ARE ALL THE COLOSSAL IGNEOUS CAPS OF THE TASMANIAN TIERS AND OF THE LOFTY MOUNTAIN PLATEAUX TRUE SILLS?

By R. M. Johnston, F.L.S., F.S.S.

Professor T. W. Edgeworth David, B.A., F.G.S., one of Australia's most distinguished geologists, has kindly sent me a copy of an interesting paper read by him before the Royal Society of New South Wales in the year 1896, regarding the occurrence of "Sill Structure" in the eruptive rocks of that colony.

It has additional interest for Tasmanian geologists, inasmuch as it raises the question at the head of this paper, viz.—"Are all the Colossal Igneous Caps of the Tasmanian Tiers, and of the Lofty Mountain Plateaux—such as Ben Lomond, Mount Wellington, and the Great Plateaux of the Lake Country—True Sills?"

Igneous Sheets or Sills.

Sir Archibald Geikie gives a very graphic description of the nature and characteristic structure of an Igneous Sill as follows:—(Text Book of Geology, pp. 573—576.)

"Eruptive masses have been intruded between other rocks and now appear as more or less regularly defined beds. In many cases it will be found that these intrusions have taken the place between the planes of stratification, The ascending molten matter, after breaking across the rocks, or rather, after ascending through fissures either previously formed or opened at the time of the outburst, has at last found its path of least resistance, to lie along the bedding planes of the strata. Accordingly it has thrust itself between the beds, raising up the overlying mass and solidifying as a nearly or exactly parallel cake, sheet, or sill. It is evident that one of these intercalated sheets must present such points of resemblance to a subaerial stream of lava as to make it occasionally a somewhat difficult matter to determine its true character, more especially when, owing to extensive denudation or other cause, only a small portion of the rock can now be seen."

So far we have a very clear definition of the manner in which true igneous sills have been formed, and their mode of intrusion along the weaker planes and fissures of strata beneath the surface. In Tasmania there are abundant illustrations of clearly defined massive sills open to inspection, especially so, along the precipitous walls of the coast line between Blackman's Bay and Cape Frederick Henry.

About 14 years ago I drew the attention of the members of this Society (1) to one of these remarkable sills exposed on the coast line near Blackman's Bay, intercalated between the stratified beds of permo - carb. mudstones and limestones; and in my large work on "The Geology of Tasmania, I again described this sill or intercalated igneous sheet—illustrated by enlarged drawings of sections (2)—in the following words:—

"In various places along the coast line of the Lower Derwent many natural sections occur where the fossiliferous mudstones (apparently) unaltered at point of contact, repose quietly in horizontal beds which naturally fill up the uneven surface of the underlying older greenstone. A sketch of a very fine section is given showing this relation for several miles between Blackman's Bay and Passage Point. One section in particular not only shows in an unmistakable manner that the fossiliferous mudstones are more recent (3) than the main mass of the older greenstone upon which they rest, but that both are older than a minor dyke or sheet of greenstone of a somewhat similar character to the older. This intrusive greenstone after bursting vertically through the older greenstone (basal sill), and the lower beds of sedimentary limestone, *suddenly bends back and forms a sheet about seven feet thick, running parallel and intercalated between the stratified planes of the marine mudstones.* Fine sections showing the same relationship also occur for miles continuously between Passage Point and Adventure Bay."

It is not surprising, therefore, that some years later (1892) Professor David, Captain Hutton, and others, to whom I had per-

---

(1) Proc. Roy. Soc. Tas., 1885, pp. 343 360, 410; *ibid*, 1886, pp. 18-26, illustrated by a number of plates and diagrams.

(2) Geology of Tas., p. 102. Plate showing position of intercalated sill.

(3) Two or three years ago in an address delivered by me to the Members of the Mining Institute of Australia, which met at Hobart, I stated that I had reason to alter my opinion in regard to the age of the older greenstone at this place, and now regard it also as an older sill thrust of colossal dimensions underlying the mudstone series at this point, but of later age.

sonally the honor of acting as field-guide at the time, were inclined to be of opinion "that the gigantic masses of *gabbro*" (*i.e.*, the *diabase* or *dolerite* of Professor Ulrich; Messrs. Twelvetrees, and Petterd, the writer, and others), which are so extensively developed along the estuary of the Derwent as well as along the South-east Coast, including Freycinet's Peninsula, *are in reality sills, rather than old lava flows as was formerly contended by some.*" The latter part of Professor David's remarks I have italicised, as it is rather misleading if it refers to the opinion entertained by myself and other local geologists who may have written about the massive diabasic rocks so largely developed throughout the central and eastern parts of Tasmania.

