HOLIDAY GEOLOGY

Hutton, Hall and Darwin: a Tale of Two Cities

Many cities have little to offer the visiting geologist, except perhaps the interest of their building stones and their museums. How lucky then to visit cities where the geology dominates the environment wherever one turns and even a business trip can turn into a mini-holiday. This year we have been to two such cities, Edinburgh and Cape Town, where the geology is not only spectacular, but is also linked by field observations in the 18th and 19th centuries that were important in the debate between Neptunists and Plutonists. These critical features are still easily seen today.

Edinburgh

The centre of Edinburgh is dominated by early Carboniferous Visean basaltic volcanics that were extruded over the Inverclyde and Strathclyde Groups of sediments. Castle Rock, a volcanic plug, overlooks the old city centre. To the east, Arthur`s Seat volcanics, forming Calton Hill, Whinney Hill and the vents of Arthur`s Seat itself, are largely within Holyrood Park. Perhaps the most striking feature is the analcime dolerite (teschenite) sill of Salisbury Crags intruded in the late Carboniferous, largely concordant with, but cropping out through, Inverclyde sandstones and marls. It extends 900 m from the north, where it is about 40 m high, with prominent vertical jointing and layering parallel to the top and base of the sill, before it thins to the south, ending close to the Lion's Head vent on Arthur`s Seat. Contact with the overlying sediments is only seen to the north of the sill, but the lower contact is observed at several points adjacent to the Radical Road along the base of the crags; the most famous of these is Hutton`s section, close to the southern end of the sill, which formed part of the evidence in the controversy with the Neptunists.

James Hutton and Salisbury Crags

We were Edinburgh medical students in the early/mid 1950`s and rushed to Salisbury Crags on Sunday mornings to climb in the Little Quarry before the park keepers came on duty. Geologically ignorant, we passed Hutton`s section without a thought and it was nearly 35 years later before we became aware of its significance. Now, whenever we return to Edinburgh we take a slower walk round the Radical Road to reverentially revisit the section, a few metres in front of the crag face (Fig. 1). At two places, the lower margin of the dolerite sill is seen with a chilled edge transgressing the subjacent laminated marls and sandstones, distorting and wedging them upwards, indicating a forcible intrusion by a hot molten magma into the country rocks. A slab of sedimentary rock has been torn away and the broken ends of the sedimentary strata were rotated upwards by the intrusion. Towards the top of the sill, a little way to the south-east, inclusions of sedimentary rock within the dolerite are seen. Hutton's section provided conclusive field evidence that the Salisbury Crags sill was formed from a magma that intruded into older layers of sedimentary rock - but this was initially disputed.

Neptunists, Vulcanists and Plutonists

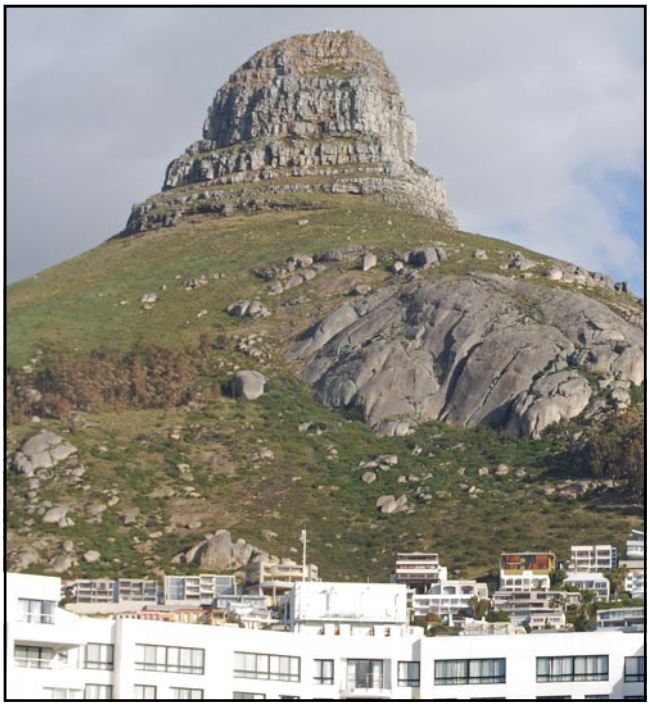
A bitter dispute began in the 18th century when Italian geologists challenged the traditional (Neptunist) view that all rocks including basalts and granite originated as aqueous precipitates or sediments. Following the discovery of the ancient volcanoes in Auvergne, Demarest of France suggested that basalt was of volcanic origin and this started the battle between Neptunists and Vulcanists. Neither Hutton nor Professor Werner of Saxony, later the leading protagonist of Neptunism, was involved in the initial skirmishes. Hutton`s interest in geology began about 1753 when farming in Norfolk. But not until 1785, when he read the *Theory of the Earth* to the Royal Society of Edinburgh, published in the *Transactions of the Royal Society of Edinburgh* in 1785 and in book form 10 years later, did he established his position as a Plutonist - developing the view that granites and not only basalts are of igneous origin. He positively sought out places where granite veined the country rock, in Glen Tilt, on Arran and in Galloway, confirming his theory that some granites might not only have been molten but also "been made to flow in the bowels of the earth, in like manner as these great masses of our whinstone and porphyry which may be considered as subterranean lavas".

