The Rocks of Pulo Ubin

by

J. R. Logan

RARE BOOK

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PULO UBIN,

WITH SOME REMARKS ON THE FORMATION AND STRUCTURE OF HYPOGENE ROCKS AND ON THE METAMORPHIC THEORY.

Pulo Ubin is an Island lying in the strait between *Singapore* and the coast of the *Malayan Peninsula*, of which the eastern extremity faces the entrance of the *Johore* river. It is about five miles in length, with a general direction from E. by SE. to W. by NW., and has a varying breadth from a mile to $^3/_4$ of a mile.

In detailing the results of four or five visits which I have made to it within the last few months, I shall first endeavour to convey some conception of the distinctive aspect of the Island, or that which would strike a stranger; and this object will be best served by giving my own first impressions as they were written down at the time in my Journal, even although they embrace some ideas that were afterwards corrected by a wider survey. I shall next describe the rocks of the Island, so far as I have observed them, noticing slightly the scenery where it is most remarkable for its beauty. The concluding portion of the paper will be occupied with some deductions from the preceding details, a notice of the relations between the Island and the adjacent localities and some remarks upon its bearing on geological theories current at present.

To begin then with the impressions made by the first sight of the Island. I crossed from a small Malayan campong on the coast of *Singapore* opposite *Pulo Ubin*, called *Passier Ries*. There is here a deep indentation in the *Singapore* coast, or rather two hilly and wooded points (*Tanjong Changy* and *Tanjong Pongal*), advance from it towards each extremity of *P. Ubin* and include with its southern shore a noble sheet of water about three miles long and two miles broad save at its extremities, where it is contracted between the *Points* and *P. Ubin* to straits of about one mile in breadth. This Island-fronted Bay must originally have been much greater on the *Singapore* side, as the creek of *Sirangoon* winds through a broad expanse of mangrove jungle, and terminates in a swampy valley the whole of which has been accumulated on the old sea bed (1). As we left *Passier Ries*, the Strait, land locked on all sides and smooth on its

(1) What follows as far as p. 7 was copied from my Journal in a paper, chiefly relating to *Pinang*, which I sent to the Royal Geographical Society of London in June last.

surface, appeared like a lake amongst low hills. It is seemingly quite surrounded by jungle, the mangrove predominating wherever there has originally been a deep indentation in the shore. On the north the opposite side of the Old Strait of *Singapore* (*Salat Tambroh*) is completely excluded from view, save at one point, by *P. Ubin*, which shews like a densely wooded low hilly range. A broad bay on its shore is nearly filled by a low flat island or mud bank, called *Pulo Tam* (properly *Ktam*); which is covered by a thick sheet of green gleaming mangroves. We stood across the strait towards this Island, passed its eastern extremity, and then proceeded eastward along the shore of *Pulo Ubin*. Several rocky points slightly project from it, and these are covered with trees of no great size, but which, from their not being so densely crowded as tropical jungles generally are, unite luxuriance with grace and freedom of growth. The abundance and abruptness of the rocky masses which are partially visible, clothed with mosses and lichens and with shrubs rooted in their clefts, prevent the trees from approximating, raise their trunks here and there into view, and, by limiting their number as in an artificial wood, afford space enough above for the branches to expand into full-leaved wide-spreading canopies, on the dark and cool shadows of which the eye, dazzled by the radiance of the sea, wishfully lingers. The rocks are however less seen themselves than by these their effects, for such is the profusion of shrubs, underwood, creepers, and parasites of various sorts, that the dead mineral masses seem to be imbued with botanic fecundity and wrapped in a living garment woven out of their own breasts. The little bays between the Points are nearly obliterated by level sheets of mangrove which, by their growth externally, tend constantly to convert the original irregular, into a straight, coast line.

One of the most striking features of the lake like scenery of the strait between *Pulo Ubin* and the *Singapore* shore is *Gunong Bau* a broad pyramidal hill, which, as we approached the eastern extremity of *Pulo Ubin*, and the wide estuary of *Johore* river on the left or north east and the wider mouth of the old *Singapore* strait on the right or south east gradually opened,—was seen up the former at a distance of 5 or 6 miles. Although termed by seamen *Little Johore* hill, it is, in reality, higher than *Marbukit* or *Johore* hill which forms one of the most prominent landmarks on entering the straits of *Singapore* from the *China* sea. From the regularity of its cone, which from this point of view seems to descend with almost perfect evenness on all sides to a level a little above that of the sea, and its apparent isolation, it resembles a volcanic hill.

We stood across the strait between *Pulo Ubin* and *P. Tikang* to the small islets called *P. Sejahat*. On our return we pulled close in to one of the points on the south side of *Pulo Ubin*, where there are several Chinese quarrymen engaged in splitting granite for the supply of the builders in town. We were struck by the extraordinary appearance of some of the granite rocks on the beach. Their sides were grooved or fluted, presenting regular vertical furrows and ridges. A little way in from the beach, and on the lower face of a hill, stood a very large rock of which two faces were visible, the remainder being concealed by luxuriant jungle, and the summit overhung with shrubs and trailing plants. At a little distance it was hardly possible not to take it for a portion of an ancient temple rudely sculptured out of the solid rock, since from its front stood out what seemed to be a range of colossal misshapen images. On ascending to it through the brushwood my amazement increased, for while it was too irregular to be a work of art, it seemed to be too close an imitation of one for a natural production. Amidst the jungles of the granitic mountains of *Pinang* I had been familiar with all the shapes and positions which I had considered detached masses of that rock capable of assuming. I had there seen it in solid boulder-like blocks of vast size, sometimes cubical, and sometimes approximating to globular. I had also seen it in smaller blocks piled one over another with all the regularity of druidical masonry. But I had never seen or read of granite carved by nature after the fashion of the mass before which I stood. In the perpendicular face of the rock were scooped out, from top to bottom, deep concave hollows or grooves varying in breadth and depth. Between these the rock projected in huge unshapely columns like a row of rude idols. Towards the top these pillars were rounded. In some a slight curved groove or fissure crossed the upper part, the convexity being downwards, and thus converting the summit into a globe resting in a cup. Below the line of the fissure the pillar contracted very much on both sides as if it had been at this place scooped evenly out. It then bulged out on both sides, but much more on the left than the right. The sides next converged, and, lower down, approached more rapidly. They then bulged out again till the soil hid the rock from further view. In some of the columns the curves of the sides assumed the form of a vase. The bottoms of most of the hollows or channels between were nearly uniform in depth altho' somewhat uneven or conchoidal. Of these singularly shaped columns five or six had a close resemblance to each other. When viewed from the side they were all seen to be scooped quite round at the places where in the front view they contracted, so that their edges appeared thus (fig. 1.)

In fig. 2, *a*, *a*, is the last of these pillars. Beyond it to the right the regularity is broken, and the grooves appear as in the shaded portions of the fig. The groove on the right of *a*, *a*, marked *c*, *c*, is a remarkable one. The upper part has a regular semi-cylindrical shape. At the line *b*, *b*, it abruptly, but with all the regularity of art, slopes inwards at a sharp angle, so that the part darkly shaded forms a cavity apparently about five feet in depth. A slight groove, an inch or two in depth, is shewn at *d*, and deeper grooves appear further along. The pillars whose side view is as in fig. 1 are on the other side or to the left of *a*, *a*. Ascending the hill I managed to clamber to the top of the rock, where I found the grooves to be partially prolonged on the surface in an inclined direction. The surface at some places was hollowed into cup like depressions. Climbing further up the hill I came, at no great distance, to another rock of much larger dimensions. It was reft or traversed by a chasm from 6 to 8 feet broad. The sides of the chasm were much fresher than the external surface, and the mass had evidently been split across at a time subsequent to its existence as a separate rock and the formation of the grooves with which it also was traversed in front. The extremity of one of the two masses projected for some distance over the sloping ground so as to form a capacious cave. At another side a larger fragment had fallen from the rock and lay against it. On its surface was a cup or rather spoon-shaped cavity about two feet in diameter and one in depth. At another place a second projecting rock occured forming another cave, about thirteen paces in length. The entire length of the rock which thus projected seemed to be about forty paces. On the same side there were numerous grooves, some not exceeding a few inches in depth and breadth, others above

$2\frac{1}{2}$ feet deep and about 2 feet broad. One groove I observed about six feet deep and two feet broad with small secondary or inner grooves fluting its surface. While examining this rock a heavy shower of rain began to fall, and as my time was exhausted I was obliged to leave before I could make more precise observations or any measurements, and, in truth, before I had recovered from my first sensation of wonder. It appeared to me that the rock must have been split on being elevated from a lower level. On returning I observed many smaller rocks near the beach with channeled sides. On the top of one of these there was a long deep trough with small grooves converging into its upper end, like the ribs of a fan. The rest of the surface was covered with slight depressions.

I believe this is the first time that grooved rocks have been observed so close upon the Equator. Their absence has been considered an argument in favour of the glacial theory of the boulder formation. None of the channels or grooves, however, which I observed resemble the parallel inclined or approximately horizontal furrows which are caused by the motion of glaciers in descending the rocky trough of a valley. But they appear to correspond strikingly, save in being vertical, with the giant cauldrons, passing into long deep grooves, which are described by Agassiz as being produced in the *Alps* and *Jura* by streams of water falling over the sides of chasms in advancing glaciers, and acting as a locomotive erosive force upon the subjacent rocks. My hurried and restricted observations hardly warrant a conjecture as to the probable origin of the *Pulo Ubin* grooves. The idea that occurred to me on the spot was, that the several rocks, before they were shattered and separated by the force which placed them in their present positions, and in some different local distribution of land and sea from that which now prevails, had formed the site of a cascade of no great force which had gradually worn the sides of the rocks into channels. A succession of falls would account for the relative positions of the rocks with respect to each other and for the spoon shaped hollows on the surfaces of some of them. It appeared to me that ordinary meteoric erosion and decomposition were totally inadequate to explain the shapes and size of the grooves. In many places they are overgrown with mosses, and in some, if not in all, they are prolonged beneath the ground, and thus protected by the soil of the hill, which must have covered them for a considerable period, since large trees are rooted in it. The aspect of the rocks is not such as rapidly disintegrating granite wears, but, on the contrary, resembles that of an ancient building. I could find no trace of any fissures coinciding with the direction of the furrows. Yet there can be little doubt that, to whatever agency they may be referred, the grooves were first opened along lines where the cohesion of the granite was comparatively weak. The regularity with which the projecting columns of the rock first noticed are scooped round at two places across the direction of the grooves, seems to prove that the granite has an internal arrangement similar to that so frequently observed in this rock, and which causes it to be shattered into blocks more or less cubical. In one of the lower rocks which the Chinese are quarrying we found two parallel vertical veins traversing the entire rock so as to include between them a plate about an inch in thickness. One side of this plate sparkled with metallic grains of a golden hue (iron pyrites). The other was covered with a rusty stain resulting probably from the fissure on that side having been permeable by the air and the consequent decomposition of the grains.

As we pulled away from this place and looked back, even the want of light and shade and the heavy rain that was falling did not prevent our acknowledging that it possessed a character of picturesque beauty of a very pleasing and uncommon kind. It, in truth, united the luxuriance and gracefulness of tropical vegetation with the open and irregular aspect of a wood on some river's bank, half rocky, in *England*. The jungle trees of *Singapore* do not in general attain sufficient size to assume that air of grandeur which distinguishes those on the *Pinang* mountains, and they are so blended with the underwood, which grows up like a thick crop of rank weeds between them, and so interwoven by creeping and pendent plants into a dense mass of green, that their individuality is extinguished. The display of botanic life is wonderful in its measureless, all pervading exuberance, and this very profusion ministers to a deeper sense of the silent, soft, spirit-like, but most potent and most motley, power of vegetation. Still no tree or humbler plant invites us to dwell delightedly on its own perfection. At this spot, however, many stately trees rose up in self dependent strength and beauty, and expanded in mid air into their complete proportions, or, if they sought companionship, they did not woo a promiscuous throng, but each embraced a single partner. The number of double or married trees congregated at this particular spot was indeed remarkable, and, — recollecting that the Hindoos either select the neighbourhood of such trees as the sites of temples or plant them where they do not grow naturally, and that, in those ages when they flourished over the Indian Archipelago, the strait between *Pulo Ubin* and *Pulo Tikang* was the portal of one of their earliest and most renowned colonies, *Zaba* on the *Johore* river, — it was again difficult to avoid surrendering the mind to a belief that the grey pillared and fluted piles, that assumed more and more an artificial appearance as each stroke of the oar reduced their size, were really the remains of some great fane overborne by many centuries of desolation (1).

