of Salts, '85.19. '93.13. Hydrochloric acid. Still the standard test for limestone. See also Aqua Regia.

Stampers, '85.46, 50, 55. '87 (ii) 4, 16. 1483. Each of the pestles in a crushing or pounding machine, especially in a stamping mill. See Text.

Steps, '93.5. - in mine workings.

Stone Hills, 'S'.8, 9. Hills containing the three kinds of stone, yellow limestone, chalk and sandstone.

Stoops, '87 (ii) 2. See Text.

Stream Work, '87 (ii) 1, 7. See Text.

Sulphur Iron, 'C'.1. When super-carbonated crude iron is run from the furnace, it is frequently covered with a scurf, which is found to be a coating of plumbago, and it is said that the iron is sulphury. [see 1799 Mushet in Phil. Mag. iv 381 note]

TALC, '93, 14. A soft, translucent, white, green or grey mineral [a hydrated magnesium silicate] with greasy feel and shining lustre, frequently occurring in broad flat plates, and used in making soap, toilet powder, paper lubricants, etc.

In popular or commercial use known as mica.

Tartar, '85.4, 5. A generic name for salts of tartaric acid. Commercially, applied not to the argol or original deposit, but to a product that has undergone partial purification.

T-Bobs, See Briggin Engine.

Temp-Stone, '85.16, 24. See Text.

Toadstone, '88.11. '93.5. 'S'.14. A collective name for several types of basaltic volcanic rock. It may be compact basalt, or may have vesicles (gas-bubble cavities), or may be decomposed to a green clay, or may be rubbly volcanic ash.

Tun Bottoms, '86.6. A large cask or barrel, usually for liquids, especially wine, beer, etc.

Turbid, '85.3. Of liquids - thick or opaque with suspended matter, not clear, cloudy,, muddy.

Turmeric, '85.5. East Indian herb of ginger family: pungent aromatic root [Curcuma Domestica] stock of this, especially chief ingredient in curry powder, as yellow dye - unsized paper tinged with turmic solution and used as a test for alkalis, which turn from yellow to brown.

VEIN, '88.11. 'C'.2. 'S'.5, 14. The body of minerals enclosed by rock. Line of deposit of mineral or earthy matter.

Vernier, Bl's, '87.2. [Pierre Vernier - 1580-1607 - French mathematician] Short graduated scale sliding along fixed scale, for measuring fractional parts of divisions of larger scale.

Vitrified, '85.52, 54. '87 (ii) 14. '93.6. Converted into glass or a glassy substance by exposure to heat; rendered glassy glazed.

Vitriolic Water, 'M'.4. Of or belonging to vitriol, having the nature or qualities of vitriol; impregnated with vitriol. Vitriol is one or other of various native or artificial sulphates of metals used in the arts of medicinally especially sulphate of Iron [green], copper [blue], cobalt [red], zinc [white].

Volatile Alkali, '85.45. Ammonia.

WATERS, '85.49. See Text.

Water Regulator, '85.58. [1825 J. Nicholson. Oper. Mech. 332] The water regulator consists of a large cistern, in which another of less area and capacity is inverted.

Weather Grey, '93.1. e.g. grey weather stones.

Wem, '87 (ii) 9, 20. A windless, a contrivance for raising a bucket from a well.

Windsor Bricks, '87 (ii) 7. A kind of red-fire resisting brick formerly at Hedgerley, nr. Windsor.

Wolfram, '87 (ii) 15. 1757. A native tungstate of iron and manganese.

YELLOW LIMESTONE, '87 (i) 1-4, 8. '87 (ii) 30. '88.1-3, 5, 8. '93.1-3, 8. Bl's, '87.1, 2, 4. 5. Bl's, '89.3, 6, 7. 'M', 1, 5, 6. 'C'.1, 2, 4. 'S'.4, 6-11, 17-20. [Antient] 'S'.12. In names of minerals denoting the presence of calcium or feldspar.

ZEOLITE, Bl's, '89.4. Generic name for a large and varied group of minerals, consisting of hydrous silicates in which the bases are alumina, and the alkalies, and alkaline earths; generally characterized by swelling up and fusing to a glass or enamel before the blow pipe, and often by gelatinizing with acids; commonly found in the cavities of igneous rocks.

APPENDIX III

DRAMATIS PERSONAE

A brief explanation is given here of persons named, with a reference to the document in which they are mentioned, in Appendix I.

MR. BACON. '85, p.29.

Anthony Bacon (1717?-1786) was the real originator of the pre-eminence of Merthyr Tydfil as the iron smelting centre of Great Britain. He converted it from a hamlet, to a flourishing manufacturing town, establishing a family concern of iron-masters and colliery proprietors at Cyfarthfa. When he died in 1786, he was considered to be one of the wealthiest men in Britain at the time. Little was known of his parentage and upbringing, apart from the tradition that he was descended from Nicholas Bacon, the elder brother of Sir Francis Bacon, Baron Verulam.(1)

MR. BEATSON. 'M', 6, 'C', 1.

Robert Beatson (1750-1790) belonged to a well-known family of Beatsons, of Bentley Grange, near Emley, not far from Dewsbury. The family fortunes are fully recorded in a book written by Miss Jane Beatson of Cawthorne, and is known as 'Jane Beatson's Book'. It was

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1. D.N.B.

A. H. John, The Industrial Development of South Wales (1750-1850), (1950), pp.24-25. See F.N. (1) p.378.

in 1783 that the name of Beatson became associated with the old industrial firm of Rotherham Glasshouse through William and Robert Beatson who had together, acquired the business. William and Robert were both cousins, and brothers-in-law, by virtue of two branches of the family coming together in the marriage of Robert to Williams' sister, Ann, in 1778, while 'Jane' was William's Aunt. The partnership which began with these two men in founding the famous firm of glass-makers still bears the name today. Robert died in the summer of 1790, and William was left in sole charge of the firm, but Robert was the scientist, and the one most likely to be the Mr. Beatson referred to in the correspondence between Michell and Cavendish.(1)

MR. BIRCH. '85, p.25.

Anthony Bacon, the great iron-master, had brought a family, father and three sons, called Homfray, from Stourbridge, into South Wales in 1782, and to them he leased the Cyfarthfa Furnace. Pre-eminent in the family was Jeremiah, the most ambitious of the three sons. He entered into various partnerships for personal advancement, and in 1801, he and James Birch, an engineer, established the Abernant Works, of which Birch became manager.(2)

DR. - later SIR CHARLES - BLAGDEN. '87 (i), p.5, '88, pp.6, 10, 'M', pp.2, 5, 'C', pp.1, 4. (1748-1820)

Blagden studied medicine at Edinburgh University, and later entered the Army as a medical officer, remaining in the service till

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1. D. Greene, The Glass Works, Rotherham (1751-1951), (1952), pp.1-12.

