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History of geology

Mineral Resources

Early humans needed a knowledge of simple geology to enable them to select the most suitable rock types both for axe-heads and knives and for the ornamental stones they used in worship.

In the Neolithic and Bronze Ages, about 5000 to 2500 BC, flint was mined in the areas which are now Belgium, Sweden, France, Portugal and Britain.

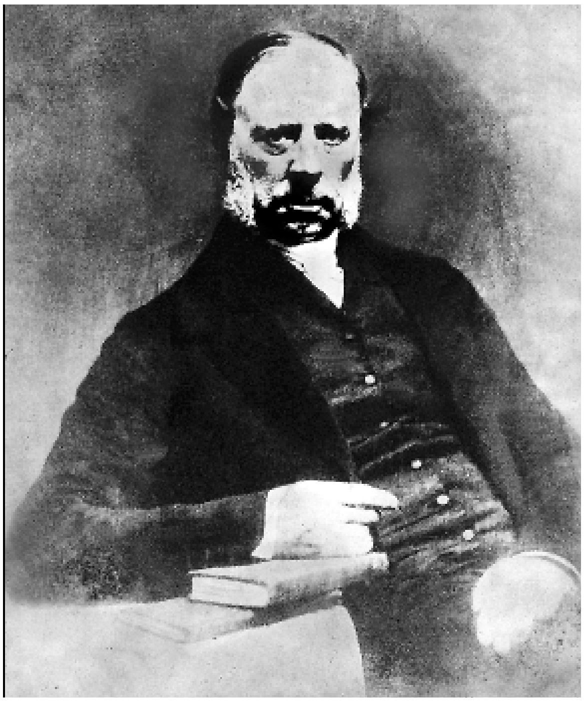
While Stone Age cultures persisted in Britain until after 2000 BC, in the Middle East people began to mine useful minerals such as iron ore, tin, clay, gold and copper as early as 4000 BC. Smelting techniques were developed to make the manufacture of metal tools possible.

Copper was probably the earliest metal to be smelted, that is, extracted from its ore by melting. Copper is obtained easily by reducing the green copper carbonate mineral malachite, itself regarded as a precious stone. From 4000 BC on, the use of clay for brick-making became widespread. The smelting of iron ore for making of tools and weapons began in Asia Minor at about 1300 BC but did not become common in Western Europe until nearly 500 BC.

The classical period

By recognising important surface processes at work, the Greek, Arabic and Roman civilisations contributed to the growth of knowledge about the earth. Aristotle, for instance, recognised erosion and deposition of surface material. Empedocles and Pliny left descriptions of eruptions at Etna and Pompeii. The early philosophers did not leave much in the nature of records. Some of the theories put forward at the time to explain natural phenomena were based more on speculation than on observations and may seem amusing today.

At about 540 BC, Xenophanes described fossil fish and shells found in deposits on mountains. Similar fossils were noted by Herodotus (about 490 BC) and by Aristotle (384-322 BC).



Reverend William Branwhite Clarke (1798-1878), the 'father' of geology in New South Wales

Aristotle believed volcanic eruptions and earthquakes were caused by violent winds escaping from the interior of the earth. Since earlier writers had ascribed these phenomena to supernatural causes, Aristotle's belief was a marked step forward. Eratosthenes, a librarian at Alexandria at about 200 BC, made surprisingly accurate measurements of the circumference of the earth by plotting the angles between the perpendicular and the sun's rays at two locations (Syene and Alexandria) on the same meridian. This gave him a measure of the earth's curvature between the two locations. The Arabs recognised the magnetic properties of magnetite and used it to make crude compasses.

Medieval and renaissance times

Although in the Middle Ages there was no marked general interest in geology, some advances were made. Authors such as Isidore of Seville (AD 570-

636) and Vincent de Beauvais and Bartholomew the Englishman, both in the 13th Century, kept alive and developed the ideas of earlier writers.

Leonardo da Vinci (1452-1519) scientist and inventor, recognised that fossil shells are the remains of once-living organisms and that changes had occurred in the relationship between sea and land. Georg Bauer, also called 'Agricola' (1494-1556) did much to advance the knowledge of minerals and metal carrying veins. His great work 'De Re Metallica' (1556) gives a clear description of mining and metallurgy as they were carried out at the time. The illustrations in this famous book are particularly instructive.