It will be borne in mind that the above are first impressions, and that, having been conducted to one particular locality to see the furrowed rocks, I believed they were confined to it. My next visit undeceived me, and proved that I had been nearer the truth when looking for tokens of an internal structural arrangement in the granite, than when conjecturing the former existence of a cascade; a conjecture which a wider exploration of the same Point would have shewn to be baseless.

I now proceed to notice the rocks at the different places which I have visited, beginning with the Eastern portion of the southern coast after passing the Quarries, going then to the western division of the Island, and finally returning to the Point where my desire to examine the Island was first awakened.

The seaward extremity of the lateral hill or ridge to the East of the Chinese Quarries is environed by mangroves.

The succeeding point advances out of the mangrove fringe. At the W. side a large mass of solid granitic rock of a greyish colour, varied by light brownish red (and consisting of grey felspar and transparent quartz with some black mica interspersed) stretches transverse-

(1) The Extract from my Journal included in the paper alluded to at p. 3 stops here.

ly along the beach, from which it rises a few feet. The beach at its base is a band consisting of the upper edges of soft semidecomposed vertical laminae. Further on another mass has its face composed of solid, slightly projecting nuclei of different shapes, with laminae between. The nuclei are similar in composition to the preceding rock, but in the laminated portions the black mica is so thickly interspersed as to form about a third of the whole. A quartzose vein about an inch in thickness traverses the face of the rock, cutting through both the solid and laminated portions. Beyond this extended tabular rocks occur, along the flat surfaces of which fissures and divisional lines run in a direction NE. by N.... SW. by S. A portion of the surface is covered with a ferruginous vesicular crust, volcanic in appearance. The next considerable rock is a ledge running out into the sea, about 30 feet in length and 6 to 8 in breadth. A portion of it is marked by a net work of contemporaneous veins of a larger grain and more micaceous than the body of the rock; at some places the veins send tongues into the latter. This structure is analogous to that which the more decomposed rocks consisting of solid nuclei and laminated curved bands exhibit.

Along this coast wherever the junction of the rock with the superjacent soil of the hill side is visible, there is, in general, an irregular band of angular fragments of the former partially intermingled with the latter, evidently resulting from the slowly descending disintegration of the rock; at some places however a layer of rounded pebbly stones is interposed between the broken surface of the rock and that of the soil. An example of this occurs here. The pebbles are chiefly of three sorts, — a porcellanous rock probably semidecomposed granite and syenite — brownish red ferruginous rock, — and jaspideous. The first is by far the most abundant. On the beach in the vicinity are numerous pebbles of the same description, and also some rounded scoriaceous stones similar to those which are so common in *Singapore*.

As the SE. angle of the Island is approached, regular spherical nuclei with concentric spherical laminae are found. The most remarkable point in the character of the rock where it assumes this structure is the abundance of black mica, which indeed constitutes the entire mass with the exception of a little felspar which serves as a basis. It is to this circumstance that the tendency to this peculiar arrangement of the crystals is in all likelihood owing. The predominating rock around these laminated micaceous globes is greyish and faint greenish quartzo - felspathic, with minute particles of mica and hornblende interspersed. In decomposing it takes a rusty colour. It is obvious that the weathering of such globular foliated portions of a compact rock, in situations where the whole was less preyed on by the sea, would give rise to cups and spoon shaped cavities on the surfaces of the more compact masses, and that rows of such spherical portions gradually excavated would ultimately assume the appearance of grooves like those formerly described (1).

The SE. point has at one place the appearance of having been subjected to the action of heat since the rock was formed. The sides of cleavage fissures have a blackish brown ferruginous hue and a thin hard laminae or seam having the same character sometimes fills

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(1) Ante, p. 5, 6.

them. Some veins of a similar substance are vesicular. I believe, however, that this appearance has resulted solely from the iron contained in these portions of the rock. Close to this is a band, about 8 feet in breadth, of vertical laminae half decomposed and with crustated projecting edges. Internally it is composed of crumbling felspar having minute scales of mica scattered through it. Towards the surface the hue is rusty and some deep black stains occur throughout.

Near the point the rock exhibits great variety in its composition even within a small compass. One specimen has a greenish grey sacchariod felspathic base in which crystals of quartz and nests of mica are sparingly disseminated. Another is somewhat similar, but the base is a dark brownish grey. In others whitish felspar and black mica and hornblende are united in different proportions, equal and well separated, or more finely granulated and mingled, so as, when the mica is absent, to approach to the character of a syenitic greenstone.

Among the other interesting examples of varying structure and composition at the Point there are some solid blocks of a rudely globular shape, with the rock in the spaces between in foliae from 1-6th to 1-8th of an inch thick. Adjoining these are some blocks which, within a circuit of a few feet, change in their appearance and composition, passing from a black doleritic rock into a well crystallized compound of hornblende and felspar (syenitic dolerite) in which the former is greatly in excess, — into a similar rock in which the felspar greatly increases and which at one place is intersected by a rhomboidal network formed by felspathic veins crossing each other, — and, lastly, into a whitish grey rock similar to that around the globes before noticed. The crystallization between the opposing convex sides of adjoining blocks exhibits yet another and still more strongly marked variety, becoming abruptly very coarse, so that some of the specimens which I took from the line of junction have, on one side, either a granite as minute in its granulation as fine sandstone, or a compact dolerite, and, on the other, crystals of felspar and scales of mica of an unusually large size.

A little beyond the SE. angle there is a band of semidecomposed rock about 2 feet broad consisting of small globular and cuboidal bosses, from 3 to 6 inches in diameter, of a very fine grained granite or eurite imbedded in, and protruding from, yellowish white clay. The former are composed of minute micaceous and hornblendic grains thickly disseminated in a base of granular quartz and felspar. It so strikingly resembles fine ground pepper, especially after decomposition has commenced, that it may be called pepper granite. The latter has originally been in great measure felspathic.

At the SE. Point the slight superficial depressions marking divisional planes, the principal fissures and chasms, and the longer sides of separate ledges are all in NE.-SW. lines, or lines not deviating far from these directions. The first have given rise to the two last. The cohesion of the rock at the divisional plane, originally least, is further weakened by partial decomposition along that line. The alternations of temperature from exposure to the rays of a burning sun succeeded by immersion under the waves, and the removal of support on either side by the mechanical action of the sea, cause the rock to split along the plane, and thus a fissure is formed. A ledge or band between two fissures is either broken up mechanically by the waves, or wasted away chemically from being more susceptible of rapid decomposition than the adjoining bands, and thus wider fissures or chasms are produced.

There is a small rocky islet or group of rocks near the SE. Point of *P. Ubin* called *S'kodo*, from a fancied resemblance of one of the blocks to a frog. Those in the middle are large and connected by sand in which some shrubs grow, and those scattered around are smaller and much worn by the waves. Some large rocks also lie in the sea on the south side of the central collection, and the longer sides of those run SW. by W., NE. by E. Parellel reddish lines or bands about ¼ an inch broad traverse the surfaces and mark the planes of weaker cohesion. The sides of some of the blocks are peeling off in parallel layers. In some, another set of divisional planes, transverse to the former, are well marked. Where the rock is breaking down, these two systems of planes divide it into rhomboidal fragments.

The rocks are of a large grained granite, and are in fact the best specimens of well marked and regular granitic crystallization that I have seen around *Pulo Ubin*. The hornblende instead of being collected in nests of small granules intermixed with felspar, or disseminated in minute particles, as is generally the case even in the most highly crystallized rocks of the Island, is here in well defined crystals of various sizes and mostly of a fibrous structure. Mica is present of a fine lustrous black colour with a faint blush of red. Nests occur from an inch to a few inches in diameter composed principally of finely granular hornblende intermixed with a lesser proportion of felspar and containing occasionally a crystal of mica.

The eastern end of the Island, in place of contracting to a mere point like the western, presents a coast of considerable extent. This arises from the eastern portion of the Island consisting of two hill ranges, with a flat mangrove tract between them. The termination of the northern range constitutes the NE. Point. The beach is composed of extended tabular masses of rock which slope curvately beneath the sea, and rise only a few feet above it. They are crossed by fissures and small grooves, the direction of several of which is S by SW. All the principal lines have a general direction towards SW., although they vary within a small range. In these a row of circular cavities lined with a ferruginous crust sometimes occurs; and where this is the case, the surface of the rock has a semi-calcined aspect.

The rock varies, but is principally composed of an opaque bluish grey saccharoid felspathic and quartzo felspathic base enclosing crystals and grains of hornblende, and translucent crystals of felspar. It bears a close resemblance to a specimen of Vesuvian lava including hornblende crystals which I possess. In some places it becomes compact, or the hornblende granules are so minute as to appear like fine black dust sprinkled on snow. Where they prevail over the felspar the rock has a bluish colour. The base has frequently a reddish brown and brownish grey colour, but this is probably the result of incipient decomposition.

Rounding the Point and proceeding westward along the northern coast, the rocks preserve the same character. They are traversed here and there by rifts, and marked by fissures or grooves of a greater or less depth, but mostly shallow. Where I noted the bearings of the divisional lines, those producing the rifts on the faces of rocks sloping abruptly into the sea were found to be either nearly S. or S. by SW., and dipping easterly. Those producing the slight grooves crossed the others, dipping to the westward, and with a SE. bearing. Another system traversed the faces of the rocks in a horizontal direction. The action of the weather and the tides had deepened many of these fissures, so as to form an irregular system of shallow channels. The rocky shore to the south and west of the Point is, like all the other projecting portions of the coast, the base of a hill. Off its western extremity, (which is separated from the eastern by a small tract of mangrove and is perhaps a distinct hill) there is a large insular rock. The external form of this islet is very plainly due to the divisional planes of the rock. Of these the principal are parallel to its N. and S. or longer sides, bear a very little S. of E. and dip at an angle of about 45° to the S. Hence while the south edge of the islet has a smooth slope, being formed of the uppermost layer produced by these planes, the northern side on the contrary is steep and rough, presenting a series of broken ledges rising over each other and dipping inwards. The surface of the rock is indistinctly marked by lines at right angles to the principal ones. At the western end, where the remnants of some of the layers stretch into the sea and are broken up by the waves, they are divided by these cross planes into irregular fragments. Other lines are occasionally distinguishable, running NE. by N. The rock is very like those at the adjoining Point, but has a greater tendency to a compact hornblendic character. The Point is succeeded by a considerable tract of mangrove.

The next Point is the steep narrow end of a spur covered with jungle save at the summit, from which rises an enormous rock, partially visible through the foliage from the water. With some difficulty I walked and clomb round it through the jungle, and a minute examination on all sides proved that its general external configuration was the result of its internal structure. The northern face, or that which overlooks the channel, is very lofty and picturesque. Its lower portion is of great length, stretching quite across the hill, and rises to a considerable height perpendicularly, or rather with a slight inclination inwards. Above this wall the rock, as it rises, retires and narrows by successive irregular steps, so as to present a ruined castellated appearance. The nearly perpendicular wall is the face of the outermost of the layers of which the whole mass is composed. Its direction, agreeing with that of the internal planes of weaker cohesion, is E. SE. nearly, but it is slightly curved. The face is marked by two systems of imperfect grooves crossing each other. One set approaches to vertical but dips some degrees to the W. The other approximates to horizontal, but has a dip of a few degrees to the E. Similar markings are found on the southern face of the mass, and they shew the directions of two systems of divisional planes. The eastern side of the rock dips inward concavely, and probably exposes the true form of one set of the divisional planes. On one side the continuity of its surface is interrupted, and the layers assume a tendency to enwrap nuclei. The west face of the rock dips outwards, descending by irregular steps. These are formed by two of the systems of divisional planes. They are much broken and in some places traversed by channels of some regularity which are evidently formed in planes of division. All the planes seem to be in some degree curved.