2. John, pp.33-34.

1814. In 1782 or early in 1783, for there is some doubt about the actual date, he became Cavendish's assistant. On the 5th of May, 1784, he was elected secretary of the Royal Society which concluded a long period of strife among its members, and he continued in office till 1797.(1) Blagden, as Cavendish's assistant, became involved in the well-known 'water controversy'.(2) The two men, who were both reserved and undemonstrative persons, remained on friendly terms for a number of years, but any break in their relations did not occur before 1787. Blagden regularly accompanied Cavendish on his geological journeys in England, but he was also a frequent visitor to the continent, and undertook several excursions. His 1789 tour into Central Europe was carried out in part, at least, at Cavendish's request, so that any formal parting before that date was unlikely.(3) It has never been known how Blagden and Cavendish came together, nor why they parted, except by the only surmise it is possible to make; viz. that the partnership 'did not suit', but it did not prevent Cavendish leaving his assistant a large legacy at his death. In 1792, Blagden was knighted in recognition of his services to science. After the war with France he resumed his visits to the Continent, and his last one was in 1819, when he took up residence in the house of his friend Berthollet. There he died on the 6th of March, 1820.(4)

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1. C. R. Weld, A History of the Royal Society (1848, 2 vols.), Vol. II, p.561.

2. See Chapter II.

3. Letters from Blagden to Cavendish. 23 and 24 Sept., 1787. Chatsworth MSS. X(b), 12, 13, 14.

4. G. Wilson, Life of the Hon. Henry Cavendish. (1851), p.131.

MR. BO/U/LTON. '93, p:7.

Matthew Boulton (1728-1809) belonged to a Northamptonshire family, and entering his father's business set himself to extend it, and so he directed his thoughts to the growth of his factory by attention to the steam-engine. He soon came into touch with Watt, through a friend, Roebuck who was Watt's partner. It is said, that if the completion of the steam-engine was due to Watt, its introduction at that time was due to Boulton. The reform of the copper coinage was another important movement with which Boulton was connected in the latter part of his life.(1)

MR. CASSINI. Bl's. '87, p.2.

Caesar Francois (1714- ?) belonged to a family which was famous in Astronomy and Physics for three generations. Cassini de Thury, Caesar Francois, born in 1714, was a member of the French Academy from his twenty-second year. He undertook a geometrical survey of the whole of France which was completed by his son in 1787. It consists of one hundred and eighty sheets.(2)

CHEV. DE BORDA. Bl's. '87, p.2.

Jean Charles (1733-1799) was a French mathematician and physicist. He served in the Army and Navy, but distinguished himself by the introduction of new methods and instruments connected with navigation, geodosy and astronomy, being in particular the inventor of the reflecting circle. He was one of the men of science who framed the new system of weights and measures adopted in France.

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1. D.N.B.
   S. Smiles, Lives of the Engineers Boulton and Watt (1904).
2. Blagden to Cavendish, 24 Sept. 1787. Chatsworth MS. X(b)12.

DUC de CRAY /Crès/. Bl's, '87, p.4.

Denis de Crès, then Decrès, at the time of the Revolution, 1813. He was born in 1761, and at eighteen was a wharfmaster, and then joined the Navy where he made a name for himself. In 1786 he went to Trinidad on a geological expedition, and it would be about this time that he would be known to Blagden. He rose in Naval rank, but was dismissed during the Revolution because he belonged to the nobility. After further adventures during the French War, he was captured at Malta by the British Navy, but was later exchanged as a prisoner, and eventually became Minister of Marine. It was in 1813 that he received the title of 'Duke'. He died in 1820 after being injured in an explosion.(1)

LORD DUNDONALD. '85, p.48.

Archibald Cochrane, ninth Earl of Dundonald, (1749-1831), was a naval officer, and chemical manufacturer. He is said to have been on intimate terms with such philosophers as Cavendish, Priestley, Black, and others. His only thought in life was to retrieve the fortunes of the family by applying the discoveries of that day. It was when on the coast of Africa that he noticed the ravages made in ship's bottoms by worms. It occurred to him to apply coal-tar and he immediately designed, and built at much cost, retorts for the distillation of tar from coal, and though correct in his views, he was unsuccessful in urging the Admiralty to try the coal-tar on ships

1. Information received from the Archives in Lille, January 1971.

in the Navy. His unbusinesslike management of his discoveries, now of national utility, led only to ruin, and as a result his last years were spent in the most depressing poverty.(1)

MR. EDWARDS. '87(ii), p.22.

John Edwards, (1731-1807), was a distinguished Cornish Industrialist, and typical of his period, being a mining adventurer and merchant, as well as copper smelter, but little has been preserved about him. It is known, however, that he became eventually associated with the Cornish Copper Company at Hayle, through the influence of that celebrated historian, Dr. William Borlase, the Vicar. There is some uncertainty when this was, but it appears that he was the manager in 1765, and by 1782 had become the leading partner of the company. John was eleven years of age when his father died, but through Borlase he was mentioned to Sir John St. Aubyn, the probable Chairman of the Company at its first meeting on the 25th of October, 1758, as a possible future manager of the commercial side of the business. Edwards was friendly with James Watt, and was one of the first to inquire about installing a rotative engine for the mine, then being planned by the firm of Boulton and Watt. He died suddenly, in February 1807, while reading prayers to his family, at his house 'Reviere', aged 76.(2)

MR. LAWSON. '93, p.7.

James Lawson, son of the Rev. A. Lawson of Kirkmanhoe, near

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1. D.N.B.

2. T. R. Harris, 'John Edwards (1731-1807) Cornish Industrialist', Transactions of the Newcomen Society, Vol. XXIII, 1942-1943, (1948), pp.13-22.

Dumfries, started work in Boulton and Watt's Soho Office in 1779. By 1782 he was one of the engine erectors in Cornwall. His work in this capacity was praised by Boulton, though at times, as later, there were some complaints about his lack of diligence. Possibly because of shortage of work on engines, by 1783 he had taken up mine surveying in Cornwall. The period of this work is uncertain and the prospects of it becoming permanent were not hopeful. In 1791, he began work directly under Boulton at the mint, though by November 1793 he had gone back to engine erecting. At this time he was asked to come back to Soho for about a week to oversee presses in connection with a large order for copper coin. Shortly before this, he had been helping on one of Watt's law suits, and by this time was in an important position, representing Boulton and Watt in Leeds and Manchester, as well as being a close friend of James Watt Junior. In 1800 he made a tour of Northern Wales and at the end of this became the firm's representative in Scotland. In 1811 he was made Superintendent of Machinery to the Royal Mint, but continued to represent Boulton and Watt in London. He was made a Fellow of the Royal Society in 1812, and died in London on the 9th of April, 1818.(1)

<u>LE NOIR</u>. Bl's, '87, p.2.

Etienne Lenoir (1744-1832), was a French mathematician and engineer. Little is known of his early life, but through years of persistent study he became a well-known artist. His chief claim to

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1. H. W. Dickinson and R. Jenkins, <u>James Watt and the Steam-Engine</u> (1927), pp.286-288.
   Smiles, pp.373, 435.

fame, however, is in connection with the reflexion circle invented by Borda to find longitudes at sea, a work with which he was entrusted in 1772.

The perfection with which he carried out this work earned praise and recognition from Louis XVI. The construction of the astronomic repeating circle again attracted the notice of the government, and it entrusted Le Noir with the making and care of all the equipment used by La Pérouse, d'Entrecasteaux and Baudin for their travels around the world. In 1788 the first lantern with a parabolic mirror was built by Le Noir for the tower of Cordonan lighthouse near Bordeaux.(1)

MICHELL. '88, p.8. 'M', 'C', 'S', p.14.