Hutton was notoriously obscure in his writings. He was unpopular as an alleged atheist and free thinker and after his death his views were opposed by Neptunists, led in Europe by Werner, in Ireland by Professor Kirwan (subsequently President of the Royal Irish Academy) and even in Edinburgh by Professor Robert Jameson. His work was defended and reinterpreted by his friend John Playfair, Professor of Mathematics, in *Illustrations of the Huttonian Theory* and later by Charles Lyell author of the epoch making *Principles of Geology*.

Figure 1. *Hutton`s section on Salisbury Crags, with distortion of the marls and sandstones by the overlying intrusive dolerite.*

***Figure 2**. Table Mountain from the Waterfront, showing the steep cliffs formed by the Table Mountain Group Sandstones.*

***Figure 3**. The Lion`s Head above Sea Point, with Table Mountain sandstones overlying the rounded, pale granite intrusion.*



Charles Darwin at Edinburgh and Cambridge

Darwin went to Edinburgh in 1825 to study medicine, and attended the official university lectures, but complained that most were stupid and boring. He was disgusted by the dull and outdated anatomy lectures of Professor Alexander Munro Tertius who, appointed in 1798, was content to read to his students his grandfather`s lectures, a century old, and although he had never been to Leyden still included the remark "When I was a student in Leyden in 1719...."! Darwin was sensitive to the sight of blood. He regularly attended clinical wards and was greatly distressed; he went to surgical operations only twice, rushing away before they were completed, upset by the brutality of surgery without anaesthetics.

The chemistry lectures of Thomas Hope, a friend of Hutton, were an exception to the general dullness, and he taught Huttonian views opposing those of Werner. Darwin also took the natural history course of Professor Robert Jameson, which included stratigraphic geology, mineralogy and some field geology. Jameson, a pupil of Werner, forcefully taught that strata were precipitated crystallised from molten crust. Darwin left Edinburgh in 1827, without qualifying and with the determination "never as long as I lived to read a book on geology or in any way study the science".

He entered Cambridge in 1828 to prepare for the Anglican clergy and found the tutorial system more to his liking than didactic Scots lectures. He passed his exams in 1831, but, with two terms before graduation, was crammed in geology by Henslow, his tutor. He probably attended lectures by Adam Sedgwick, and accompanied him for geological field studies in North Wales. After Edinburgh and Cambridge, Darwin was well aware of the Neptunist v Plutonist dispute and of the significance of Huttons`s observations on Salisbury Crags. He was aware of Sedgwick`s view that the evidence of the igneous formation for Northumberland trap rock was complete, and was able to contrast it with Jameson lecturing on a trap dyke in Salisbury Crags and ascribing it to sediments filled in from above but "adding with a sneer that there were men who maintained that it had been injected from beneath in a molten condition".

In September 1831 he was offered the post of geologist, naturalist and gentlemanly companion to Captain FitzRoy of H.M.S. Beagle and sailed from Plymouth in December, 1831. He landed in Cape Town in 1836 on the voyage back to England.