The internal structure of the rock not only determines its general external figure, but even the vegetation which it supports. Thus the S. and N. sides, being nearly perpendicular, do not retain moisture, or afford beds for the larger rock plants. They have a partial covering of lichens. The E. face is bare. The West face, on the contrary, from it slope, roughness and numerous hollows, retains moisture, and is clothed with a thick mass of dark green ferns, mosses and other plants. The rock is a variable mixture of felspar and hornblende confusedly aggregated, and from the preponderance of the latter decomposes into a deep red soil.

A very extensive tract of mangrove succeeds, occupying the wedge shaped space between the two hill systems of the Island, or rather, as seems probable, between the two Islands. At a point near the eastern end of the Island a rock is exposed which is splitting into small cuboidal fragments. It possesses a twofold mineralogical character, being either a remarkably large grained and beautiful compound of opaque white felspar tinged green, and blackish green hornblende; or a very fine grained black greenstone approaching to basalt, in which the felspar is thickly dispersed in minute granules in a granular base of hornblende. It is occasionally traversed by minute veins of felspar. The more felspathic rock is in like manner traversed by hornblende veins. The junction of the two characters in a specimen is sudden, but from the hornblende nests in the larger rock frequently resembling the fine grained rock, and the felspar near the plane of junction assuming a greener tinge, the transition does not appear abrupt.

The western point of *Pulo Ubin* is eminently beautiful. A group of large blackish wave worn rocks advance in front into the sea, and, from the acuteness of the Point, (hence by the Malays called *Tanjong Tajam*) stand out from the land in full relief, as if they had been planted there to stem the force of the western currents, and defend the Island from their assaults. Behind these rise great masses, with their perpendicular faces sinking into the water, and their serrated summits overshadowed by the branches of lofty trees. The peaks of other and probably still larger rocks are partially seen through the branches and in the forest twilight behind. Rounding the projecting group of blocks the coast presents a succession of noble and varied rocks, here advancing into the sea, there abiding by the land, and sometimes stretching along it continuously like a grey rampart; while over all a glorious profusion of many formed, many coloured foliage is spread out in which gay flowers are not wanting; and the massy forest ascends high and dark behind, or, where the rocky wall is broken and irregular, advances some of its mighty children into the breaches. The trees here, as indeed almost every where around the shores of *Pulo Ubin*, are strikingly varied, beautiful and imposing.

I have only partially examined the northern coast near the eastern and western points. Not far from the latter there is a very large grooved rock half concealed by mangroves. The grooves are curved in their descent and those at one place in an opposite direction to the others. The grooves face N. by NW. After passing a mangrove tract to the eastward the spur of a hill projects and exposes a broad rocky face. From this plates from 3 to 4 inches thick are falling off. These are composed of laminae from $\frac{1}{4}$th to $\frac{1}{5}$th of an inch in thickness. The direction of the laminar planes is S. by SE. and they slightly dip to W. by

SW. Parallel divisional planes intersect the face of the rock at irregular distances of one, two and more feet, dipping southerly about 45°. The rock is a syenitic greenstone consisting chiefly of crystallized felspar in which dark green hornblende is disseminated, frequently in aggregations mixed with granules of felspar, sometimes the one and sometimes the other predominating. It also occurs in small cloudy spots and fibres of extreme tenuity in the felspathic base so as to give it a faint varying greenish hue. At the base of the rock are large angular fragments of a dark blackish greenstone similar to that of *Pulo Sejahat.*

To the east of *Tanjong Tajam* along the southern shore rocks are abundant. I landed at an open sandy place where there were marks of footsteps and ascended through the jungle by a crooked path, half concealed beneath brushwood, to the brow of the hill. Here an acre or two has been recently cleared by Malays who occupy two little huts or rather *pondos.* Close below on the E. is the bottom of a valley separating this from the adjacent hill, and running NNE. and SSW. The soil is sandy clay and seems to be decomposed granite of a light reddish colour. Granite very hard and with quartz apparently predominating protrudes at some places. It is covered by small parallel veins or fissures running E. and W. and SE. and NW. The faces of two of the blocks are very slightly grooved. In the soil are some pieces of altered rock like those which abound on many hills in *Singapore*, and which I had considered altered granite. One piece which I picked up is quite calcined to appearance like the ordinary scoriae of *Singapore.*

On, or rather in front of, the beach, and within the influence of the tide, there are large blocks of various sizes and from 20 to 3 or 4 feet in height. On the beach behind them are smaller rocks, and further in large blocks again, projecting from the soil of the hill side. The E. side of one of the latter has a singular aspect, appearing as if, to the depth of 3 or 4 inches, it had been torrified. The surface is rough, semivesicular and blackened, the sides of veins or fissures reddish black. The interiour is like the half decomposed granite found in fragments on *Kaynan's* hill in *Singapore.* The SW. face of one of the large blocks on the beach slopes seaward and is furrowed, but the furrows are not very regular or well marked. This rock is a syenite. It nearly resembles that of Mr. Dres's hill in *Singapore*, but the hornblende is of a lighter green. On the SSW. side of the next large block to the west, the grooves face the SSW. On the sea face there is a deep split or crevise half way through the rock, and varying from 2 to 3 feet in breadth. Its direction is about NE. by E. The NNW. side of the rock has large grooves which face the SW. nearly. On the W. side there is one groove and on the NW. none.

Beyond this (to the W.) a large flattish slightly convex rock occurs somewhat in external aspect like that of *P. Sejahat.*

Further W. there is another extended convex ledge. The surface at some places appears as if it had been much acted on by fire, so as to be covered with a rough partially vesicular coating of altered granite. Where most altered, and also partially in the veins or fissures, it in some degree resembles the ferruginous scoriaceous parts of the torrified sandstones to the S. of *Singapore Town.* Where least altered the granite resembles the ferruginous fragments of *Kaynan's* hill. This rock is traversed by two rough horizontal grooves and numerous veins or slight fissures running in the direction of its length or NW. by W. and SE. by E. nearly, a line which cuts the hill of *Tanjong Pamoodang* on the main. In the lower of the two grooves or channels there is a cup, the surface of which is rusty coloured. Two sharp pieces of rock project from it. One of them is of a very dark green owing to the hornblende greatly predominating. In the cup I also found a globular volcanic stone, semi-vesicular on one side. It is very heavy, consists of a rusty substance, and exhales a strong chalybiate smell; at right angles to the above there are other splits. At one place, where the beach is formed of decomposing rock, a ledge about 6 inches high and 2 feet broad runs out and dips below the water; originally it was probably harder than the rest but is now soft. It has a whitish and yellowish red colour. Felspar predominates in this neighbourhood. On the beach altered fragments are strewn. Some are large rounded blocks, which, internally, are of a deep brick red colour. The shore of the next point is strewed with blocks of various sizes. Further in there are large masses, of which some are broken. The Point is the rounded extremity of a low hill (or one of the flanks of the range of the Island) which rises from the beach. Piles of rock are partially seen through the jungle on the hill side. From the W. angle I ascended the slope. A few yards up there is a remarkable mass of rock partially split. The SW. portion, is in its general outline, as viewed from the SE., a pyramidal block, separated on the NE. from the rest of the mass by an irregular chasm, and, where its base rests on the mass below, also fissured. Its face is grey with lichens and mosses, and so rough with channels as to appear wholly wrinkled. The channels face the SE. and are mostly inclined to the NE., but they are frequently irregular, curvilinear, or slightly sinuous. The rock is a syenite, consisting of felspar, dark green hornblende and quartz, — the first greatly in excess.

At the bottom the syenite changes abruptly into a greenish black hornblendic semiflinty substance, similar to that of *P. Sejahat*. At some places it is about 2 feet thick. This was probably the thickness all along the base originally. The fissure between this block and the mass on which it rests runs through this substance, as the upper surface has in some places a thin coating of it. It is broken with great difficulty. I hammered at the edges for some time with no other effect than to knock off the thin coating of decomposed rock, and had to be satisfied with fragments of some small rhomboidal masses which I found loose in the fissure of junction. The rock decomposes at the surface into a soft yet tough greyish powdery substance. The line of junction between the hornblende and syenite could not be minutely examined on account of the weathered state of the surface. I succeeded in knocking off one small specimen at the junction. In this the black flinty rock first passes into a greenstone, then the grey felspar increases till the hornblende appears in cloudy spots, streaks and grains, dispersed in a base of felspar. Then in this compound base, crystals of felspar appear. The number of crystals increases till the base entirely disappears. The parent mass is of great size, stretching from the fissure which divides it from the block described above to the SE. Beyond this it turns to the NE. and exposes a high perpendicular face, of which the upper half is deeply channelled, and the summit broken into irregular sharp pinnacles, — the terminations of the ridges that separate the channels. One of the channels, the second from the SW angle, reaches a little lower than the others gradually shallowing like them as it descends; the stem of a tree rooted at the base ascends the face of the rock and enters the bottom of the groove, following it till, as the depth increases, it is lost to sight; at the summit it re-appears and spreads its branches above the rock. At the NE. extremity of this portion of the face, the rock retires a few feet, and then stretches again to the NE., shewing a high quadrangular face with only a few channels.

Facing this side, and at a distance of 15 to 20 yards, a much larger and more regular mass rises in the jungle. The face opposite (and I am particular in noting the directions of the faces, because they appear always to coincide with structural planes of division or imperfect cohesion) is about NE. by N., that is, nearly the same as that of the rock opposite. This face is nearly quadrangular, and, judging by the eye, somewhat above 30 feet in height. The upper portion exhibits a few furrows, some of considerable depth, but, as the face slightly inclines inwards, these terminate near the top. The NW. and SE. face (i. e. that facing the strait or SW.) is more imposing still. It is 110 feet in length and about 40 in height. It is slightly inclined inwards, and is exfoliating. The upper part alone shews two or three furrows, a few feet in length. It is surmounted by a thicket of shrubs. The rock is a syenite, white felspar in general constituting the great bulk. In some places portions of it have a light greenish hue. The hornblende is irregulary dispersed, generally in a state of confused aggregation, and sometimes mixed with felspathic grains, but frequently also in long drawn streaks and seams. At one place it was so much in excess as to give the fractured surface of the rock a very peculiar variegated appearance, blackish green, light green, and a light iron hue, being variously intermixed with a lesser proportion of white and greyish. On the SE. side the rock slopes to the ground so that I was enabled to climb to the summit and examine it. It is throughout more or less furrowed, but the furrows are irregular in their size, positions and directions, and do not approach to the symmetrical or artificial appearance of those on the sides of some of the rocks. About the middle of the rock, from the bottom of the slope on the SE. to the edge of the opposite or NW. side, there are some well marked divisional lines running NW. by N. nearly, but there are others less marked at various angles with these. The rough holes and gutters on this part generally follow the same direction, which is also that of the general slope. Towards the NE. face the summit slopes in that direction, and the hollows take the same course. Some of these are prolonged in channels which descend the vertical NE. face, which is of considerably less height than the SW. The examination of this rock satisfied me that the slope of the rock, and the direction of the structural planes of imperfect cohesion, determine the direction of the channels, and, this being the case, the conclusion seems inevitable, that rain has been the great agent of erosion. On the SE. face, where there is a gradual slope to the ground, the hollows cover the whole surface, but are irregular, because there the rain torrents descended with less impetus, and their action was not greatly aided by the gravity of the masses on which it acted. At some places it has worn depressions of considerable depth and breadth along a line of division, but, owing probably to the occurrence of portions of rock of a different and less decomposable arrangement or apportionment of ingredients, these are separated by solid walls or small fissures. Occasionally a small channel has been worn through the bottom of these dividing walls.

On the SW., where the structural planes are inclined inwards and the sheets of rock between them are falling off, there are only a few well marked grooves at the upper edge. At one place where the rock has less deeply exfoliated on one side of a cross divisional plane (i. e. one perpendicular to the face) than on the other so as to present a side of a few feet broad at right angles to the face, a channel, about 3 feet deep and 1 foot broad, opening on this side and parallel to the face of the rock, shews clearly that here a portion of the sheets has been loosened, split, and then fallen out. The bottom has afterwards been worn concave from its serving as a rain channel.

The NW. face, so far as the rock continues nearly perpendicular, presents deep furrows, and, when it inclines inwards, these disappear.

The NE. face, being perpendicular or slightly inclined outwards presents channels from the summit to the base.