The Rev. John Michell (1724-1793), Rector of Thornhill, near Dewsbury, was an accomplished mathematician and geologist, a good geometrician, and skilled in the use of instruments, and was the first to suggest the use of Hadley's Quadrant in surveying and pilotage. He was associated with Queen's College, Cambridge, first as a student, and later as a Fellow, and in 1762 he was appointed Woodwardian Professor of Geology and may even have taught the subject. He held the post for several years, though he left Cambridge in 1763 because of a coming marriage, and after several moves he settled at Thornhill in 1767, where he remained for the rest of his life. It is not known when Cavendish and he became friends, but herpaps they met at Cambridge where they had a common interest as natural philosophers. Cavendish may even have attended Michell's lectures. Both led outwardly uneventful

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1. Nouvelle Biographie Universelle, Vol. 29-30, p.670.
M. Marie, Histoire des Sciences Mathematiques et Physiques. Vol. 9, p.305.

lives; both became Fellows of the Royal Society on successive elections in 1760. In the same year Cavendish became a member of the Royal Society Club, an intimate dining society which met weekly. On trips to London, Michell was a frequent guest of the Club, which afforded an opportunity for Cavendish and Michell to discuss their projects, and to be on close terms. A letter from Michell to Cavendish, relating chiefly to geological observations is among the Cavendish manuscripts.(1) It concludes, 'with best respects to yourself, and due compliments to all friends, when you see them, particularly those of the Crown and Anchor, and Cat and Bagpipes Clubs'. The Crown and Anchor was the tavern where the Royal Society Club helds its meetings, but less is known of the Cat and Bagpipes - it appears to have been in the neighbourhood of Downing Street, and was a scientific 'Club', which had some permanence as Michell referred to it in 1783 and 1788.(2) It must also be recorded that Michell was the author of a noteworthy paper on the cause and phenomena of earthquakes.(3) He is, however, best remembered for having constructed an apparatus for measuring gravitational attraction by the aid of a torsion balance based on a principle which he had suggested and used as far back as 1768, though he did not live to make any actual measurements with it. This apparatus came into the hands of Cavendish, who, after reconstructing it, made

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1. Michell to Cavendish, 14 August, 1788, Chatsworth MS. X(b)15 - Appendix

2. Wilson, p.177.
R. McCormach, 'John Michell and Henry Cavendish: Weighing the Stars', The British Journal for the History of Science, Vol. 4, No. 14 (1968), pp.127-130.

3. Weld, Vol. II, p.10.

his celebrated determination of the mean density of the earth. In connection with the Cavendish Journeys, reference is made to Michell, but it is doubtful if he ever took part in them.

'CAPTAIN' MITCHELL. '87 (ii), p.21.

There appears little information available about this person, who was apparently connected with the Tresivane Mine, in the Parish of Gwennap, but no reference to him occurs in a book by the late C. C. James on the history of that parish. In a memoir of the Rev. Joseph Entwistle, it seems that he visited Cornwall on Wednesday, the 7th of February, 1827, and said: 'I travelled through a mining country which has an unsightly appearance at Gwennap ... I had a comfortable bed in the neighbourhood, at Captain Joe Mitchell's. They call those who have command of the mines 'Captains'. Captain Joe has about two thousand persons under his command. He is a pious man, and has been a class-leader thirty years'.(1) The term 'Captain' is a title used in Cornish mining for a manager or overseer, and is said to have been introduced by German miners in the fifteenth century. Mine Captains for the most part were men of considerable ability and character, and socially they stood high in their communities.(2)

A further reference to Captain Mitchell's mine is given in a note to a long poem, titled, 'Gwennap'. It says, 'Tresavean, like

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1. Rev. Joseph Entwistle, Memoir by his son:- Fifty years a Wesleyan Minister (9th edition, 1867), p.348.

2. John Pearce (ed), The Wesleys in Cornwall: Extract from the Journals of John and Charles Wesley and John Nelson (1964), p.52.

other of our mines, was worked originally for tin, and copper ore was discovered very near the surface. About one hundred years ago a company was formed to work it for copper ... But the lode becoming poor the steam-engine was silenced, though many tributors worked above the adit level. The mine was again drained, and the workings prosecuted to great advantage ...'[1]

MR. MOURAN. Bl's. '87, p.4.

The reference by Blagden to a Mr. Mouran of Calais was in connection with the use of coal, but from investigations made, no trace can be found of a person of this name who might have been a coal dealer, or even an importer of English Coal, about 1787. There was, however, in Calais about this time a family of the name of Mouron whose members were engaged in various activities. It appears that a succession of Mourons were officials of the Military Hospital in Calais, and as such an institution would require fuel of this kind, the Mouron in question may be one identified with the Hospital. Thus he could be Jacques Mouron, born 1754, or Felix or even Auguste, Keeper of the hospital main store. An important member of the family, Louis, who died in 1791, was Treasurer, magistrate and consul in Calais before the French Revolution.[2]

MR. PIC[K]ARD. '85, p.33.

James Picard was originally a button-maker in Birmingham, but

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1. W. Francis, Gwennap - a descriptive poem in 7 cantos (1845), p.16. [British Museum General Catalogue of Printed Books. No. 78. 11642e13.]

2. Information received in a letter from the Mayor of Calais, 1 April, 1971.

later became a workman in Watt's employ, and while Watt was engaged in finding a way to produce a rotary motion to his single acting engine by the use of a crank, the Soho workmen, particularly the pattern makers, were naturally curious about his new inventions which became a subject for their off-time conversations. These invariably took place at the 'Waggon and Horses', an old public-house still standing at Handsworth. While drinking together, thenoisiest of them, Dick Cartwright, was in a position to give away much useful information. One of the eaves-droppers, in the garb of a workman sitting in a corner of the kitchen drank in all that was being said, and off he went to London to take out a patent for the crank which Watt had not believed patentable. Picard revealed the secret to a man named Matthew Washborough of Bristol, who made various contrivancies the subject of a patent in 1779, but was unsuccessful, so he joined himself to Picard, who in 1780 took out a patent, /No. 1263/, for the use of the crank in the steam-engine. Watt, finding himself shut out by Picard's patent developed himself to devising other means for converting a reciprocating into a rotary motion. Some attempt was made to agree with Picard for the use of the crank but Watt's pride revolted from buying back that which he said was his own invention; and he said he had no wish to destroy Pic/k/ard's patent.(1)

MR. PRAI/E/D. '87 (ii), p.17.

Humphry Mackwroth Praid, belonged to the Parish of Lannant.

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1. D.N.B.
Smiles, pp.260-265.

The reference in the text is to Mr. Praid's clay, and is described as a brownish sand with just enough clay to give it consistence. It was said to be excellent for cementing the Windsor bricks which were used in the hearth of the reverberatory furnace. Borlase says, 'In the parish of Lannant there is a yellow clay much coveted for building furnaces; 'tis carried off to Bristol and Wales, and other places in such quantities every year, that Humphry Mackworth Praid, Esq. owner of the soil, makes above 100 pounds per annum of this clay ... Bricks made of this clay melt and vitrify in the fire, running into one solid body; but afterwards never stir till quite calcined, enduring the most intense fire beyond any bricks used for like purposes.'(1)

MR. SMEATON. '87 (ii), p.29.

John Smeaton (1724-1792), was educated for the Bar, but he abandoned the legal profession for engineering. In 1753 he was elected a Fellow of the Royal Society, and in 1759 awarded the Copley Medal. He was entrusted with the re-building of Eddystone Lighthouse in 1755, which was completed in 1759. It stood till 1882, when it was replaced by a new structure. Smeaton was also employed on many works of great public utility, including the Firth and Clyde Canal.