In 1565 in Switzerland, Conrad Gesner published a fine descriptive and illustrated work with a long Latin title which meant, in short, ‘all about fossils, stones and gems’. In England George Owen carried out systematic observations on strata as early as 1570, but unfortunately his work was not published until 1796.

The seventeenth and early eighteenth centuries

Until the time of Nicholas Steno (1638-1686), most advances in geological knowledge were in the fields of mineralogy and mining. Steno studied rocks in the field in a broad geological way and used direct observation to enable him to reach a number of useful conclusions.

Particular aspects of sedimentation had been recognised earlier but Steno was the first to state important principles about layers of sedimentary rock. He illustrated his theories with diagrams showing the geological history of Tuscany. He divided the history into six phases and believed, wrongly, that the six phases were of worldwide application.

In the Eighteenth Century it became popular among men of culture to record their findings in the natural sciences. The succession of rocks in the coalfields of England became well documented and it was believed to apply over a much wider area. In 1719 and 1725 John Strachey published two interesting illustrated papers showing the order of rocks in south-west England. He pointed out that, although the coal strata were all more or less inclined, the overlying rocks lay horizontally across them.

Elsewhere in Europe the first real attempts to apply systematic subdivisions to the rocks were made by Giovanni Arduino (1714-1795) in Italy, Johann Lehmann (1719-1767) in Germany and Peter Pallas (1741-1811) in Russia. Arduino classified the rocks of Northern Italy into Primitive, Secondary, Tertiary and Volcanic. His classification was based on the appearance of the rocks and on the occurrence of fossils.

Lehmann in 1756 distinguished three orders of mountains:

a) those he believed to have been formed when the world was made;
b) those formed from sediment deposited in sheets under water;
c) volcanic mountains.

Lehmann's work was followed by that of George Fuchsel (1722-1773) who published in 1762 one of the first geological maps in his book 'A History of the Earth and the Sea, Based on a History of the Mountains of Thurinqia'.

Pallas, in Russia, recognised three broad divisions of mountains and rock groups. He saw that there was clear evidence of the presence of the sea in former time in some areas and supposed that the elevation of the mountains was caused by uplift during what he termed ‘commotions of the globe’.

Geology becomes a science

Development of geology as a separate branch of science took place in the years between 1775 and 1830. Geologists commemorate 1775 as the year in which, at a small mining academy at Freiburg in Germany, geology was first taught by Abraham Werner. Charles Lyell published the classic textbook, 'Principles of Geology', in 1830-1833. Many basic principles of geology were recognised and described during this period. Particularly important were those set out by James Hutton in Scotland. Two other writers of note were William Smith in England and Georges Curvier in France.

Abraham Werner (1749-1817) was a careful mineralogist who drew up an excellent system of classification of minerals based on their properties. He did not travel extensively, but based most of his geological ideas on the small region around Freiburg with which he was familiar. Unlike many present-day scientists, Werner published few of his theories but the ideas presented in his popular lectures were soon spread throughout Europe by the enthusiasm of his students.

Werner held that rocks such as granite had formed during the earth's early history by crystallisation in a worldwide ocean. He concluded therefore that the oldest rocks in any region were granites and other crystalline rocks. He did not believe that volcanoes were important in past geological eras. Because of his theory that what are known today as igneous rocks originated in the sea, Werner and his followers were called Neptunists.

James Hutton (1726-1797) must be regarded as the ‘father of modern geology’. A medical graduate of Edinburgh University, Hutton inherited a comfortable income and took up farming. He spent a great deal of time examining interesting rock outcrops in Scotland and Northern England, and presented his ideas to the Royal Society of Edinburgh in 1785 in a paper entitled 'Theory of the Earth'. The Royal Society of Edinburgh was at that time the most active scientific body in the world.

Hutton recognised the importance of unconformities and pointed out that many igneous rocks clearly intruded surrounding rocks, and therefore were younger. Because Hutton and his followers held that igneous rocks came from molten material within the earth, they were called Plutonists. His friend, the mathematician John Playfair (1748-1819) publicised Hutton's theories and added further ideas.