The NW. and SW. faces may have originally been grooved to the bottom, as the channels are (on the latter very obviously) decreasing in length by the gradual exfoliation of the rock in planes which intersect them. The lower surface is fresh. Where the channels exist the rock has a black, grey or hoar antique look. If the channels are altogether owing to an operation which is still in progress, the period required to produce them must have been very long, as the weathering now going on must be extremely slow. The surface is coverd with such a close vegetable covering, that it must, in great measure, protect it from the mechanical action of the rain. Descending a little to the east of the spot where I had entered the jungle, I examined some large syenitic masses which rose from the beach. One of these was divided by a chasm, and on one side, to the breadth of a foot or more, and on the other, to the breadth of 3 or 4 feet, the rock was a black hornblendic basalt inclining to flinty, similar to that before mentioned. This must originally have been a connected zone or dyke about 8 feet broad. The basalt has been freshly quarried and this at one limited place exposed the line of junction of the two rocks. It is sharp and well defined, and on each side the rocks possess precisely the same character which they have at a distance from it. Some of the fragments lying around, however, exhibited the two rocks blending at the line of junction somewhat in the manner of the specimen mentioned above p. 12, but frequently thin laminae of the basalt penetrate the crystallized portion of the rock. From the very variable nature of the syenites and volcanic rocks of this Island, and the abruptness with which the proportions of the constituents of the same mass often change so as entirely to alter its aspect, I had been previously led to suppose, that the whole belonged to one and the same formation. The appearance of this zone at once pointed to the contemporanity of its origin, and I have no doubt that is was formed in the mode suggested by Mr. Darwin (1), viz. by the opening of a fissure in the syenitic mass while yet viscid into which the most fluid ingredient, hornblende, drained from the sides or rose

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(1) Darwin on Volcanic Islands, p. 124

from below. The basaltic rock is intersected by three systems of parallel planes of imperfect cohesion, which divide it into rhomboidal pieces, the sides of which are white, owing to a slight superficial decomposition. Of these systems of planes one has a strike NW. by W. nearly, and is almost vertical but with a slight, dip easterly. Another runs NE. by E. nearly, and deviates more from vertical to the SE. by S. than the other.

Proceeding along the beach to the eastward I found a large mass, on the SE. side of which was the remnant of a basaltic dyke which was marked by a few horizontal grooves. The face of the remnant is cavernous, and looks as if it had been torrefied. Further on I noticed a small portion of basalt adhering to a large syenitic block. The next noticable rocks were some masses of soft semidecomposed syenite with the surface to some depth vesicular. This is possibly due to the continued action of the waves and the atmosphere.

To the E. of this I found on the beach a small globular rock, 3 to 4 inches in diameter, of a volcanic appearance. Externally it had a smooth enamel of a reddish and blackish brown colour. This is succeeded by a red and reddish yellow band from ¼ to ⅓ of an inch thick. Internally it is a uniform finely vesicular mass of a dull brown hue and with a portion drusy. Near this the beach was plentifully strewed with small stones, many resembling those found on some of the *Singapore* hills, and amongst which ferruginous fragments of semidecomposed rocks, granite, syenite, greenstone etc. can be recognized.

The hilly point was succeeded by a mangrove flat, which continued till we reached the point opposite the western end of *Pulo Tam*. The mangroves fringe the point which is the extremity of a hill of a brownish red soil without any rocks exposed. The soil appears to be deep and tolerably friable. The forest trees are tall and luxuriant, but many of the finest have been felled by Chinese woodcutters, by whose tracks I was enabled easily to ascend the hill.

Beyond this Point, and along the greater portion of the strait of *Pulo Tam*, the coast is a mangrove jungle. There is a small creek at one place, and so far as I could judge from the appearance of the hills on either side it seemed probable, that the mangroves here extend quite across the Island, and that it formerly consisted of two separate islands. The northern coast on the opposite side of the Island is also the margin of a broad mangrove swamp which I observed to be likewise penetrated by a creek. If there is one continuous creek across there must still be in fact two islands. Towards the E. end of *P. Tam*, where we again come in sight of the *Singapore* coast, two lines of high jungle rising over the mangroves mark the direction of the next hill flanks. The base of the first is wholly enveloped by mangroves. The next advances to the beach at one spot where a reddish rock rises immediately from the water to the height of about twenty feet. The front alone is exposed. The sides are shaded by the jungle, and over the summit is a luxuriant canopy of shrubs and small trees which fairly entitle it to be called the fertile rock. One of the trees is exceedingly beautiful being covered with a dense mass of dark green glossy foliage which it seems to spread triumphantly, towards the loftier trees growing around it and rooted in the soil but less adorned than their sister of the rock. The face of the rock is scaling off. It decomposes into a deep red earth, and the prevalence of iron which colours the soil probably also gives the dark green to the vegetation which it supports. The whole rock is one rudely rounded mass and apparently composed of concentric layers. Towards one side a wide chasm penetrates it leaving at the eastern angle a columnar portion divided by a horizontal fissure into two rounded blocks of which the upper is still at the top connected with the mass. The neck of junction consists of the remnants of numerous layers wedged in as it were, one half with their convex sides to the spectator or embracing the rock above and the other half with their concave sides towards the spectator or capping the block beneath, thus presenting the appearance which a number of somewhat stiff sheets of paper or other flexible substance do if they are compressed tightly in the middle and their ends made to diverge on both sides.

Beyond *Pulo Tam* a point occurs from which a large furrowed rock advances into the sea. This I inspected with some minuteness. The channels, even on the same face, run in different directions so that they sometimes cross; but, more frequently, after meeting, one only is continued. In all cases they evidently occupy the lines of division or imperfect cohesion. On the side facing the NW. the direction of the larger ones is nearly NE. and NW. On the S. side they are deep and face the S. These latter it appeared to me had been gradually excavated by the alternating action of the sea and the atmosphere. A little further to the E. the gutters of the rocks faced NE. by N. nearly; at one place the rock is nearly worn through and the breach is half filled with large angular fragments, the remnants of the layer or ledge which had originally occupied the cavity. Its sides are parallel and mark two planes of division. The furrows beyond this were generally in one or other of two directions according to the slope, that is either facing the NE. by N. or WNW. nearly. The general surface at some places is uneven, which occasions varying slopes, and it appeared clear that the directions of the furrows at these places were fully explained by the directions in which the slopes would cause the rain currents to run down them. In many cases, the latter did not exactly coincide with the former, because no fissures or lines of division did. But of the two systems of parallel divisional lines by which the surface was intersected, that which most nearly agreed with the slope had given their directions to the gutters. Where the face of the rock was slightly hollowed the gutters converged. The ridges between the divisional lines are sometimes crossed by gutters but only where this would be rendered necessary for the descent of the water.

It was not until I had examined both the eastern and western portions of the Island that I was able to revisit the point where my acquaintance with it had commenced. It proved that I had seen only one small section on the S. side, and that the SE. and E. faces possessed the principal rocks. These stand in great profusion along the beach or rise from the water in front, while the hill behind appears like some ancient "castled steep" with remnants of flanking walls midway up, and broken battlements frowning from the summit. Many of the piles are on a grander scale than any that are found elsewhere; they have a greater air of antiquity; and rising as they do in diversified forms, — here in solid cubical masses, there traversed by deep chasms and bristling with sharp pinnacles, at one place standing out in full relief in their grey mossy coating, and at another covered with a trellis work of roots, trees ascending from their summits into midair, and the entire rock buried under a load of varied vegetation, — the effect of the whole is at once picturesque and imposing in an extraordinary degree. I can only afford to notice a few of the most remarkable rocks, although a faithful description of the whole is desirable, since the Chinese quarrymen are proceeding so rapidly in their work of destruction that it is to be feared these grand and singular natural phenomena will, in a few years, have been entirely obliterated.

One of the most striking of the rocks is a connected pile of great bulk and extent which stretches from the base of the hill across the beach into the sea. It is cleft in a few places by narrow dark chasms, three of which, in particular, divide it into four principal portions. The inner is a great cuboidal mass based in the land, and its sides, being very slightly furrowed, rise perpendicularly like solid walls. At the NW. angle rises what may be called a great columnar turret, partially severed from the mass by a deep narrow chasm, and traversed from top to bottom by deep channels divided by narrow ridges, and with its summit ascending some yards above the level of the pile. A tree rises from the pinnacled summit, and the whole of the western side of the columnar mass is reticulated by its roots. The principal of these run down the channels to the ground, and, as they descend, give out numerous lateral branches which closely embrace the rock, following its sinuosities and entering the cleft between it and the main mass. The roots are so numerous and so interlaced that they conceal the greater part of the rock; and, towards the summit, where they converge beneath the trunk, only some narrow portions of the ridges are visible. These differ so little in shape and colour from the roots, and are so closely united with them, that, from some points of view, the whole appears as the solid stole of the tree. From other points of view some of the acicular summits of the turret are free from the net work of roots, and others pierce through it. One of the long nearly horizontal branches of the tree which stretches seaward above the pile is literally covered with air plants save at its extremity. The second mass of the pile is also cubical, but distinguished by a bulky awkward looking protuberance, which rises above it towards it edge and leans to one side, but for which it is impossible to find any architectural prototype. Its rounded shapeless edges and partially depressed sides give it a form more resembling a bit of ginger root than anything ever shaped by art. The W. side of the mass above which it rises is traversed by a few furrows nearly vertical, but dipping a little from N. to S. The upper portion, or about two thirds, of the east side is rather more furrowed. The lower portion bulges out and is smooth. The furrows incline to the southward, bending more decidedly in that direction as they reach the bulging portion of the rock, on the upper surface of which they terminate. The third portion of the mass is smaller than the preceeding; and its upper surface slopes seaward. Its sides are much channeled. The upper portion of the southern face of the fourth or external mass slopes curvately from the cleft that separates it from the preceeding mass till its lower portion approximates to vertical and dips beneath the sea. Its surface is on all the three exposed sides an uninterrupted series of sharp ridges and included furrows which vary in depth and breadth. The depth is from two to five feet. Some are broad and deep semicylindrical concavities — the surfaces of which are grooved or fluted all round. The grooves are continued without interruption, and with all their regularity of form, beneath the level of the sea where they are quite covered by shell fish. The axis of the grooves on the front runs NW. by W. and SE. by E. nearly.

At the SW. side there is a curious ladle shaped cavity of which the bottom is flat and about a foot in depth. A channel leads into it from the upper edge of the rock and another, very shallow, descends from it. On one side is a small heart shaped hollow. A band of black hornblendic rock traverses the upper part of the cup and includes the hollow.

The appearance of the whole mass from the sea is very remarkable. The summit seems to consist of numerous peaks, the lower being the projecting extremities of the ridges, and the higher rising well above the mass like turrets, while the tree spreads its arms protectingly over the whole.

On the vertical surface of an adjacent rock there is a deep cup like depression. The Chinese have partially broken the rock at this place, and below the surface of the cup it is seen to be arranged in concentric foliae corresponding with the cup.

A little to the E. of the pile above described, a large wedge shaped rock rises out of the sea. It is furrowed on all sides.

Half way up the hill behind, there is another very remarkable mass, the face of which stretches along the hill in a horizontal direction for apparently 150 to 200 feet, and with a height in some places of 40 to 50 feet. A peculiar feature of this rock is, that, while the western portion is grooved vertically, the eastern is traversed by a series of parallel clefts or furrows dipping from E. to W. at an angle of apparently about 45°. The belts of rock between them are broken through in many places by irregular channels often approximating to vertical. The surface of this side is further back than that of the rest, and as a small projecting portion of its upper edge, which is continued in the same plane with the latter, presents vertical channels of similar dimensions and aspect to those which mark it, I conclude that after the whole face of the rock had been channeled out, a tabular mass here fell off leaving only a portion where the cohesion was firmer, and that the next layer or laminae, possessing a different structural cleavage, has been since furrowed in the direction of its principal divisional lines. This conclusion is strengthened by the circumstance that this portion of the face has an angular broken appearance, and that neither its inclined nor its approximately vertical channels have the smooth regularly curved surfaces which characterise the grooves of the rest of the rock in common with the other masses in this locality. It is to the latter, like the first rude angular outline shaped by the sculptor to his finished work. Nevertheless it also bears the impress of a high antiquity being covered by vegetable incrustations, and embraced by the reticulations of the roots of a tree similar in species to that before noticed. Many of the principal roots run along the bands or ridges between the grooves. Some prefer the latter, and some pass from one groove to another by the gutters which intersect the dividing ridge. The summit of the rock presents a dense mass of vegetation.