MR. PAUPER? /TANNER/. '85, p.29.

No reference to any person of this name can be traced, but it is known that in 1784, the immediate successors of Bacon at Cyfarthfa, were Mr. Tanner of Monmouth and two others. According to one authority

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1. W. Borlase, Natural History of Cornwall (1758), p.65.

the works prospered for a time, but ultimately Tanner having lost money sold out. It appears there were dozens of Tanners in Monmouth in the 18th century, all connected with the iron trade. They lived at the Grange which William Tanner bought about 1750. His brother David (senior) was Mayor of Monmouth in 1745 and 1754. William was Mayor in 1752, 1761 and 1767, and died in 1776, and is buried in St. Mary's. David (senior) died about 1756, and his widow Mary Tanner and her two sons, David (Junior) and William were the most important members of the family, so far as the iron trade was concerned. David acquired Tintern Iron and Wire Works c. 1775, Redbrook Works in 1780 and the Lydney Iron and Tinplate Works, Blaendare Works near Pontypool, Llanelly Furnace near Abergavenny, and the Cyfarthfa Works c. 1785. David is most likely the Tanner referred to by Cavendish. He moved to St. Brides, and in 1792 became High Sheriff. He became bankrupt in 1798, and left England for India, where, presumably, he died.(1)

<u>MR. WATT</u>. '85, pp.32, 38, 45, 58, 62. '93, p.6.

James Watt (1736-1819) the famous engineer was born at Greenock. He suffered throughout life from ill-health, inspite of which he was one of the most determined and persistent of men. Watt adopted the trade of a mathematical instrument-maker, and was early employed in making surveys and reports in connection with canals, rivers and harbours.

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1. L. B. Namier, 'Anthony Bacon, M.P., an Eighteenth-century Merchant', (<u>Journal of Economic and Business History</u>, II, (1929), 20-70) in W.E. Minchinton, ed., <u>Industrial South Wales 1750-1914</u>, (1969).
J. A. Bradney, <u>History of Monmouthshire, Hundred of Trelech</u>, Vol. 2, Part 2. (1904-1933),.4 Vols.).
C. Wilkins, <u>The History of the Iron, Steel, Tinplate and other trades of Wales</u> (1903), pp.60-62.

He appears to have succeeded Smeaton in the position of engineering adviser to the Carron Foundry. He is remembered chiefly in connection with his steam-engine, which he patented in 1769 and became a partner with Boulton at Soho Engineering Works, Birmingham, 1775-1800. He frequently visited Cornwall to superintend the construction of the engines to drain mines. Watt always had some scientific investigation to engage his inquiring mind, the composition of water, was an example, experimenting in his laboratory with the eagerness of a boy 'wearing out his life, not rusting'. He set about the task of developing and improving Newcomen's Steam Engine, used hitherto as a pump. Not till 1781 was it used for spinning and for other sorts of machinery. He was one of the claimants in the Water Controversy, already discussed in Chapter II. One of the chief units of electrical power, the 'Watt' is named after him. He was accorded a monument in Westminster Abbey.(1)

MR. WEDGWOOD. '87 (i), p.6. '87 (ii), p.10.

Josiah Wedgwood (1730-1795), was the thirteenth and youngest child of Thomas and Mary Wedgwood. After the death of his father, when he was not yet nine years old, his school career was closed, so he began work as a potter at Burslem. Probably about 1759, when 29 years old, he became a master potter, and gradually securing additional accommodation, until in 1773, he moved to the Etruria Works. Then, in 1776, Thomas Wedgwood, who had been employed in the factory since 1759, was taken into partnership. In the same year Josiah acquired

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1. D.N.B.

a suitable site between Burslem and Stoke for a new factory and residence, and later built a village for his workmen, to which he gave the name, Etruria. The new Etruria factory was opened on the 13th of August, 1769, ten years after Wedgwood had started in business on his own account. At the same time many other important matters engaged his attention. Among these was the extension of the Canal system to his own locality. He was in frequent consultation with James Brindley, the engineer, and Francis Egerton, third Duke of Bridgewater. The Grand Trunk Canal, and the Trent and Mersey Canal, which was opened in 1777, passed through the Etruria Works. He was elected a Fellow of the Royal Society in 1783, and contributed papers to the Philosophical Transactions.(1)

MR. WHITEHURST. 'S', p.14.

John Whitehurst (1713-1788), horologer, was born at Congleton, Cheshire, the son of John Whitehurst, clock and watch maker of that place. In 1736 he entered business on his own account in Derby, and distinguished himself by inventing ingenious pieces of mechanism. He was consulted in almost every undertaking in Derbyshire, and the neighbouring counties in which skill in mechanics, pneumatics, and hydraulics was required. About 1775 he removed to London, and his house in Bolt Court, Fleet Street, became the constant resort of men of science of every nation and rank. In 1778 he published his 'Inquiry into the original state and formation of the Earth'; a second appeared

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1. D.N.B.
P. Mantoux, Industrial Revolution in the Eighteenth Century (1961), p.125.

in 1786, enlarged and improved; and a third, after his death, in 1792. In 1779 he was elected a Fellow of the Royal Society. In 1783 he was sent to examine the Giant's Causeway and volcanic remains in Northern Ireland. About 1794 he contrived a system of ventilation for St. Thomas's Hospital. Certain of his papers appeared in the Transactions of the Royal Society. He died at Bolt Court on the 18th of February, 1788.(1)

<u>LORD WINCHELSEA</u>. 'M', p.3.

Lord Winchelsea belonged to an old titled family whose original name was Finch,, but during the eighteenth century it was joined through a marriage, with that of Hatton. The person referred to here was probably George Finch-Hatton, Eighth Earl of Winchelsea, and fourth Earl of Nottingham, who succeeded to the title on the death of his uncle, Daniel Finch, the Seventh Earl, in 1769. He was a nobleman who had filled many important offices, and was prominent in Court circles during the reign of George III. Well known among his ancestors were Lord Chief Justice Finch, who officiated at the trial of John Hampden, and Sir Heneage Finch, Speaker of the House of Commons in the reign of Charles I.(2)

<u>DR. WITHERING</u>. '85, p.32.

William Withering (1741-1799), physician, botanist, and mineralogist, was born at Wellington, Shropshire. He practised in Stafford from 1767-1775, before removing to Birmingham as Chief Physician to the

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1. <u>D.N.B.</u>
2. <u>D.N.B.</u>

hospital. His attention was directed temporarily to mineralogy, and he contributed to the Philosophical Transactions of the Royal Society of which he became a member in 1785. He was meanwhile engaged in chemical researches to combat as he says, 'that monster Phlogiston', a subject which he, however, handed over to his friend Priestley. He also witnessed Experiments with Watt. He analysed Rowley ragstone and toadstone in 1782, and experimented on barium carbonate, afterwards called 'witherite', in his honour.

APPENDIX IV

INDEX OF PLACE-NAMES

The alphabetical index contains a complete list of place names mentioned in the texts of the Journeys, and also in several other documents which follow, while the technical terms, even of the simplest kind, are listed separately in the Glossary, and both bear similar kinds of references, e.g. '85.31, indicating the year, and the actual page in the MS.. The reference to the undated Journey is given as, '88, the probable date of this tour.

Immediately following the texts of the Journeys are two personal letters, one from the Rev. John Michell to Henry Cavendish, and the other is Cavendish's reply, while a further document, which purports to be a summary description of the geological strata of England is also recorded.