Cape Town

Table Mountain presents an iconic image (Fig. 2) and is the northern end of a sandstone mountain range forming the spine of the Cape Peninsula. Its main feature is a level plateau 1085 m high and about 3 km wide, surrounded by steep cliffs. The plateau, flanked by Devil`s Peak to the east and by Lion`s Head to the west, together with Signal Hill (or Lion's Rump), forms a natural amphitheatre about central Cape Town and Table Bay harbour. To the south of the main plateau, along the Atlantic coast the range continues as the Twelve Apostles, a series of buttresses divided by faults, with resort towns at the foot, and then onwards to Cape Point.

The oldest rocks forming much of the lower ground are Precambrian sediments, the Malmesbury group of greywackes and shales, deposited as turbidites on

the continental slope of the Adamastor ocean and subsequently distorted in the Saldanian orogeny with folding best seen between the Waterfront and Sea Point or on Robbens Island. The sediments were intruded by the Peninsula granite during the Ordovician (540 Ma) and contacts can clearly be seen on the Lion`s Head and Rump (Fig. 3) as well as on the sea shore at Sea Point. Table Mountain Group sandstones, of fluvial, deltaic, tidal flat and shallow marine origin, were deposited on the eroded basement of Malmesbury sediments and granite. The basal Graafwater Formation, composed of 50 m of thinly bedded, pale brown sandstones and maroon shales, is distinctive, and along Chapman`s Peak Drive is seen lying directly on the granite (Fig. 4). Above, about 500 m of more thickly bedded pale grey sandstones of the Peninsula Formation form the ramparts of Table Mountain and extend southwards as far as Cape Point. Small remnants of diamictites related to Ordovician glaciation are found near Maclear`s beacon on the plateau summit.

Captain Basil Hall at Cape Town

Basil Hall R.N. was the second son of Sir James Hall of Haddington, a companion and friend of Hutton and a protagonist of the igneous origin of granite. Basil visited Cape Town in 1812, and his observations of Table Mountain, in a letter to his father, were presented to the Royal Society of Edinburgh by Playfair in 1813**.** He described vertical beds of "Schistus or Killas" (Malmesbury greywackes) on the lower slopes of Table Mountain penetrated by veins from the main granite and similar features on the Lion`s Head and Rump: "the contact was the finest thing of the kind I ever saw..... The number of veins that we could distinctly trace to the main body of the granite was truly astonishing; and the ramifications which extended on every side, were of all sizes from the breadth of two yards to the hundredth of an inch. Masses of killas cut off entirely from the main body of that rock floated in the granite without numbers, especially near the line of contact and the strata there appeared broken, disordered, and twisted in a most remarkable degree." Higher up the mountain, he noted a line where the granite ceased to

Figure 4. *Contact between pale granite and overlying pink Graafwater Formation is clearly seen in the view, from Hout`s Bay, of Chapman`s Peak road, which runs horizontally for several kilometers along the contact.*

Figure 5. *On the shore at Sea Point, pale granite, on the right, infiltrates sub-vertical beds of the Malmsbury Group with melting and migmatisation.*

be succeeded by strata of horizontal and undisturbed sandstone (Table Mountain Group Sandstones). Playfair concluded that the granite younger than the greywacke "has come up from below.... and is not one of which the materials have been deposited by the sea in any shape either mechanical or chemical. It is a species, therefore, of subterraneous lava.... (that) has always existed in the bowels of the earth..... and is highly favourable to the opinion that granite does not derive its origin from aqueous deposition".

Charles Darwin at Cape Town

Darwin visited Cape Town in 1836 on the return journey of the Beagle to England. There he went to the granite/sedimentary contacts on the Lion`s Head and Rump recorded by Hall, and gives Hall precedence in his notebook. He also visited Sea Point shore where granite infiltrates the Malmsbury Group sediments (Fig. 5), producing a spotty hornfels with andalusite and cordierite crystals and a narrow zone of migmatisation that extends up towards Lion`s Head. Large xenoliths of country rock are contained within the granite and he wrote to Lyell concerning his findings, and their significance in the genesis of igneous rocks. A memorial plaque existed at Sea Point to commemorate Darwin`s visit and observations. Alas, in modern South Africa scrap metal is worth more than sentiment, and the plaque has been vandalised, leaving the seashore exposure to speak for itself, as ever.

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