On the top of the hill, which is here very steep, there are several piles of rocks whose perpendicular sides project from the declivity, while their summits are nearly on a level with that of the hill. One of these is divided into distinct entire masses by wide vertical chasms. The perpendicular faces are grooved. Another adjoining pile, on the other hand, has been broken up into a number of cuboidel blocks, and long tabular masses resting on these. The passages between the former are in many places broad and deep, and, where they are covered by the superincumbent rocks, form dusky cavernous hollows, which are tenanted by bats. Some of the external passages are like doorways being about 7 feet in height and 6 across. At the side of one of these entrances half of the horizontal surface of one of the supporting rocks is exposed. It is hollowed out into a shallow basin about 6 feet in diameter and 6 inches deep, which is filled with vegetable debris and water. One of the horizontal tabular masses is about 30 feet long. On its *under* surface, which is smooth, are two semiglobular hollows. An adjacent mass is about 40 feet in length, and 8 in breadth. On its *under* surface also I observed a cup about 3 feet in diameter and 1 in depth at the centre. The hill is here very narrow and slopes steeply on the inner side to a mangrove flat. On this side there are also several rocks. One of considerable size had a smooth rounded surface unmarked by any furrows.

The rocks along the beach, although with a few exceptions not remarkable for their size and architectural features, are geologically interesting. At the farthest Chinese hut to the eastward are broad flat masses stretching across the beach, and only a few feet in height. Their surfaces are traversed by parallel rectilinear fissures and slight grooves, marking divisional planes, and the direction of these, and also of the longest edges of the rocks, is almost due NE. and SW. Proceeding along the beach to the westward, a fine example of concentric or parallel curved exfoliation occurs. Of what has originally been an extensive mass of rock there only remain a few solid blocks, of cuboidal and rudely spherical forms, which rise from the decomposed and semidecomposed bed worn down nearly to the level of the beach. Embracing the rounded bases of these *nuclei*, and forming the bed, are the upper edges of parallel curved laminae, which continue till those spreading out from an adjacent nucleus meet them. Sometimes the same laminae are seen, after embracing the end of one block, to bend reversely and embrace another nucleus, so that the surface or horizontal section exhibits a series of narrow parallel S. shaped bands. The variation in the curves according to the form of the sides of the nuclei is very great and striking. The lower corner of one of the blocks is conical, and the concentric sheaths or caps have the same shape. In the triangular spaces left where three systems of laminae meet, are prismatic masses, solid but of a crumbling structure, and in composition similar to the laminae.

Near one of the Chinese houses I observed that the face of a rock, freshly split by the Chinese, was a regular curve, and on the hill the side of a large rock had a similar curve. I partially re-examined the rock mentioned *ante*, p. 7. The W. side is marked by deep grooves, of which the axes are NE. by E. nearly. The planes in which these are formed also determine the direction of the face of the rock overlooking the channel. Many of the grooves on the west side are a succession of deep pear shaped cavities. I think there can be no doubt that these are owing to sheathed nuclei having been gradually excavated. That such nuclei are very abundantly dispersed amongst the rocks is evident.

A little to the W. of this rock and towards the beach there is a large flattish rock. One side is a curve in which parallel laminae, after retaining their continuity for some thickness, part in the middle and give off two systems perpendicular to the first. If this rock, which is nearly buried in the soil, were exposed to meteoric action, a deep groove woold soon be formed in the line were the laminae part and bend inwards.

The metallic vein formerly noticed runs NE. by E. The whole rock is traversed by other planes in the same direction, as appears from slight scorings on the surface. Another principal divisional plane is SE. by S. as is well seen by the direction of the edges of some large rocks adjoining.

To the SW. of the grooved rock first described, the rocks on the beach are either extended and flat, and a few feet above the level of the beach,—or, were worn down nearly to the level of the beach, they are broken into small cuboidal and spherical fragments disposed, where this has been recently done, in regular lines. It is obvious how readily rocks with such a structure may be worn into cavities and channels.

Having now sufficiently gone into details for the scope of this paper, it remains to explain the conclusions to which I have been led by my observations. In truth, however, I have not much to say on this subject (save what is of a general speculative nature) that has not been anticipated in the second portion of the preceeding remarks. The first circumstance worthy of note is, that the observer after he has partially explored the Island is wholly unable to conjecture, at many of the Points, whether the next few paces along the shore will bring him to a granitic, a syenitic, a dioritic, or a basaltic rock, or even whether the mass before him, although at the place where he has broken off a fragment decidedly a granite, may not in other places be found to consist of any or all of these other minerals. The Island, in its general mineralogy, seems to break through all arbitrary distinctions of plutonic and volcanic, and to confirm, in a very striking manner, the conclusion, to which most geologists have arrived, that these great classes of rocks are essentially similar in origin. The difference in structure, as between a compact basalt and a crystalline granite, is referred to the difference in pressure to which the basalt, cooling near the surface, and the granite, cooling at great depths, were subject at the time of their solidification. That this may, or rather must have a great influence is certain; but the occurrence of such rocks as these of *Pulo Ubin* cannot be explained by difference of pressure, and, indeed, proves that there are in nature causes independent of variations in pressure, adequate to the contemporaneous production of rocks belonging both to the volcanic and the plutonic series (1). Under whatever circumstances the granite of the Island was produced, under the same circumstances were the syenites and greenstones also produced; and some other cause than great difference of depth and consequent pressure must have determined the mutations in the mineral character of the mass. But if it be certain that such cause existed, would not that cause of itself be adequate as a general origin of the differences in igneous rocks attributed to inequalities of pressure? Mr. Lyell (perhaps the most distinguished of our English writers on geology, whether we consider the originality of his views, the philosophical spirit in which they are generally conceived, or the graceful sim-

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(1) Mr Lyell confines the term *plutonic* to *granites* (*Elements* vol. I. p. 15 and vol. II. Chap. 32.) and I here use it in the same sense. Other writers, and perhaps Mr. Lyell himself occasionally, give it a wider meaning.

plicity of the language in which they are expressed) in the Chapter of his *Elements* in which he treats of the plutonic rocks, and in which he refers them to a deep subterranean source, quotes the following passages from Dr. MacCulloch's System of Geology.

»The ordinary granite of *Aberdeenshire* is the usual ternary compound of quartz, felspar, and mica; but sometimes hornblende is substituted for the mica. But in many places a variety occurs which is composed simply of felspar and hornblende; and in examining more minutely this duplicate compound, it is observed in some places to assume a fine grain, and at length to become undistinguishable from the greenstones of the trap family. It also passes in the same uninterrupted manner into a basalt, and at length into a soft claystone, with a schistose tendency on exposure, in no respect differing from those of the trap islands of the western coast." The same author mentions, »that in *Shetland*, a granite composed of hornblende, mica, felspar, and quartz, graduates in an equally perfect manner into basalt." Mr. Lyell continues: »In *Hungary* there are varieties of trachyte, which, geologically speaking, are of modern origin, in which crystals not only of mica but of quartz are common, together with felspar and hornblende. It is easy to conceive how such volcanic masses may, at a certain depth from the surface, pass downwards into granite" (1).

This is very true, but although the facts previously cited from Dr. MacCulloch prove the easy gradation between basaltic and granitic rocks, they seem as little reconcileable as the rocks of *Pulo Ubin* are with the theory of a necessarily deep tartarean origin of the latter, and less subterranean origin of the former. In *Singapore* there are blocks of greenstone as highly crystallized as any granite but in which large isolated portions become compact and approach to basalt. In these cases it is impossible to refer the change from a compact to a crystalline structure merely to the mechanical pressure of the superincumbant crust, for such a force must have acted uniformily throughout the whole mass before solidification. The cause of the variations in the igneous rocks (excluding those which cool in or near the atmosphere), must be chemical or electrical more than mechanical. It is probable that Mr. Darwin, in drawing attention to the established influence of disturbance in causing certain of the ingredients of a molten mass of different elements to crystallize and separate from the mass, and thereby attain the power of ascending or descending through it to a different level according to the specific gravity of the crystals, has discovered a very potent mechanical agent which is subservient to the chemical causes of the gradations in the plutonic and volcanic rocks. While believing, however, that the influence of continued uniform pressure (and this implies the absence of disturbance) will be chiefly exhibited in communicating a homogeneous character to the fluid rock solidified under it, I would not be understood to limit the effect of disturbance to the mere separation of ingredients by their different relative gravities. It rather appears to me that a very important operation of mechanical agitation has been overlooked by Mr. Darwin.

This leads me to notice the next remarkable feature of the *Pulo Ubin* rocks, their cuboidal, globular, laminar and zoned struture, which I conceive to be intimately connected with

(1) Lyell's Elements of Geology (2d ed.) vol. 2 p. 334.

their varying mineralogical character, and, in fact, to be an effect of the same cause. As the varying crystallization of the rocks seemed to reject the distinction of plutonic and volcanic so their structure not only approximates to that of both those divisions, but even partakes, often in a striking manner, of that which characterizes some of the principal members of what Mr. Lyell terms the metamorphic series. The alternation of beds or zones of different composition, and the approach, where mica abounds, to the structure of gneiss, frequently assimilate them to rocks of that series; while the predominance of granitic types, and the general character of the whole rocks, demonstrate their direct origin from igneous fusion. The close approximation of this developement of igneous rocks at some of its points to certain points in gneissose developments will be more particularly considered in the sequel (1).

Some geologists appear still to doubt whether granite ever has an original concretionary structure. Thus Sir H. de la Beche in his valuable Report on the Geology of *Cornwall, Devon* and *West Somerset* (p. 450) in reference to the detached blocks, protruding rocks, and hollows called rock basins, which abound in the granitic tracts of that district, says that, after having given much attention to the subject, he is far from perceiving good evidence in favour of the opinion that the globular blocks are owing to an original concretionary arrangement of the granite. He adds, that after much careful observation he is inclined to refer the rounded character of a large proportion of the blocks, either scattered over the surface or still existing in the *tors* of the granitic districts, more to the decomposition of surfaces produced by divisional planes than to any other cause. Many of the exposed granite blocks on the *Pinang* mountains are rounded at the edges, and this is undoubtedly there the result of mere weathering. That an originally angular block must disintegrate more rapidly on the edges than elsewhere is evident, for there two faces both subjected to meteoric action approximate and meet, so that the edge decomposes quite through, and being in every fall of rain converted into the summit of a petty waterfall, the same mechanical process which, on a grand scale, is wasting the cliffs of *Niagara*, wears down the decomposing edge. But such an operation would not explain the occurrence of really globular blocks, and as these are seen on *Pulo Ubin* in the very act of separating from the original compact masses in which they had been formed, and exposing the concentric coats of which they consist, the fact of granite assuming this structure under certain conditions is matter of ocular demonstration. The fact, however, is not new, for although it is not noticed by Lyell, Phillips, or any other of our recent English writers on the plutonic rocks with whose works I am acquainted, and Sir H. de la Beche is evidently not aware that a concentric laminar structure had ever been actually observed in granite, it is distinctly mentioned by one of Werner's pupils, the most able and learned of our few mineralogists, Professor Jameson of *Edinburgh*, in his article on mineralogy and geology in the *Edinburgh Encyclopædia*, and it seems to be also well known to many continental geologists. Professor Jameson says. « Some granites are disposed in rounded balls or concretions, which are from

(1) See *Post* p. 27.

a foot to several fathoms in diameter. These balls are sometimes composed of curved lamellar concretions, which always include a harder central mass or nucleus. The spaces between the concretions are filled with granite of a softer nature which decays readily, and thus leaves the harder central masses heaped on each other, or strewed about. Such heaps, or tumuli, have been erroneously described as rolled masses brought from a distance to their present situation by the agency of currents that formerly swept the surface of the earth. Examples of this kind of structure occur in the island of *Arran*, *Bohemia*, *the Hartz*, *the Fitchtelgebirge*, and in other countries" (1).