The references to the place names, and to the scientific terms in these MSS. . are recognizable through the initial letters, 'M', 'C' and 'S', respectively. In the case of Blagden's Journeys, the reference is prefixed by the initials, Bl's.

APPENDIX V

Unpublished Papers of Henry Cavendish

1731-1810

The White Book No. 1

1786-1799

On Wednesday, 16th July, 1969, His Grace, The Duke of Devonshire became the owner of documents, additional to ones he already had, which originally belonged to Henry Cavendish, but latterly had been the property of the Rt. Hon. The Lord Chesham, P.C.

Lord Chesham is a direct descendant of Lord George H. Cavendish (First Earl of Burlington of the second creation) from whom the Sixth Duke inherited the Cavendish Library, and the papers now at Chatsworth. It would seem probable that the documents, referred to here, became separated from the main collection, by chance rather than design, at an early date.

There were two lots; the first lot was described as Miscellaneous Autograph Papers, circa 1786-1810, while the second was: An Important Unrecorded and Unpublished Paper on Heat, and a rough draft of the same.

The most striking document contained in the first lot, was styled White Book No. 1., bound in original white vellum, inscribed with the title on the upper cover, 1786-1799, and measured 10 9/10" x 8½", by 1½" thick, with inside pages of

$10\frac{1}{2}$" x 8". There is a loose leaf autograph index inside the cover, which measures $12^7/10$" x 8", with 4 pages $6^7/20$" x 8", headed Contents.

The document is described as a fair copy book of chemical experiments on inorganic materials, of 138 pages, the rest of the volume left blank, and would appear to be the only known writing of Cavendish preserved in volume form. There is difficulty in finding any systematic arangement in it, because the entries are not recorded chronologically, and subjects are often introduced on a later page, as a result of further experiments or after thoughts. This is nothing unusual, for most of Cavendish's manuscripts are in the form of loose leaves and notebooks, and have the stamp of untidiness, being invariably defaced with corrections and crossings out, of which the texts transcribed in this Part are typical.

Some of the names of these experiments have a familiar ring about them as they could very well be connected with the specimens collected on the geological journeys of Cavendish and Blagden over the years 1785 to 1793. Many of these experiments are dated, which together with the supplementary loose notes, of which there are many, extend the boundaries of his interest as far back as 1775, and right up to the close of the eighteenth century. Thus, it is not unreasonable to assume that his thirst for research and investigation encouraged Cavendish to explore for himself, and embark on the series of excursions which are so well-known.

Sir Archibald Geikie [Sci. Pap. Vol. 2, p.432] has suggested that these tours were quite superficial, but this view is not acceptable, because the only evidence available to him was the parcel of MSS.. labelled "Journeys" in the Chatsworth Collection, and there is no indication in these documents that his opinion could be sustained.

Details of the contents of this volume now follow, but without recording an index of place names, a list of scientific terms, or any reference to persons mentioned.

Contents

of

The White Book

Sept. 1787. Expt. with red feldspar.

pp.23-24. Anglesea copper ore.

pp.25-27. Apl. 1787. Glacial oil of vitriol from Dolfuss.

Sept. 7. 1787. Further expt., with diagram. Continued on page 29.

p.28. Native iron from Mexico.

Sept. 1787. Mural nitre.

pp.29-40. Continuation of expts. from p.27.

pp.41-44. June 17. 1788. Lava from Vesuvius, from Mr. Greville.

pp.46-47. Undulated mica from Mr. Greville.

White mica from Mr. Greville.

p.48. Dec. 1788. Talc.

pp.49-52. May 10. 1788. Glacial Oil Vitriol.

with Dolfuss and Blagden.

pp.53-54. Mural Nitre, continuation from p.28.

pp.55-56. Terra Panderosa in Nitrous acid.

Manganese got Sept. 1788 from Templeman.

pp.57-58. Kish or Plumbago from Beatson.

p.59. Aug. 1789. Mural Nitre, continued from p.54.

pp.60-62. Borax earth from Sr. J. Banks.

unpurified borax - Tinial [Tincal?]

[...70] of Tinial of my father's being dissolved in water etc.]

p.63. May 1790. Sope Leys. Iron contained in Calx of irons.

p.64. Reduction of luna cornea.

pp.65-68. Platina.

Loose Leaf /measures $12^7/10"$ x 8" 1 page, writing on 4 pages $6^7/20"$ x 8". A letter D. J./

pp. 69-70. Cubic pyrites from more.

pp.70-72. Sulphurated Copper and Iron.

pp.72-74. On the quant. deph. air required to set N. air tried by ~~mixing~~ adding the N. air gradually to the deph. air without being in contact with water.

pp.75-76. Distillation of pyrites with red precipitate.

pp.76-78. Distillation of sulphurated iron with red precipitate.

p.80. Sulphurated iron.

p.82. Feb. 20. 1792. Mural nitre.

p.83. Seltzer water.

pp.84-90. Spring 1793. Finery cinder from /Mr./ Cockshut.

pp.92-96. Porzolan and Tarras continued on p.101.

Loose Leaf /measures $6^4/10"$ x 8", 2 sides of writing. Expts. on Porzolane.

p.97. Limestone from Breedon Hill, Leicestershire.

p.98. White matter from mine at Overton.

pp.99-100. Blue Lyas.

pp.101-103. Porzolane continued from p.96.

pp.106-107. Toadstone.

p.108. Iron ore from pit near Overton.

p.109. Lava.

pp.110-112. Earth from Sr. C. Bl/agden/ I believe came from Isle of Man.

pp.112-113. White part of diamond spar. Mr. Grevilles.

pp.114-115. Substances found by Sr. O. B[lagden] in Italy,

Tufa, Black substance Serpentine.

p.116. Mica. French chalk. Tobacco pipe clay.

p.117. White earthen stoneware.

Loose Leaves. 2 @ 13" x 8", and 1 @ 6½" x 8".

Writing is on 4 complete sides, and a little on two other separate sheets. Labelled, 'Paper given to Cockshutt' and notes of conversation with Cockshutt.

pp.118-119. Substances from Cockshutt.

p.120. Soluble earth alum in vinegar.

pp.121-126. On the absorption of deph. air by grass in drying.

Loose diagram attached [6½" x 8 2/10"]

diagrams on both sides.

Labelled Fig. 1, Fig. 2, and Fig. 3.

Loose pages. Notes for expts. Various sizes.

28 ff. [pages]

pp.127-130. 1799. Platina.

Loose leaves. 68 ff. [pages] various sizes.

Notes on expts.

pp.131-135. Phosph. acid from earth bones.

Loose Leaves. 30 ff. [pages] Notes on expts.

Loose Leaf. 2 pages. Artific.: Porgalane.

Loose Leaves. 30 ff. [pages] Notes on expts.

APPENDIX VI

A BIBLIOGRAPHY OF CAVENDISH'S WORKS PUBLISHED IN HIS LIFETIME

Cavendish's reluctance to publish any of his researches is well-known, and it is not surprising that his contemporaries were unaware of the vast store of unpublished material which was to be found among his MSS. many years after his death. Thus his reputation as a man of science rested solely on his published work.

All his published chemical work was done between 1766 and 1788, and from what can be gleaned from his unpublished work in chemistry that also must have been carried out within those dates.