Argument between Plutonists and Neptunists continued until nearly 1820, but eventually the views of the former group were found to be valid. Several of Werner's best pupils became Plutonists after becoming convinced by field evidence. Leopold van Buch (1744-1852), in particular, recognised the extinct volcanoes of Auvergne and described them correctly, thus making an important step in the recognition of ancient volcanic activity.

Hutton's most important concept was that of uniformity – the idea that processes active today were also active in the past, and thus that all geological phenomena can be understood in the light of present processes. The concept was developed from earlier ideas of G.H. Toulmin and became known as 'uniformitarianism'.

William Smith (1769-1839) is regarded as one of the greatest of the early geologists. His recognition of stratigraphical successions based on fossils and his excellent geological maps mark the beginning of a new era in geology. Despite his scanty writings, Smith's ideas and maps justify his eminent place in the history of geology. In 1815 he wrote: "I have, with immense labour and expense, collected specimens of each stratum, and of the peculiar extraneous fossils, organic remains and vegetable impressions, and compared them with others from very distant parts of the island, with reference to the exact habitation of each, and have arranged them in the same order as they lay in the earth; which arrangement must readily convince every scientific or discerning person that the earth is formed as well as governed, like the other works of its great Creator, according to regular and immutable laws which are discoverable by human industry and observation and which form a legitimate and most important object of science".

By the end of the 18th Century there was general agreement about the order of formation of the rocks in Europe. The accepted stratigraphic succession was as follows:

- Tertiary and Volcanic
- Secondary
- Transition
- Primitive.

The establishment of a geological time scale

In 1822 the local names given by Smith to many units of the Secondary rocks began to be used in a wider sense and became the names in use today. W. Phillips and W.D. Conybeare suggested the name Carboniferous for what were popularly called 'coal measures'.

The name Cretaceous (creta, chalk) was introduced by d'Halloy for the chalk rocks of England and France. The Jurassic System was also named by d'Halloy.

The Jurassic System was the one which William Smith studied most when he established the principles of stratigraphy. At about the same time, Baron Cuvier, a French biologist and geologist, established, in association with Alexander Brongniart, new standards and methods in stratigraphy, and especially in palaeontology. Cuvier wrote "the most important consideration ... is to ascertain the particular strata in which each of the species was found, and to observe the greater or less resemblance between these fossil species and those which still exist upon the earth".

Cuvier thought that changes in the fossils found in rock successions indicated sudden revolutions in which deposition was halted and living forms were destroyed, being replaced later by newly created forms. He wrongly believed that only a certain number of species had ever existed and that those destroyed were always replaced by an equal number at the end of each period of geological time. Cuvier's 'catastrophic theory' exerted a great influence on geology for many years.

In 1833 Adam Sedgwick, professor of geology at Cambridge, mapped rocks in Wales which he called Cambrian after the old Roman name for Wales. At the same time Charles Lyell was suggesting a subdivision of the Tertiary period based on the relative number of fossils similar to living forms. His subdivision is still largely accepted. In Germany von Alberti introduced the name Trias (sic), and in 1835 Roderick Murchison published his work on the Silurian System.

Murchison's Silurian rocks included some which Sedgwick regarded as Cambrian. The two, who had been friends, fell out and each refused to alter his ideas. A solution was finally proposed by

Lapworth in 1879 when he named the Ordovician System. It included the upper part of Sedgwick's Cambrian and the lower part of Murchison's

Silurian. In 1840, after visiting Russia, Murchison named the Permian System (Perm in Russia), while the Devonian System (Devon in England) was named in the same year. About 1855 William Logan in Canada studied rocks older than the Cambrian and called them the Precambrian System. Thus, by the middle of the Nineteenth Century, the general geological time scale based on fossils and stratigraphic mapping was established.

Hutton, Lyell and others recognised that the principle of uniformitarianism required very long periods of time, and that the presence of unconformities indicated long time breaks when a local area was being eroded.

There was, however, considerable opposition to the geological method of calculating the ages of minerals and rocks, both from religious authorities and from physicists.

Some of the former based their concept of the age of the earth on Biblical chronology calculated by Bishop Ussher in the 17th Century. They thus thought that Creation occurred in 4004 BC.