In the *Pulo Ubin* rocks the laminar structure is seen well defined and unequivocal. In the globular form it is as regular as that of trappean rocks; and Mr. Scrope's description of some remarkable examples of this structure in a resinous trachyte or pitchstone porphyry in one of the *Ponza* Islands might be applied verbatim to some of the *Pulo Ubin* rocks. It is not confined to spherical concretions, however, for, as we have seen, it sometimes occurs in rectilinear zones (2), or on the plane surfaces of cubical masses (3), and, at other places, in irregular variously curved planes (4). In these latter cases it is not improbable that the nuclei are spherical or hemispherical towards their centres, and that the laminae only began to depart from this form, as the expanding nuclei approached each other and prevented further independent development. In such cases it is obvious that the upper portions of the laminae have been decomposed and removed by meteoric or oceanic action, and, sometimes, by both combined. Whether the nucleus in most of these cases where only the upper portion is exposed be wholly globular or pass internally into a cylindrical form I am not at present able to say.

In a paper of great interest upon the granitic mountain of the *Brocken* and its sea of rocks" read before the *Berlin* Academy of Sciences on the 13th December 1842, and of which an abstract is given in the first number of the Journal of the Geological Society of *London*, M. von Buch refers the external blocks with which the mountain is covered and the concentric laminar structure of granite bosses in general, to contraction of the mass on cooling. He gives this view a grand application by suggesting that the body of ellipsoidal granite mountains consists, like small bosses, of concentric layers, each repeating the form of the mountain on a diminished scale, — the whole of this structure resulting from the mechanical operation of refrigeration. This structure is well marked in the granites of *Devon* and *Cornwall*, which have a stratified appearance, the beds conforming to the surfaces of the schistose rocks when these are superincumbent. Sir H. de la Beche considers that the laminae or beds probably agree in form with that of the original surfaces of the granite masses after protrusion. He observed at one place alternating beds of a decomposed and hard granite, and he thinks that the difference of original structure may be due to a tendency of the

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(1) *Edinburgh Encyclopadia*, vol. 14 p. 414.

(2) *Ante* p. 8 &c.

(3) *Ante* p. 10 &c.

(4) *Ante* p. 8, 18 &c.

whole to arrange itself in false beds coinciding with the surface of the erupted mass. At another place he observed a similar alternation of beds, which, however, in this case appeared to be at right angles to the bearing of the granitic mass in which they occurred. Schorl rock and granite were seen in another locality in alternate zones. These phenomena appear to be similar to some of those of *Pulo Ubin* which we are considering.

Whatever were the mechanical conditions under which the mass of *Pulo Ubin* solidified from a fluid state, we must admit that to no single uniform causes can we ascribe the phenomena which it presents. Assuming, as I think observation requires, that the whole is of one contemporaneous origin, we must allow that the chemical ingredients of the mass were irregularly distributed, if not originally, then at a time immediately preceeding solidification. Variable mechanical disturbance may have been mainly instrumental in producing local inequalities in chemical and polar action during the transition from a fluid to a solid state, and this might have the effect of attracting certain elements to particular places and there exciting particular mineralogical developments. A portion of the rocks beneath which the granite rose may have been melted into it, and varied the relative proportions of the old ingredients, or added new ones. It is perhaps rash to pursue this subject without an exact chemical analysis of the rocks under consideration. But so far as we can take the ascertained general composition of minerals as a guide, we may enquire whether the passage of the same connected mass from a rock in which mica is entirely absent into one in which it predominates does not support the above views? Can the frequent substitution of hornblende for mica be otherwise explained? It is true there is a great similarity in the chemical composition of the different minerals which make up the rocks of the Island, but some powerful forces must have operated to cause the segregation, in limited spaces, of certain elements from the surrounding fluid mass. Mica is very inconstant in the proportion of its ingredients, and there are species which approach very closely to hornblende, but even in these the lime of the latter is represented by potash. Where we find the mica ceasing, and hornblende taking its place, we must suppose that in the original fluid or viscid mass lime had been segregated in the space now occupied by the latter.

A circumstance mentioned by Sir H. de la Beche with respect to the granite of *Devon* and *Cornwall* bears materially on this subject. He says that towards the borders of the granitic tracts, — that is where the granite comes in contact with the circumjacent rocks, — it alters its character, passing from a compound of quartz, felspar and mica to a schorlaceous rock. The mica first disappears, being replaced by schorl, and then commonly the felspar also disappears, and the rock is converted into a compound of quartz and schorl which are generally aggregated in nearly equal proportions. Sir H. de la Beche also mentions that near the joints by which the granite is traversed, its character alters, and that it is adjoining these joints that the character of the mass at its confines becomes particularly quartzose and schorlaceous. In the lower spurs of a granite chain in *Pinang* I remarked that the rock was devoid of that general uniformity throughout considerable tracts which distinguished the central ridge. It was variable in its composition and texture, being frequently coarse grained. Quartz was largely developed, and in some places schorl, which I do not recollect having any where noticed in the ridge, appeared in large crystals and fibres. Sir H. de la Beche seems to consider that the joints, and the change in the mineralogical character of the rock at their sides must have been produced subsequent to the consolidation of the granite, since in many places the same joints traverse the schistose rocks. Would it not be a simpler explanation of these phenomena to suppose that the schistose rocks were heated and consequently expanded by the fluid granite, — that the crystallization and solidification of the granite commenced in a band or layer next the surface where it would sooner cool, and where the contact of the solid schist, the immersion of fractured portions of it in the granitic fluid, and the greater disturbing motions (1) would favour crystallization; — that, under such conditions, quartz and schorl are developed at the surface; — that, as the heat escaped, or crystallization advanced, planes of minor tension, ultimately giving rise to the joints or planes of disconuity, were produced by contraction, variable motion, polar action, or the mutual action of regularly arranged spheroids; that they traversed the schistose mass immediately above, because, being heated by the adjacent granite, any effect poduced by contraction on refrigeration, the forces of crystallization, or polar action, would, to a certain extent, be common to both, and extended through the superjacent schists to some distance because a splitting of a solid mass tends to extend itself mechanically and the schist was probably in a state of tension from the upward pressure of the granitic bubble; — that, finally, the granite being still in a viscid state when the joints were formed, the surfaces of the joints became quartzose and schorlaceous? Why the granite towards the joints should have an excess of quartz at some places and of quartz and schorl at other places, is a question as difficult as it is important. It may be considered under two hypotheses, either that foreign ingredients were not introduced on the opening of the joints, or that they were. If we believe the joints to have been formed at a period in the gradual cooling of the fluid mass, some time prior to complete solidification and while the crystals, whether incipient or ultimate, were in a viscid state and admitted of motion amongst themselves (2), we shall then have a separation of the mass into geometrical cubes, prisms etc., in each of which crystallization would proceed separately. If in these cubes we suppose the nonsiliceous elements to have united first with the proportions of silex necessary for the formation of felspar, mica etc. and the crystals thus formed to be then attracted together leaving a base of silex for ulteriour consolidation, (as seems to have been the case, from the quartz in common granite filling the interstices between the other ingredients) then, if there be a considerable surplusage of quartz, we should expect to find it accumulated towards the surfaces of the cubes. In those cases where schorl accompanies the quartz, some of the ingredients necessary to the schorl, such as boracic acid,

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(1) It is evident that where the surface of a granitic bubble, swelling up from a vast fluid expanse, came in contact with aqueous rocks, perhaps of unequal resistance, there must have been greater and more variable mechanical disturbance than in the body of the bubble.

(2) We must believe that granite existed for a considerable period in a transition state between fluidity and solidity i. e. as a viscid or pasty substance, and that the ultimate crystals which solidified were not produced during the early stages of this period.

may have risen in a state of gas or vapour through the joints. But, without resorting to this hypothesis, let us suppose that, from the first, all the ingredients existed together in the mass. The external portion of the cube etc. differs more in mineralogical than in chemical character from the internal. The schorl of the former, compared with the felspar of the latter, has a great excess of alumina and a great deficiency of silica. But this difference is compensated, and the balance of ingredients restored, by the quartz which accompanies the schorl. If we therefore reduce the internal and external portions to their constituents, we shall find that the essential difference is only about 10 per cent, and that it consists in the latter having about 9 per cent of oxide of iron instead of only 2 per cent, and in having about 2 per cent of a new ingredient, — boracic acid. We can hardly err in attributing the difference mainly to the chemical action of the acid, which, whether by itself or in combination with soda, is remarkable for its fusibility, and its power of communicating this property to compounds. The tendency of certain substances in a fused mass to retire towards the surface when other substances are there found for which they have a stronger affinity than the other constituents of the mass is well known. But there is no difficulty in conceiving that such a transfer may have been mainly mechanical. The boracic acid may have retained a portion of the matter with which it was in combination in a fluid or viscid state, for some time subsequent to the crystallization and partial solidification of the felspar etc., and the internal pressure of the semi-solidified mass alone may have forced this towards the sides and caused it to rise to the surface. It is ascertained that both felspar and quartz remain in a viscid state at temparatures greatly inferiour to that at which they are fused, and hence there must have been a degree of internal pressure subsequent to crystallization. The fugitive character of schorl is more than once pointed out by Sir H. de la Beche in his Report. Amongst other instances of alterations produced on sedimentary rocks by contact with granite he mentions some slates in which schorl has been introduced between the laminae. A more remarkable case occurs in a granite consisting of large felspar crystals in a base of schorl and quartz. At some places the felspar crystals have been decomposed and replaced by crystals of schorlcrossing each other in various directions, and the schorl in the surrounding base is evidently deficient.

The abundance of quartz at the surface may be due in some measure to the circumstance that the boracic acid, whether expelled from the interiour on the crystallization of the felspar and mica or derived from without through the joints, would, wherever its ultimate locality was, be hostile to the formation of felspar and mica there.

However we may account for it, the fact of the schorl taking the place of felspar and mica in the *Devonshire* and *Cornwall* granites, appears to be analogous to that of hornblende replacing mica in the granites and syenites of *Pulo Ubin*, and if we extend the preceeding speculations regarding the one transition to the other, we shall find them in harmony with the views formerly expressed. We must in the first place consider the Island itself as the summit of one granitic bubble, of which much of the external portions have disappeared. A portion of the bubble (its superjacent rocks, whatever they were, having been swept away) is now elevated above the sea, so as to expose a belt below high water mark to the action of the waves which are working into the nucleus, and, in their progress, laying bare the structure of the external layer of the bubble. This portion we must conceive to have been nearer the pre-existing superjacent rocks than the central and higher mass, (which was probably denuded to the nucleus before it was elevated to its present level) and the great variations in its structure and ingredients may have resulted from that circumstance under the influences previously adverted to (1).

The leading fact relating to the structure of the rocks is, that the principal vertical or approximately vertical planes of division have a general direction approximating to NE. . . . SW. It is also observable that the zones of softer rock and the majority of the grooves have the same directions. *Pulo Ubin* lies in the great plutonic band of elevation stretching from *Assam* to *Banca*, and having, from *Junkceylon* southwards, a south easterly direction. The divisional planes are therefore nearly at right angles to the axis of elevation. Is this a general geological phenomenon? It probably is, because in a locality so far removed as the south west of *England* it is repeated. Sir H. de la Beche informs us that the divisional planes of the granite and other rocks in *Cornwall* and *Devon* are generally NNW. . . . SSE. The grand conclusion which he draws is, that this direction approximates to the present magnetic meridian of the district, and may therefore, in its origin, be related to it. Pre-occupied with this view he has overlooked the fact that this direction is at right angles to the direction of the principal granite masses of the district (E. 24° N. W. 24° S. (2) which, beginning at *Dartmoor*, are continued to the *Scilly Islands*. Not merely the south western division of *England*, but the general configuration of the *British Islands*, seems to be due to axes of elevation having the same or an approximate range. Thus the great body of *Scotland* and *Ireland* may be considered as one connected mass upraised on such axes. Professor Phillips (3) mentions that the anticlinal axes of the *Highlands* and *Lammermuirs* in *Scotland* prolonged to *Donegal* and *Cavan* in *Ireland*, and those of the *Cumbrian* mountains, *the Isle of Man*, and *North Wales*, all range NE. and SW. It also appears from Professor Phillips diagram shewing the result of his examination of the joints in the mountain limestone districts of the north of *England*, that the great majority of the divisional planes are there in NNW. and SSE. lines (4). A coincident range has been observed in the joints in other localities in *England*, and also in *France* « more particularly" says Sir H. de la Beche « in granites and grauwacke" (5). I think it probable,

(1) If the views advanced in a subsequent part of this paper are correct, we must recognize in granitic fluid masses a period, in the gradual diminution of their temperature to the fusing point, when the external layer, having just extended itself into the superjacent rocks by melting them into its substance, was arrested in its further extension by crystallization. Hence the external layer should often be variable, and partake of the chemical ingredients of the adjacent rocks', because time was not allowed for their thorough mixture with the general mass. In fact this layer must often be merely a layer of the adjacent rock fused down and immediately crystallized into a granite. (See note, p. 33, Post.)