The electrical researches, in which he rose to some of his greatest heights occupied him between 1771 and 1788. After that date the centre of his interests seems to have been directed chiefly to terrestrial and astronomical subjects, including his celebrated paper on the density of the earth. Terrestrial magnetism, a subject on which he began to make observations with his father, continued to occupy his attention at intervals throughout his life.

A list of his investigations published during his lifetime is tabulated below in chronological order.

1766 Three Papers, containing Experiments on Factitious Airs.

Philosophical Transactions, Vol. 56, 1766, 141, et seq: with a plate. [Sci. Pap. Vol. II, pp.77-101.]

1767 Experiments on Rathbone-Place Water.

Philosophical Transactions, Vol. 57, 1767, 92. et seq.

[Sci. Pap., Vol. II, pp.102-111.]

1771 First Published Paper on Electricity.

An Attempt to explain some of the Principal Phenomena of Electricity by means of an Elastic Fluid.

[Read Dec. 19, 1771 and Jan. 9, 1772]

Philosophical Transactions, Vol. 61, 1771, pp.584-677.

[Sci. Pap., Vol. 1, pp.33-65]

1775 Second Published Paper on Electricity.

An Account of Some Attempts to imitate the Effects of the Torpedo by Electricity. [Read Jan. 18, 1775.]

Philosophical Transactions, Vol. 66, 1776, Part I, 196-225.

[Sci. Pap., Vol. I, pp,189-210]

1776 An Account of the Meteorological Instruments used at the Royal Society's House.

Philosophical Transactions, Vol. 66, 1776, 375 et seq. with a plate.

[Sci. Pap., Vol. II, pp.112-126.]

1783 An Account of a new Eudiometer.

Philosophical Transactions, Vol. 73, 1783, 106 et seq. with a plate.

[Sci. Pap., Vol. II, pp.127-144.]

Observations on Mr. Hitchins's Experiments for determining the Degree of Cold at which Quicksilver freezes.

Philosophical Transactions, Vol. 73, 1783, 303, et seq.

[Sci. Pap., Vol. II, pp.145-160.]

1784 Experiments on Air.

<u>Philosophical Transactions</u>, Vol. 74, 1784, 119, <u>et seq</u>.

[<u>Sci. Pap.</u>, Vol. II, pp.161-181.]

Answer to Mr. Kirwin's Remarks upon the Experiments on Air.

<u>Philosophical Transactions</u>, Vol. 74, 1784, 170, <u>et seq</u>.

[<u>Sci. Pap.</u>, Vol. II, pp.182-186.]

1785 Experiments on Air.

<u>Philosophical Transactions</u>, Vol. 75, 1785, 372, <u>et seq</u>.

[<u>Sci. Pap.</u>, Vol. II, pp.187-194.]

1786 An Account of Experiments made by Mr. John McNab, at Henley House, Hudson's Bay, relating to freezing Mixtures.

<u>Philosophical Transactions</u>, Vol. 76, 1786, 241, <u>et seq</u>.

[<u>Sci. Pap.</u>, Vol. II, pp.195-213.]

1788 An Account of Experiments made by Mr. John McNab, at Albany Fort, Hudson's Bay, relative to the Freezing of Nitrous and Vitriolic Acids.

<u>Philosophical Transactions</u>, Vol. 78, 1788, 166 <u>et seq</u>.

[<u>Sci. Pap.</u>, Vol. II, pp.214-223.]

On the Conversion of a mixture of dephlogisticated and phlogisticated Air into Nitrous Acid.

<u>Philosophical Transactions</u>, Vol. 78, 1788, 261, <u>et seq</u>.

[<u>Sci. Pap.</u>, Vol. II, pp.224-232.]

1790 On the Height of the Luminous Arch which was seen on Feb. 23, 1784.

<u>Philosophical Transactions</u>, Vol. 80, 1790, 101, <u>et seq</u>.

[<u>Sci. Pap.</u>, Vol. II, pp.233-235.]

1792 On the Civil Year of the Hindoos, and its Divisions; with an Account of the three Hindu Almanacs belonging to Charles Wilkins, Esq.

Philosophical Transactions, Vol. 82, 1792, 383, *et. seq.*

[*Sci. Pap.*, Vol. II, pp.236-245.]

1797 Extract of a letter from Henry Cavendish, Esq., to M. Mendoza y Rios, January, 1795.

Philosophical Transactions, Vol. 87, 1797, 119, *et seq.*

[*Sci. Pap.*, Vol. II, pp.246-248.]

1798 Experiments to determine the Density of the Earth.

Philosophical Transactions, Vol. 88, 1798, 469, *et seq.*,

[*Sci. Pap.*, Vol. II, pp.249-286.] with two Plates.

1809 On an Improvement in the Manner of dividing astronomical Instruments.

Philosophical Transactions, Vol. for 1809, 221 *et seq.*

[*Sci. Pap.*, Vol. II, p.287 *et seq.*]

BIBLIOGRAPHY

The place of publication is London unless otherwise stated.

A. PRIMARY SOURCES

I. Manuscripts

Holograph unless otherwise stated. Chatsworth MSS.

Chatsworth MS. X b 1.

Letter from Rev. Nevil Maskelyne, Astronomer Royal, to Henry Cavendish, from Greenwich, 5 Jan. 1773, 1 page, re: rules on the attraction of hills.

Chatsworth MS. X b 2.

Letter from Dr. M. Maty, former Secretary of the Royal Society, to Henry Cavendish, from London, 26 Dec. 1773, 2 pages, re: Hudson's Bay Observations.

Chatsworth MS. X b 3.

An extract from Capt. Richard Nairne, Quebec, 13 July 1775, 2 pages. Description of a violent thunderstorm at sea.

Chatsworth MS X b 4.

Letter from Charles Blagden to Henry Cavendish, undated (Saturday night), 2 pages, re: Kirwin's experiments, and reference to Phil. Trans., Vol. 74, 1784, p.175. See Sci. Pap. Vol. II, pp.182-186.

Chatsworth MS. X b 5

Letter from A. Dalrymple, Hydrographer to the Hon. East India Coy., and the Admiralty, to Henry Cavendish, from Simmons Bay,

near the Cape of Good Hope, (undated, but probably 1776-1777), 2 pages, re: the Dip-Needle.

Chatsworth MS. X b 6.

Letter from A. Dalrymple, to Henry Cavendish, 1776. 11 pages of writing from 3 large double sheets folded in half, re: Observations with the Dipping Needle made on a voyage to India.

Chatsworth MS. X b 7.

Letter from A. Dalrymple to Henry Cavendish, from Fort St. George, 19 Feby. 1776. 1 page, refers to a copy of the Journal of his voyage to India, but apologises for the poor copy, and promises to send another by the next conveyance in about 3 or 4 months.

Chatsworth MS. X b 8.

Memorandum in French to Francken Universite de Frise, from Pimlico, 25 Jan. 1779 (no signature).

Notes on some exceptional meteorological observations over the New Year Dec./Jan. Reference also to De Luc.

Chatsworth MS. X b 9.

Letter from Frederick Cavendish, Market Street, to his brother Henry Cavendish, at Great Marlborough Street, London, Wed. 1 Mar. 1780, 3 pages.

A description of the Aurora Borealis. Written at mid-night. See also Sci. Pap., Vol. II, p.69.

Chatsworth MS. X b 10.

Letter from Charles Blagden to Henry Cavendish (undated and no address). The letter contains a reference to an extract of a letter from Mr. Kirwin in London to Professor Gell [?]