The physicists, led by Lord Kelvin, maintained that the earth could not be more than 100 million years old. They made the assumption that the earth began as a molten mass and was in process of cooling. The discovery of radioactivity in minerals about 1896 showed that the earth was cooling down at a much slower rate than Kelvin had estimated and thus his figure for the age of the earth was too low. Since then techniques based on the breakdown of radioactive isotopes of uranium, strontium, potassium, carbon and other elements have made it possible to measure the age of the earth and the extent of each geological period.

Other geological advances

During the second half of the l9th Century, while stratigraphic data on various parts of the world were being refined, many other geological advances were being made.

The science of petrology had its origin early in the l9th Century in the careful descriptions of rock specimens by von Buch, Nicol and others. Petrology expanded rapidly after the development of the petrological microscope. In 1851 in England H.C. Sorby published the first description of thin sections of sedimentary rocks, and in 1870 Zirkel described basalts in Germany.

Important advances in the understanding of the chemistry of rocks followed. Bunsen (of bunsen burner fame) suggested in 1851 that igneous rocks were derived from two separate magmas, ‘acid’ and ‘basic’. V.M. Goldschmidt, who collected a vast amount of data about the distribution of elements in the earth's crust and interior, may be considered the founder of the science of geochemistry. At about 1910, Bowen began laboratory studies in experimental petrology, examining the behaviour of melts of silicates under various conditions. Similar experimental work is now being widely carried out with greatly improved equipment which can simulate high pressures and high temperatures and assist in the study of the complicated chemical reactions taking part in the deep crust of the earth.

Geomorphological studies were advanced by the work of Agassiz, who in the 1840s recognised the effects of Pleistocene glaciation in Europe and the USA. Later Gilbert and Powell made classical studies on arid erosion in the western USA. The strongest influence up to 1900 was the work of W.H. Davis, an American who worked both in USA and Europe and who first defined the cycle of erosion.

Davis pointed out that the landscape was the product of the underlying structure (rock type, folding, etc.) the acting processes, and time. Davis concentrated on climatic conditions and structure, but later geomorphologists have given more detailed attention to a wide range of processes, including river action and sea erosion.

The development of geology in Australia

Geology before Clarke

Much of the stimulus of the earliest workers came from encouragement by Sir Joseph Banks who, until his death in 1820, maintained a great interest in scientific discoveries in Australia. Banks was responsible for the purchase of drilling equipment. It arrived in Sydney in 1800 and was used in the search for coal, first near Liverpool then at Newcastle. He also encouraged Bass and Flinders in their early exploration.

The botanist Robert Brown, who travelled with Flinders around Australia in 180l-1802, collected many rock samples which aroused interest in Europe. In 1803 A.W.H. Humphreys was appointed as official mineralogist.

Although Humphreys carried out some surveys in Tasmania, Victoria and New South Wales, he was not enthusiastic about the work and eventually retired to become a magistrate in Tasmania.

Explorers such as Oxley and Cunningham, the Frenchmen Baudin and Peron, Alexander Berry, and later Mitchell and Sturt gathered much valuable geological data about Australia. In particular Mitchell's reports on the extinct vertebrates preserved in Wellington Caves were important to scientists in all parts of the world.

In 1836 Charles Darwin visited New South Wales. He was in error in attributing the formation of the huge valleys of the Blue Mountains to the action of the sea and to faulting. Darwin was enthusiastic about the variety of geological formations he saw about him. He had learnt much of his geology through studying the great 'Principles of Geology' by his friend, Charles Lyell. About the same time J.B. Jukes made many important observations around the Australian coast during the voyage of the HMS Fly.

W.B. Clarke, 1839-1878

The Reverend W.B. Clarke had studied geology at Cambridge under Professor Sedgwick. He was well trained in the stratigraphic principles of Cuvier and Smith. Shortly after his arrival he worked with JD Dana, a famous American geologist who visited Sydney with the US Exploring Expedition of 1838-1842. They examined localities such as Prospect Hill and the Blow Hole at Kiama and described the rocks around Sydney and Newcastle.