(2) De la Beche's *Report* p. 157.

(3) *Treatise on Geology* 2nd vol. p. 258.

(4) *Id.* 1st vol. p. 65.

(5) *Report* p. 275.

therefore, that the jointed structure of rocks will be found to be much more connected with the directions in which igneous rocks have swelled up and been injected, and islands, mountains and continents been consequently upraised, than with the magnetic meridians. If due to mere tension, it may have originated under both or one of two influences. If we conceive, what is most reasonable and consistent with observation, that the formation of mountain chains is accomplished by a slow movement or succession of movements prolonged during a great geological period, then we must admit that the upper layers of the gradually ascending and cooling mass have been exposed to continued or repeated pressure from below, which, of itself, would cause the partially hardened or viscid crust to crack, or would give rise to planes of inferiour resistance to tension in which the mass would have a tendency to part. But there is another source of tension which may co-operate with external pressure, or exist independently of it, and that is simple contraction after crystallization on cooling.

In and near *Singapore* we find the stratified rocks in general elevated into low ranges of hillocks, of which the axes coincide with that of the *Malay Peninsula* and the Islands from *Singapore* to *Banca*. The strata have commonly been tilted up at very high angles, frequently approaching vertical. Considering the *Peninsula* and its prolongation in the Archipelagoes south of *Johore* as one band which has been subjected to elevatory plutonic forces (1), the first external effect of these forces must have been to cause a great tension from NE. to SW., across the zone, followed by a rending and displacement of the superincumbent strata, and injection of ignifluous matter along lines at right angles to that of tension, or from NW. to SE. The principal divisional planes must have been the result not of a transverse tension like the first, but of a subsequent longitudinal one (2).

The great rending and displacement of the strata, and the circumstance of the heads of adjoining strata being sometimes broken up and intermingled, prove that mechanical movements of great violence, and combining a horizontal vibratory with a vertical action, must have attended their upheaval. The direction of these movements must have agreed with the line of tension, because they were nothing more than the effect of the tension reaching the limit which the rocks subject to it could bear. The strata are generally inclined from SW. to NE., although there are several exceptions. The elevatory force therefore acted, to a certain extent, in this direction. Was there an actual propulsion of the fluid or viscid matter from SW. to NE. or merely an undulating motion in this direction? Such a motion is even now experienced in a slight degree along the western border at least of the *Peninsula* when the subterranean forces are acting beneath the western border of *Su-*

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(1) Whether a simultaneous action elevated both the central granitic chains of the *Peninsula* and the semi-volcanic hills along their base and to the south of the *Peninsula*, or the latter were due to a later subsidiary action connected with the shifting of the subterranean forces to *Sumatra*, does not affect the above reasoning, since the fact of agreement in direction is clear.

(2) See Mr. Horais's papers, *Researches in Physical Geology &c.*

matra (1). There is a source less remote of motion in the upper portion of volcanic and plutonic fluid or semi-fluid masses which I have not seen noticed by geologists. When the superincumbent *strata* were fractured in NW. — SE. lines, and the fluid mass pressed into the openings, the adjoining portions would acquire a temporary motion towards the openings or at right angles to the lines of fracture. In all cases of plutonic elevation there must either be a slow continued motion upwards as the strata insensibly give way to the pressure, or an accelerated motion when great rents in the strata are abruptly produced. In most cases the viscid granitic mass has probably been of too great extent, and the motion too slow and uniform, to give rise to any variableness of structure.

If a motion, however induced, of the igneous fluid from SW. to NE. be assumed, the alternations which we find in the *Pulo Ubin* rocks, in bands running SW. — NE., might perhaps be explained on the same principle by which Professor Forbes accounts for the viscid mass constituting a glacier being zoned in the direction of its length, — an explanation which Mr. Darwin has applied to the lamination of volcanic rocks of the trachytic series. In the case of the *Pulo Ubin* rocks, the general agreement in direction between the zones of variable mineral character and the principal joints, renders it in a high degree probable, if not certain, that, if not contemporaneous in origin, the continued action of the same cause superinduced both. This cause must have begun to operate when the mass was in a fluid or viscous state. Now as some zoned glaciers are of as great bulk as many exposed granitic masses, such as those of *Cornwall* or that of *Pulo Ubin*, we may safely consider that the influx of a viscous body of granite into fissures gradually enlarging into great cavities, would, at least sometimes, under a certain range of motion, and where the conditions assimilated to those of glacier motion, be attended with mechanical structural effects somewhat similar to those observed in glaciers, and repeated in the experiments made by Professer Forbes on other viscid substances. The conditions under which plutonic masses rise must vary very greatly, but there is no difficulty in believing that they sometimes, and particularly in masses of no great bulk, approximate sufficiently to those which, in glaciers, produce parallel bands of variable tension, vertical towards the surface.

Reverting now to the analogies between the rocks of *Pulo Ubin* and rocks of a decided gneissose structure (2), let me request that, in reference to this subject, the preceeding discussion be kept in view. Mr. Darwin remarks that such facts as the vertical or highly inclined lamination of felspathic rocks, such as he observed at the island of *Ascension*, and which exist elsewhere, » are manifestly of importance with relation to the structural origin

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(1) In the most recent instance of an earthquake of great power, — that experienced on the west coast of *South America* in 1835 and the phenomena of which clearly proved the identity of plutonic and volcanic power, — the undulations appear to have proceeded from the SW. extending consequently in NW. . . SE. waves. Mr. Darwin says: » The fissures in the ground generally, though not uniformly, extended in a SE. and NW. direction and therefore corresponded to the lines of undulation or of principal flexure." Darwin's *Journal* p. 311 (2d. ed.)

(2) *Ante* p. 20.

of that grand series of plutonic rocks which, like the volcanic, have undergone the action of heat, and which consist of alternate layers of quartz, felspar, mica and other minerals" (1). The origin of this series of rocks is one of the great debateable questions of geology. As in so many other instances, both of physical and metaphysical questions, where an array of probabilities can be advanced on each side, both parties may be in the right and both in the wrong; or rather, nature, capacious and multiplex while harmonious, can embrace and assimilate the ideas of both. If we limit our views to *India*, we can hardly deny an identity of origin to granite and gneiss. Upon the question generally I shall not enter, but it may help us to a better understanding of *Pulo Ubin*, if some facts, gathered from the papers of *Indian* geologists, be here placed side by side with those local facts with which they appear to be connected by some general law. Dr. Voysey, one of the earliest and ablest labourers in the field, remarked, in 1823, — « up to the present time I am inclined to think that both the granite and gneiss of *India* are contemporaneous, as they are perpetually passing into each other and have the same subordinate rocks. I think it probable they owe their difference of structure to a different mode of consolidation (2)." Dr. Buchanan Hamilton's recently published report on the Eastern Districts of *Bengal* confirms Dr. Voysey's view, and suggests still more important considerations bearing on the geology of the *Malay Peninsula* and its Archipelagoes. In reading it I was struck with several features of the hill ranges of *Bengal* which strongly reminded me of those of *Singapore*. I have been led to think that the same relation subsists between these hills and the great mountain ranges behind them, — between the lower hill ranges on both sides of the *Peninsula* of *Southern India* and the central mountains, — between the hills on the flanks of the *Sumatra* chain and the chain itself, — between the hills along the coasts of the *Malay Peninsula* and the mountain groups of the interiour; — and between the hill ranges and the mountains of *Australia*. Some remarkable characteristics are common to all these hill ranges and groups, and every addition to our knowledge serves to confirm my impression that they must be referred to one geological era and one peculiar plutonic or volcanic action operating over a region of great extent, in which *Southern Africa*, *India*, the *Malay Peninsula*, a large portion of the *Eastern Archipelago* and *Australia*, are included. It would require a separate paper to bring together the facts that have induced and confirmed this impression. I will here only notice some circumstances mentioned by Dr. Buchanan corroborative of Dr. Voysey's view, and bearing on the structure of the *Pulo Ubin* rocks. The minerals of what Dr. Buchanan terms the southern central division of *Bhagulpore* consist, in general, of aggregate rocks composed of felspar or schorl intermixed with quartz and sometimes with mica, and disposed in vertical strata running easterly and westerly. The quartz is not only found as a portion of the aggregate, but in parallel layers alternating with it, and even in whole strata. « In some of the strata the component parts were pretty uniformly scattered, thus forming granites, according as they contain-

(1) Darwin *on volcanic Islands* p. 72.

(2) Brewster's *Edinburgh* Journal of Science vol. X p. 375.

ed 3 or only 2 ingredients; but in by far the greater number certain plates or flakes, as it were, contained a greater proportion of one ingredient, and certain portions a greater share of the other, forming thus what by some is called Gneiss. The length of these plates is always disposed parallel to the general direction of the stratum, and the edges are vertical, or nearly so. There were also other stones, in which the component matters were disposed in what may be called striae; that is a great proportion of one of its component parts run horizontally through the others in lines parallel to each other, and to the direction of the stratum. Such stones have also been included under the name of gneiss.

»In many of these stones may be occasionally found vertical layers of white fat quartz, running parallel to the stratum, and entirely separating one part of the aggregated matter from the other, without producing the smallest interruption of substance; nor is the stone more easily broken there than anywhere else. In these stones, when entire, there is nothing like a schistose, or striated fracture; but in a state of decay, if exposed to the weather in certain situations especially so that the rain may lodge on the surface, the stone gradually splits into thin plates like slate, and this seems to happen as readily to pure quartz, or to perfect granites and granitels, as to the gneiss. In other cases again, especially where blocks have been detached, the stone decays concentrically and of course, losing its angles first, becomes a rounded mass (1)." The rocks of what Dr. Hamilton terms the northern intermediate division consist also of granites and gneiss.

The recent publication in the Journal of the Asiatic Society of *Bengal*, of Captain Herbert's Report his mineralogical survey of a portion of the *Himalayas* (2) has shewn that gneiss is the grand constituent of these stupendous mountains, but the gneiss frequently loses its laminar character and approaches or passes into granite; a species of granitic gneiss is common, which appears very often to form the transition between granite and gneiss. The observations of Captain Herbert appear to me to tend very strongly to the conclusion that the gneiss and granite of the *Himalayas* were of contemporaneous plutonic origin. The gneissose structure may be simply the consequence of an excess of mica, for in most instances where Captain Herbert notices the occurrence of granite, he adverts to the diminution of the mica. Again, as mica diminishes the laminar structure disappears. Thus at one place the gneiss gradually loses its mica and becomes an unlaminated mixture of quartz and felspar, having the aspect of quartz rock. A rock occurs composed of felspar and hornblende in different proportions apparently very similar to some of the *Pulo Ubin* varieties; and at one place Captain H. observed it passing into gneiss, although in general the transition is abrupt. It occasionaly contains mica and even quartz. Greenslate passing into greenstone occurs frequently. The direction of the principal beds into which the gneiss is separated (true strata according to the Wernerians and metamorphists,) coincides with that of the mountain zone of greatest elevation,

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(1) Martin's *Eastern India*, vol. 2, p. 187.