(Chemical Annals, No. VI. June 1784, p.523); 2 pages re; Henry Cavendish's Experiments on Water submitted to the Royal Society.

Chatsworth MS. X b 11.

Letter from Henry Cavendish, from London, to M. T. A. Mongez le Jeune au Bureau du Journal de Physique, at Paris, 22 Feb. 1784. 1 page only. Copy.

Chatsworth MS. X b 12.

Letter from Charles Blagden to Henry Cavendish, from Dover, 24 Sept. 1787. 4 pages, intends crossing to France Sat., and requests certain things bringing to Dover, if H.C. proposes coming before he leaves.

Chatsworth MS. X b 13.

Letter from Charles Blagden to Henry Cavendish, from Dover, 16 Sept., 1787. 3 pages re; Blagden's conclusions after reading the Nomenclature Chimique with request to return it to Sir. Joseph Banks. Also reference to Cassini's Circle and refraction.

Chatsworth MS. X b 14.

Letter from Charles Blagden to Henry Cavendish at 4 Bedford Square, from Dover (City of London), 23 Sept., 1787, 4 pages. Finished the perusal of the Nomenclature Chimique, refers to Cassini and observations on refraction. Concludes, 'The French have been smuggling troops into Holland from Dunkirk in small parties, and it is said have now a force upon the sea, under M. de Bouillie to attack Jamaica'.

Chatsworth MS. X b 15.

Letter from the Rev. John Michell to Henry Cavendish, from Thornhill, 14 Aug. 1788. 7 pages re: Geological Observations, particularly yellow limestone. Accepts a parcel of plumbago from Mr. Beatson which he passes on to Cavendish.

This document always referred to as 'M'. Printed in Appendix I.

Chatsworth MS. X b 16.

Letter from A. Dalrymple to Henry Cavendish from London probably, 16 Mar. 1792. 1 page only. Letter of sympathy, having heard that Henry Cavendish has had an attack of the Gravel.

See also <u>Wilson</u>, p.176.

Chatsworth MS. (unnumbered).

Letter from Henry Cavendish to Rev. John Michell, no address, and undated but probably late Aug. 1788. 6 pages. Obviously a reply to Michell's letter, as further reference is made to Michell's observations, and to Mr. Beatson and the plumbago.

This document always referred to as 'C'. Printed in Appendix I.

Chatsworth MS. (unnumbered).

A summary of the upper strata formations of England and Wales, 20 unnumbered pages written by Cavendish.

This document always referred to as 'S'. Printed in Appendix I.

Chatsworth MS. X a 1.

Blagden's Journey 1787, 25 Sept.-9 Oct. 5 numbered pages. France, chiefly in the area of Calais and Boulogne.

Printed in Appendix I.

Chatsworth MS. X a 2.

Journey 1793, 24th Aug.-1 Sept. 12 numbered pages. Chiefly the East-Midlands from Middlesex to Lincolnshire. Printed in Appendix I.

Chatsworth MS. X a 3.

Journey undated (1788?), but probably took place in 1788, July/Aug. 14 numbered pages. Extended tour from South to North, and from East Yorks. to N.W. England, and North Midlands. Printed in Appendix I.

Chatsworth MS. X a 4.

Computations and Observations in Journey 1785, 17th July- 6 Aug. 62 numbered pages. Chiefly in South Wales and West Midlands. Printed in Appendix I.

Chatsworth MS. X a 5.

Computations and Observations in Journey 1786, 22 Aug. 7 numbered pages. North East Coast - Whitby. Printed in Appendix I.

Chatsworth MS. X a 6.

Journey 1787 (ii), 30 July-10 Aug. 30 numbered pages. Chiefly the tin and copper mines of Cornwall. Printed in Appendix I.

Chatsworth MS. X a 7.

Journey 1787 (i), 15 July. 8 numbered pages. South West Country. Printed in Appendix I.

Chatsworth MS. X a 8.

Blagden's Journey 1789, 20 Sept.-1 Nov.. 10 numbered pages.

Central Europe, the longest of all the Journeys.

Printed in Appendix I.

Chatsworth MS. unnumbered.

The Henry Cavendish Catalogue

Recently re-bound in hard back with brown leather covering, but spine and overlap of $2\frac{1}{2}$ inches is the original calf leather. The spine of six divisions has the word Catalogue in gold stamped on a red background. The Catalogue, 16 x 12 x 4 inches, contains 18 different subject classes, with nearly 500 pages of parchment paper, with plenty of spare leaves. There are nearly 10,000 different entries.

II. Printed

Henry Cavendish. The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. I, The Electrical Researches, ed. James Clerk Maxwell, rev.: Joseph Larmor. Cambridge, (1921).

Henry Cavendish, The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. II, Chemical and Dynamical, ed. Edward Thorpe. Cambridge (1921).

Henry Cavendish. The Electrical Researches of the Honourable Henry Cavendish, F.R.S., ed. J. Clerk Maxwell. Cambridge (1879).

W. Francis, Gwennap. A descriptive poem in 7 Cantos (1845), p.16. (British Museum General Catalogue of Printed Books. No. 78. 11642 e 13).

H. M. Leicester and H. S. Klickstein, A Source Book in Chemistry, 1400-1900, New York (1952).

John and Charles Wesley, and John Nelson. The Wesleys in Cornwall, Extracts from the Journals of John and Charles Wesley, and John Nelson, ed. John Pearce. Truro (1964).

B. SECONDARY SOURCES

I. Reference Works

R. M. Besançon, ed. The Encyclopedia of Physics. New York (1966). Especially for Cryogenics, pp.142-144.

E. H. Bolton, ed. Historical Abstracts, 1745-1945. (1963-1969).

G. E. Cokayne. The Complete Peerage of England, Scotland, Ireland, etc. extant, extinct, or dormant, revised by V. Gibbs, H.A. Doubleday, et al., (1910-1959, 13 Vols.).

J. Farey, Senior. General View of the Agriculture and Minerals of Derbyshire, (1811-1817, 3 Vols.).

S. Glover, The History and Gazetteer of The County of Derby, ed. T. Noble. Derby (1829-1833, 2 Vols.), especially Vol. II, Part I, pp.220-254.

M. Le Dr. Hoefer, ed. Nouvelle Biographie Universelle. Paris (1852-1866, 46 Vols.). Vol. 30 (1859), p.669.

B. M. King, ed. British Humanities Index, (1962-1970, 9 Vols.).

S. Lee, ed. Dictionary of National Biography, (1885-1900, 63 Vols.).

S. Lewis. A Topographical Dictionary of England, 7th Edition (1848, 4 Vols.).

S. Lewis. A Topographical Dictionary of Wales, (1849, 2 Vols.).

S. Lewis. Atlas to the Topographical Dictionaries of England and Wales, (1849).

R. V. Louis, gen. ed. Biography Index A cumulative Index to Biographical Material in Books and Magazines. New York (1946-1969, 9 Vols.).

M. Marie. Histoire des Sciences Mathematiques et Physiques. Paris (1883-1888, 12 Vols.).

A. Mawer, gen. ed. English Place-Name Society. Cambridge (1926-1970, 45 Vols.).

Vol. IV. The Place Names of Worcestershire. (1927).

Vol. VIII. Pt. I. The Place Names of Devon. (1931).

Vol. IX. Pt. II. The Place Names of Devon. (1932).