There never was, to my knowledge, any question at any time under discussion among local geologists as to whether our massive diabasic intrusions—forming the prominent features on our mountain caps, tiers, and along our Eastern shores—were originally erupted subaerially as *lavas*, or whether as colossal *sills* they were originally injected or intruded into strata lying below the surface; the superincumbent rocks which formerly enveloped their mass, have been long since swept away by subsequent denudation continued for ages until now. Up to the time at which Messrs. Twelvetrees and Petterd commenced their splendid microscopic investigations of our igneous rocks—of which their latest contribution read this evening is, in itself, a rich mine of wide and valuable knowledge and logical deduction—the local general geologists were not possessed of the necessary data to enable them to form conclusions that would be at all satisfactory in a question of this kind. Without a thorough survey of all our igneous rocks—by such methods of careful systematic microscopic examination as are, now, so ably being carried on by our own observers, Messrs. Twelvetrees and Petterd—I do not think any conclusions as to their exact mode of origin can be of much scientific value.

What, hitherto, specially attracted the attention of local observers and of the earlier geologists, Jukes, Selwyn, Milligan, and Gould, as regards the greenstone masses now capping permo-carb. and mesozoic rocks on the Great Lake Plateau, Ben Lomond, Mount Nicholas, Fingal Tier, Mount Wellington, and elsewhere was, "Were they superimposed massive caps, or were they massive greenstone cores against the flanks of which the permo-carb. mudstones and the mesozoic coal measures rested?" The economic importance of this question is very great; for if the massive greenstones on top of Ben Lomond, Mount Nicholas, are caps which may have been fed by roots from below, we might hope to follow our coal seams throughout the areas enveloped by these extensive masses. But if these colossal *caps* are themselves continuous through the permo-carb. and mesozoic rocks as vast co-extensive diabasic *cores*, then the limits within which we may follow the coal seams on their flanks will be correspondingly reduced. This, and this aspect of the case a one, had hitherto been the vexed question between some of our Tasmanian geologists, and not the newer aspect raised, viz., *lava versus sill*, structure and mode of origin.

Lava versus Sill Origin of the Higher Mountain Caps.

Nearly two-thirds of the whole area of Tasmania in its Midland and Eastern part is occupied continuously or ramified by masses of the diabasic greenstone rocks which were erupted towards the close of the mesozoic era. The great plateau of the Lake Country alone is almost continuously occupied by this rock for over one thousand square miles Its outer edge to the West, North, and East, forms precipitous tiers bordering the lower plains and generally reaches a height of from 3000 to 4000 feet, and, in some cases, rising to a height of over 5000 feet.

The general thickness of the more characteristic mountain caps of greenstone, as on Ben Lomond and Mount Wellington, even now, after ages of exposure to denudation, are from 1700 to nearly 3000 feet thick. If we assume, for purposes of illustration, a period of two and a half million years having elapsed since the close of the mesozoic era; and that our higher levels have been continuously exposed to denudation for the whole of that period—What would the extent of waste represent in the destruction of the masses of rock of whatever nature which were originally super-imposed upon them over their existing high level limits?; and—What are likely to have been the character of the rocks which have been wasted away from above them?

The usual estimate of the rate of denudation by atmospheric influences and gravitation is reckoned to be equal to a waste, on the average, of one foot of rock in 3000 years. In the space of $2\frac{1}{2}$ millions of years it follows that rock of a uniform depth of 833 feet has been swept away from the tops of all our higher greenstone tiers and mountain plateaux.