Clarke published many papers and books of great importance, particularly 'Remarks on the Sedimentary Deposits of New South Wales' and 'Report on the Southern Goldfields of New South Wales'. Clarke recognised the order of deposition of the rocks of the Sydney Basin and was particularly interested in the coal measure rocks.

During the 1840s many interesting characters carried out geological work. They included ‘Count’ Strzelecki and Dr Leichhardt the explorer. Strzelecki published a geological map of eastern Australia which summarised the knowledge of his day, Leichhardt made careful measurements at Newcastle, in the New England region of New South Wales and in Queensland.

The Geological Surveys, 1851-1891

Just before gold discoveries at Bathurst became public in 1851, the New South Wales Government had appointed Samuel Stutchbury to the position of Mineral Surveyor, after trying to get several other persons from the British Survey. Stutchbury had previous knowledge of Sydney. He had visited the colony in 1825 prior to surveys in the South Pacific and Tahiti, returning to England in 1827. As Mineral Surveyor in New South Wales he was carrying out detailed surveys in the Bathurst region when gold was discovered at Ophir. He immediately went there and as the sole official prevented the gold rush becoming a riot. His report to the Government outlined clearly the nature of the gold occurrences. Stutchbury was treated poorly in Australia and was opposed by Clarke. He made careful surveys of the Bathurst – Hill End – Wellington area and later moved north into Queensland. On his journey to Moreton Bay Stutchbury conducted a comprehensive survey of the Newcastle Coalfields, extending through to Wellington and the Warrumbungles area in 1853. He surveyed the Darling Downs, Brisbane and Ipswich areas and later the islands of Moreton Bay in 1854. Stutchbury returned to England in 1856 after supplying an excellent series of reports, maps and diagrams to the New South Wales Government.

In 1853 the Victorian Government, instead of appointing a single geologist, set up a Geological Survey under the direction of A.R.C. Selwyn from the British Geological Survey, then the best equipped in the world. Selwyn was a man of enormous energy, a skilled geologist and a stern disciplinarian. He set to work to train his men in the methods of geological mapping and soon produced some excellent geological maps of the mining areas of Victoria.

Among the men trained by Selwyn were CS Wilkinson, H.Y.L. Brown, R.L. Jack, Brough Smyth and E.F. Pittman. In 1869 the Victorian Government refused Selwyn's demands for increased funds for the Survey and he resigned. Selwyn departed to Canada where he later built the Canadian Survey into an efficient organisation. R.A.F. Murray, Brough Smyth and A Howitt continued the Victorian Survey, with little assistance, for many years. Howitt's study of the petrology of some igneous and metamorphic rocks was the first detailed work of this nature carried out in Australia.

In 1873 the New South Wales Government agreed to set up a Geological Survey. They had previously employed Clarke on a part-time basis during Stutchbury's time in Australia and had inspectors of coal mines such as J. Keene and J. MacKenzie carrying out some geological mapping. C.S. Wilkinson was chosen as leader. Wilkinson rode from Melbourne on horseback visiting mining fields in southern New South Wales and arriving in Sydney several months later with his first report ready. Later the New South Wales Survey employed men of the calibre of E.F. Pittman, J.B. Jaquet, T.W.E. David and J.E. Carne.

H.Y.L. Brown became Government Geologist of South Australia, working almost alone until about 1910. R.L. Jack, R. Daintree and R. Etheridge became geologists in Queensland and carried out good work under difficult conditions during the 1870s and 1880s.

Although individual geologists such as Bruhn and Milligan had worked in Western Australia and Tasmania, geological surveys were set up rather late in those states. H.P. Woodward began in Western Australia in 1882.

The Tasmanian Survey under W Twelvetrees was inaugurated in 1899, although Charles Gould had carried out important surveys in Tasmania between 1859-1862 during which he named the ‘geological’ mountains such as Mt Lyell, MT Murchison, etc. in Western Tasmania.

The major contributions up to 1890 were made by the surveys, but among other men who contributed were Fr J. Tenison-Woods (particularly in South Australia), DR Odernheimer (Newcastle Coalfield 1855), Professor R. Tate (South Australia) and G. Thureau (Tasmania).

The formation of the geological surveys ensured the continued development of geology, which was aided by the later development of University research.

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