A. H. Smith, gen. ed. Vol. XXX-XXXV, Pts. I to VI. The Place Names of the West Riding of Yorkshire. (1961).

Vol. XXXVI, Pt. VII. The Place Names of the West Riding of Yorkshire. (1962).

Vol. XXXVII, Pt. VIII. The Place Names of the West Riding of Yorkshire. (1963).

A. H. Smith, gen. ed. Vol. XXXVIII, Pt. I. The Place Names of Gloucestershire. (1964).

Vol. XXXIX, Pt. II. The Place Names of Gloucestershire. (1964).

Vol. XL, Pt. III. The Place Names of Gloucestershire. (1964).

Vol. XLI, Pt. IV. The Place Names of Gloucestershire. (1965).

J. A. H. Murray, ed. The New English Dictionary. Oxford. (1888-1928, 10 Vols.).

G. M. Patterson, ed. Index to Theses Accepted for Higher Degrees in the Universities of Great Britain and Ireland. A.S.L.I.B. (1950-1967).

W. F. Poole, ed. Poole's Index to Periodical Literature, revised edition. (1963, 5 Vols.).

A. W. Pollard and G. R. Redgrave, eds. A Short Title Catalogue of Books Printed in England, Scotland, and Ireland, And of English Books Printed Abroad 1475-1640. (1926).

G. Roberts, ed. A Bibliography of the History of Wales. Cardiff. (Revised edition, 1962).

L. E. Seltzer, ed. The Columbia Lippincott Gazetteer of the World With 1961 Supplement. New York. (1962).

J. Thewlis, ed. The Encyclopaedic Dictionary of Physics. Oxford. (1961, 9 Vols.).

A. Webels. Technical and Scientific Dictionary. (1930).

II. Monographs

W. H. G. Armytage. A Social History of Engineering. (1961).

W. R. Aykroyd. Three Philosophers. (1935).

D. B. Barton. A History of Tin Mining and Smelting in Cornwall. Truro. (1967).

A. J. Berry. Henry Cavendish, His Life and Scientific Work. (1960).

F. Bickley. The Cavendish Family. (1911).

E. T. Bradley. Life of the Lady Arabella Stuart. (1889, 2 Vols.).

J. A. Bradney, History of Monmouthshire, Hundred of Trelech. (1904-1933, 4 Vols.), especially Vol. 2, part 2.

P. Cane, Giants of Science. New York. (1959), especially pp.62-65.

H. W. Dickinson, and R. Jenkins. James Watt and the Steam-Engine. Oxford. (1927).

J. Entwistle. Memoir by His Son: Fifty-Four Years a Wesleyan Minister. Wesleyan Conference Office, City Road, London. 9th Edition. (1867).

T. C. Fitzpatrick, A. Schuster, et. al. A History of the Cavendish Laboratory, 1871-1910. (1910).

T. D. Ford, and J. H. Rieuwerts, eds. Lead Mining in the Peak District. Peak Park Planning Board, Bakewell. (1968).

J. R. Green. A Short History of the English People. (1874, Revised and Enlarged, 1919).

D. Greene, The Glass-Works, Rotherham (1751-1951). Rotherham. (1952), especially pp.1-12.

P. M. Handover. Arbella Stuart. (1957).

E. J. Holmyard. British Scientists. (1951), especially 'The Pneumatic Chemists', pp.34-36.

R. Irwin. The Origins of the English Library. (1958).

R. Irwin. Supplementary Notes to 'The Origins of the English Library'. (1959). University of London School of Librarianship and Archives. Occasional Publications No. 9.

R. Irwin. The Heritage of the English Library. (1964).

A. H. John. The Industrial Development of South Wales 1750-1850. Cardiff. (1950).

E. Larsen. The Cavendish Laboratory. 1962.

P. Mantoux. The Industrial Revolution in the Eighteenth Century. (1928, revised edition 1961).

W. E. Minchinton. The British Tin-Plate Industry. Oxford. (1957).

R. Neves and C. Downie. Geological Excursions in the Sheffield Region and the Peak District National Park. Sheffield. (1967).

C. Singer, E. J. Holmyard, et al., eds. A History of Technology. Vol. IV, The Industrial Revolution - c.1750-c.1850. Oxford. (1956).

S. Smiles. Lives of the Engineers Boulton and Watt. (1904).

A. J. P. Taylor, R. R. James, et al. Churchill, Four Faces and the Man. (1969).

F. W. Thompson. A History of Chatsworth. (1949).

C. R. Weld. A History of the Royal Society. (1848, 2 Vols.).

C. Wilkins. A History of the Iron, Steel, Tinplate and Other Trades of Wales. Merthyr Tydfil. (1903).

E. Carleton Williams. Bess of Hardwick. Glasgow. (1959).

G. Wilson. The Life of the Honble. Henry Cavendish. (1851).

III. Articles

E. S. Barr. 'Henry Cavendish', in American Journal of Physics. Vol. 28, No. I. New York, May 1960, pp.463-466.

G. R. Batho. 'The Library of the 'Wizard' Earl: Henry Percy, Ninth Earl of Northumberland 1564-1632', Transactions of the Bibliographical Society 'The Library', Fifth Series, Vol. XV, No. 4, Dec. 1960, pp.246-261.

D. C. Goodman. 'Henry Cavendish', in R. C. Olby, ed., Late Eighteenth Century European Scientists. Oxford. (1966), pp.95-126.

G. Grigson and C. H. Gibbs-Smith, eds. People. Englewood Cliffs, N.J., (1956), especially Henry Cavendish, pp.59-60.

H. Guerlac. 'Joseph Black and Fixed Air', Isis, Vol. 48, Part 2. (1957), pp.433-456.

T. R. Harris, 'John Edwards - 1731-1807, Cornish Industrialist'. Transactions of the Newcomen Society, Vol. XXIII, 1942-1943. (1948), pp.13-22.

R. V. Louis, ed. 'Historic Researches, No. XVII, Chemical Elements and Atoms: Henry Cavendish', The Engineer, Vol. 182. New York. (1946), p.136.

A. M. Low. 'The Hon. Henry Cavendish' in A. M. Low, They Made Your World. (1949), pp.41-44.

R. McCormach. 'John Michell and Henry Cavendish: Weighing the Stars'. The British Journal for the History of Science, Vol. 4, No. 14. (1968), pp.126-155.

R. McCormach. 'Henry Cavendish: A Study of Rational Empiricism in Eighteenth Century Natural Philosophy', Isis, Vol. 60, Part 3, No. 203. (1969), pp.293-306.

L. B. Namier. 'Anthony Bacon, M.P. An Eighteenth Century Merchant'. (Journal of Economic and Business History, Part II, 1929), reprinted in W. E. Minchinton, ed. Industrial South Wales 1750-1914. (1969).

J. R. Partington. 'Cavendish' in A History of Chemistry, 1700-1800. (1961-1964, 5 Vols.), Vol. 3 (1962), pp.303-362.

M. Schofield. 'Henry Cavendish', Chemistry and Industry, Vol. 62, (1943), pp.41-42.

C. Susskind. 'Henry Cavendish, Electrician', Journal of the Franklin Institute, Vol. 249, No. 3. New York (Mar. 1950), pp.181-188.

T. Young. 'Life of Cavendish' (From the Supplement to the Encyclopaedia Britannica 1816-1824). Reprinted as an appendix to The Scientific Papers of the Honourable Henry Cavendish, F.R.S., Vol. I. Cambridge. (1921), pp.435-447.