This is not at all an exaggerated estimate of the amount of rock-waste, whose mass originally covered the present greenstone masses. These greenstones at the points now exposed to waste, are proved by the valuable microscopic investigation of Messrs. Twelvetrees and Petterd, to be of such composition and crystalline texture (sill structure), as to have required the pressure of an immense superincumbent mass of rock; and great slowness in cooling; to induce that original character and successive forms of crystallisation which the gentlemen named have been able to determine as *sill structure.*

From such considerations we may follow with confidence the general conclusions arrived at by Messrs. Twelvetrees and Petterd.

Messrs. Twelvetrees and Petterd, whose prior investigations are recorded in the Proceedings of this Society and elsewhere, in their latest observations "On Mesozoic Dolerite and Diabase in Tasmania," have now, shown how extensive these investigations are. They have examined carefully numerous microscopical sections from all parts of Tasmania, and they modestly state that such observations are merely regarded by them as "stepping stones to more complete knowledge."

The general conclusion formed by them as regards the nature and mode of origin of our greenstone rocks *still remaining unwasted by denudation* are, that:—"They were never in the form of a lava overspreading the land in the presence of the atmosphere. They have been undeniably produced by the crystallisation of a magma which was injected or intruded into strata lying below the surface. They have not crystallised rapidly, but under the pressure of superincumbent rocks, which we seemed compelled to believe have been carried away by subsequent denudation. There is absolutely nothing to show that they ever succeeded in establishing communication with the surface. If, however, they did, both the pipes by which the magma ascended and the basaltic flows in which that ascent finally resulted, have been wasted without leaving a trace behind. The entire absence of mesozoic basalts in the island suggests that these dolerites always were subterranean, and that the faces and cliffs which we now see are subterranean sections lifted for our inspection by one or other of the earth movements, which geological science so often reports."

I quite accept the conclusions of Messrs. Twelvetrees and Petterd that the sections examined by them (which must in the case of the caps of the mountains, regarding subsequent denudation, be from levels from 1000 to 3000 feet below the original surface) (1) Were never in the form of a lava overspreading the land in the presence of the atmosphere; (2) That they have not crystallized rapidly while under the pressure of superincumbent rocks, which have subsequently been wasted by long continued denudation.

What thought occurs to me at this stage is—(1) Could a massive sill, 2000 to 3000 feet thick, be thrust for vast distances between the planes of stratified bedding—say within 800 feet of the surface—without causing innumerable fissures and fractures through which some portions of the magma would be forced to the surface in the form of lava, ashes, etc.? To me it seems incredible at present (2) Supposing also, that by gigantic fissure eruptions a tide of lava welled upwards to the surface, and in places attained in its flow a thickness of two thousand or more feet before cooling. What, eventually, would characterise the more rapidly cooling surface from the magma, more slowly cooling, at a depth of from 1000 to 2000 feet below the upper surface of the same flow? Would it not be possible for the slower cooled magma at great depths to show "*sill structure*" as regard crystallisation?

It must be remembered that at a depth of 3000 feet from the surface the pressure from a superincumbent mass would be equal to the weight of 240 atmospheres, *i.e.*, the pressure at the surface, and at a depth of 3000 feet respectively, would be as 1 is to 240. The rate of radiation of heat from a cooling mass, from surface to base, would, at the same time, proceed in an inverse ratio.

Geikie states that "In former geological ages extensive eruptions of lava, without the accompaniment of scoriæ, with hardly any fragmentary materials, and with, at the most, only flat, dome-shaped cones at the points of emission which have taken place over wide areas, from scattered rents along lines or systems of fissures. Vast sheets of lava have in this manner been poured out to a depth of many hundred feet, completely burying the previous surface of the land, and forming wide plains or plateaux. These truly "massive eruptions" have been held by Richthofen and others to represent the grand fundamental character of volcanism; ordinary volcanic cones being regarded merely as parasitic excresences on the subterranean lava reservoirs, very much in the relation of minor cinder cones to their parent volcano."

It may be inferred from these observations which are merely the outcome of speculative contemplation, that one may conceive of magma slowly cooling under the immense pressure of superincumbent rock and unexposed to the atmosphere without the agency of a true typical "*intercalated sill.*" Might not, also, similar crystalline structure to that of dyke, root, or sill be produced in a similar way? It will be interesting to hear further from Messrs. Twelvetrees and Petterd with special reference to these speculative suggestions.