(2) The date of the survey is not given, but Captain Herbert was at *Almorah*, engaged in it when Bishop Heber visited the mountains in 1842. (See Heber's Journal).

the dip being to the NE. These strata-like divisions are frequently crossed by fissures at right angles to them, and sometimes by another system in a different direction. In some places, particularly in the higher regions, the gneiss, though perfectly laminar, is not divided into regular beds by parallel seams but is crossed by fissures in all directions. In a lower zone of the *Himalaya* a range of granite tracts of considerable extent occurs. This zone is parallel to the direction of the axis of the mountains and the strike of the gneiss. The most eastern tract, at *Chumpawat*, is soft like the *growan* of *Cornwall*, and contains much felspar and little mica. Hard blocks are strewed over it. A portion of the next mass is exclusively felspar »which, it would seem, is stratified". Near *Dhee*, Capt. Herbert describes some spheroidal blocks of great size, which are exfoliating in the same manner as those of *Pulo Ubin*. One of these was 60 feet in diameter. Numerous veins, consisting almost wholly of quartz and feslpar, traverse the granite. Schorl abounds. The next mass, proceeding westward, is at *Almorah*, where granite and granite gneiss occur. A fourth mass is found at *Palee* which precisely resembles those to the eastward. It appears to pass into gneiss on its borders. On a line to the westward »a rock oscillating between granite and gneiss" is found. Near *Dhoocot* the rock development is so interesting in itself and bears so much on the subjects discussed in this paper that I shall cite Captain Herbert's description. »In a geological sense the rock may be called a gneiss, but it exhibits small patches (forming regular transitions amongst themselves) of the most regular micaceous schist (earthy type), and, again, of the most legitimate granite (growan). These three rocks, so different in composition, in mineralogical character, and in supposed geological origin, may be here observed in the compass of a few yards all naturally (mutually?) interchangeable, while nothing like a veinous appearance can be attributed to any of them". On the same zone with the preceeding masses, but at a great distance to the westward, the *Choor Peak*, which rises to the height of 12000 feet, is composed of granite.

The zone of gneiss is 24 miles in breadth and includes all the higher summits of the *Himalayas*. The gneiss was seen at altitudes of from 2,800 to 25,709 feet. To the southward succeeds a zone of about the same breadth formed principally of micaceous, chloritic, talcose and hornblendic schists, but including limestone and the granitic tracts formerly mentioned. These types vary exceedingly in themselves, and in their transitions into each other. This schistose tract is succeeded by a band of sandstone which is referred to the New Red. The general dip of all the rocks from the sandstone to the gneiss is from 20° to 30° to the NE. or *towards* the great central plateau of *Asia*. The lowest system is therefore the new red sandstone: and the highest the gneiss. Captain Herbert seems to consider that this fact negatives the idea that the planes of apparent stratification are really what they seem, and he is obviously rather disposed to refer them to a similar action to that which produced the fissures transverse to them. It is scarcely possible to conceive that a continuous mass of strata, about 60 miles in horizontal breadth at their present inclination, which would give an original vertical depth of about *sixteen miles*, should have been raised on its edge and made to move through an arc of 150° to 160° until it rested in its present position, with the gneiss, originally 16 miles below the sandstone, now as many miles above it. Such displacement does no doubt sometimes occur on a great scale. Thus in the *Alps*, and, as we learn from the great work of Sir R. Murchison and M. de Verneuil, in the *Ural* mountains, thick masses of strata are in some places overturned, and, on the flanks of the latter mountains, the order of superposition is thus sometimes inverted. But such cases cannot justify us in supposing that in a similar convulsion on a transcendent scale the *Himalayas* originated. The metamorphic theory might get rid of the difficulty if it could be shown that the gneiss and other rocks resting on the new red sandstone were really more modern sedimentary rocks! (1) Until we possess further light we seem justified in considering that the researches and conclusions of Captain Herbert tend to prove that the passage of gneiss into granite or the reverse may be determined simply by the variable proportions of mica and the conditions of crystallization from a common state of fluidity or viscidity. A portion of the *Himalayas* has more recently been examined by Dr. MacClelland, and he declares positively that the granite is stratified, the strata being nearly vertical and appearing to be composed of nodules around which concentric layers are wrapped. He states also that *the gneiss rests on the granite in conformable strata,* and that the two rocks pass insensibly into each other (2).

The metamorphic theory starts on a basis of fact and is demonstrably true up to a certain limit. But when applied to mountain masses of enormous thickness we leave that limit far behind. The conversion of the *Himalayas* from soft sedimentary into crystalline matter cannot be explained by the plutonic action of granite on known aqueous rocks, even where it has pervaded them to the thickness of a few hundred yards. If the *Himalayas* were metamorphosed, the process must have been different, or plutonic influences must have been in operation of far greater potency, and having in some respects a different mode of action. There is an unsatisfactory want of definiteness about the metamorphic theory even when expounded by its great advocate M. Lyell. If the ingredients of gneiss, were originally arranged as we find them at present, then it only differs from the Wernerian theory in substituting a posteriour for an aboriginal consolidation, and places gneiss on the same footing with any of the secondary or tertiary sandstones that have assumed a stony texture since they were deposited from water. On the other hand if it takes a bolder grasp of the difficulty and asserts that the whole structure of the rock, the regular form of its crystals, and the separation of those of different species into alternate laminae, are due to the mass having been melted into a viscid state and subjected to crystallization *de novo*, it appears to come so close to direct plutonic formation that it is not easy to see where room is to be found for a vast metamorphic laboratory on the confines of the latter. Its advocates have probably seen and shrunk from the difficulty of defining the conditions

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(1) Dr. Buckland estimates the thickness of *all* the European stratified rocks including the primary at ten miles. *Bridgewater Treatise*, vol. 2, p. 39.

(2) M. Calder describes the granite in the district of *Tinnivelly* in *Southern India* as arising above the surface in remarkably globular concretions and in *perfectly stratified masses*", forming low detached hills near *Palemcotta* the strata of which dip at an angle of about 45o to the SW. (Brewsters *Edinburgh Journal of Science*, vol. X, p. 130). Other writers on the geology of *India* mention the occurrence of granite in many places with a similar appearance. Humboldt in his work on Central *Asia* describes the remarkable structure of the granite surrounding the mass of the *Altai*. At *Kolyvan* a large grained granite is "regularly stratified".

necessary for the existence of a metamorphic region subsidiary to the plutonic and so wonderfully related to it that, — while, in all unequivocal instances of change in sedimentary rocks from the neighbourhood of a pultonic fluid, the power of the latter has been confined to the narrow limit which we now see (1) to be altered, or, beneath the present base of the rock, has entirely reduced and transmuted it, — in the region in question the power of the plutonic fluid was so much weaker that the original strata of the sedimentary rocks subjected to its influence were left unobliterated even up to the plane of contact, and yet so much greater that the substance of the entire mass, throughout thousands of yards in thickness, was melted, re-crystallized and arranged in laminae (2). Until these conditions have been defined and illustrated by facts, it is not unreasonable to suspend our judgment, and to believe that the tendency of plutonic rocks having the same ingredients as gneiss to a stratified or zoned structure, and even, where mica is abundant, as in the latter rock, to a laminar arrangement, may hereafter be found to explain the origin of such enormous bedded and laminated crystalline masses, as the *Himalayas* exhibit, more simply than the theory of metamorphism as at present developed.

The *beds* of gneiss are no doubt devoid of that regularity which divisional planes possess, and in this respect resemble strata of deposition, (3) but it appears to me they are not ana-

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(1) Mr. Lyell is not able to adduce an instance of alteration beyond 400 yards from the point of contact, and this he admits to be an extreme case. *Elements*, vol. 2. p. 403 and 411.

(2) It is well ascertained that stratified rocks of a limited thickness may be metamorphosed by granitic influence without losing their division into strata, but the difficulty is in conceiving a plutonic action so powerful as to extend to the upper part of a mass of some miles in thickness and reduce it to »a state of semifusion" (Lyell's Elements 2d. vol. p. 411) without destroying all vestiges of the original strata in the lower part. The plutonic influence may have been conducted through fissures, but in that case it would be necessary to shew that a system of viens ramifies throughout the *Himalayan* mass, for instance, almost as complete as those which distribute the blood throughout the body of an animal. If, as seems probable, there are, between the great plutonic tracts of elevation, extensive tracts suffering depression (such as those covered by the Bay of *Bengal* or the *Indian Ocean* generally) their rocks must be exposed to plutonic influence laterally as well as from below, and this would reduce the difficulty. Mr. Lyell says that, »granite may have been another result of the same action (i. e. that which produced gneiss by semi-fusing sedimentary strata) in a higher state of intensity, by which a thorough fusion has been produced: and in this manner the passage from granite into gneiss may be explained." Now when in the *Himalayas* we find miles, and in *Scotland* great depths, of gneiss and its associated rocks, containing frequent beds of granite, it is not easy to conceive how the metamorphic influence in ascending through masses of such thickness, should be so unequal as to melt down some portions, while only half melting the bulk of the strata. In the lower regions this is quite conceivable, but when we find the same inequality in sections of the mass near the summit, that is many miles in some cases above the level whence the action emanates, the theory seems to halt.

(3) Lyell's El. 2d. vol. p. 390. The strongest argument in favour of the sedimentary origin of gneiss is that insisted on by Professor Phillips. He says that »in gneiss and mica schist the felspar, quartz and mica are rolled or fragmented masses, showing clearly that the crystals had been exposed to attrition previous to their deposit" (article *Geology* in *Penny Cyclopaedia* vol. XI. p. 139. and *Treatise on Geology* Ist. vol. p. 112). It is clear that such must be the condition of the ingredients of sedimentary rocks derived from the wasting of granite, and subsequently consolidated so as to resemble gneiss, as in those ascertained instances where injected granite has been the agent of solidification. But if the fact be universally true with respect to gneiss, it is fatal to the hypothesis of the plutonic origin of that rock in any case. It is a two edged weapon, however,

logous to the divisional planes which alike penetrate plutonic rocks and the strata above them usually in directions approaching to vertical, and which also exist in gneiss, but to those beds in granite which von Buch considers as always conforming to the external surface of the granitic bubble, of whatever form that may be, and which Sir H. de la Beche describes as being in *Devonshire* and *Cornwall* actually parallel to the strata of superjacent sedimentary rocks where the plane of contact can be seen (1).

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for it would destroy the metamorphic theory also. The *Treatise on Geology* was published in 1837, and the second edition of Mr. Lyell's Elements in 1841, but in noticing some objections to the metamorphic theory Mr. Lyell does not allude to Professor Phillips' argument. It is to be presumed therefore that he discredits the fact on which it rests, and as I do not find it mentioned by Prof. Jameson, who has studied gneiss carefully, nor by other writers, we must wait for further investigation. Professor Jameson, on the contrary, in Murray's *Encyclopaedia of Geography* published in 1834 (p. 219) positively states that the concretions of limestone, gneiss, mica-slate and other rocks of the *primitive class have the* same characters as those of granite i. e. »they are joined together without any basis or ground, and at their line of juncture are either closely attached together or are intermixed," and frequently branches of the one concretion shoot into the other or the concretions mutually impress each other.

(1) The study of plutonic rocks and of mineralogy appears to have been somewhat neglected by geologists of the English school, and, making due allowance for the influence of Werner's theories, I should be disposed to give much weight to the inferences of the Scottish *geologists* who, animated by the ardour first kindled at *Freyberg*, during many years laboriously and minutely explored the mountains, coasts and *islands* of their native country. Gneiss is largely developed in the north of *Scotland* and frequently associated with granite, and the analogy between them must be very strong to admit of Professor Jameson declaring that »granite occurs in masses, often many miles in extent, surrounded by gneiss, mica-slate, and clay-slate, and so connected with these rocks, that the whole may be considered as the result of one grand process of crystallization; that is, the granite is of contemporaneous formation with the gneiss as the gneiss is with the super-imposed mica-slate, and the mica-slate again with the clay-slate which rest upon it. ***In other instances the granite alternates in beds, often of enormous magnitude, with gneiss, mica-slate, clay-slate, and other primitive rocks***, or it traverses these in the form of veins." Again, »granite is sometimes disposed in great beds in gneiss and other rocks, and occasionally these beds appear divided into strata. In other instances, in granite mountains we observe besides the tabular, globular and other structures, also the stratified; but this latter is, in general, less perfect than what is observed in gneiss and other rocks". It is true Professor Jameson then believed in the *Wernerian* theory (which he has since largely abandoned, for in his latest classification he distributes the hypogene rocks into Plutonian and Neptunian) but he would not misrepresent facts, and the facts which he observed in *Scotland* seemed to him to demonstrate the derivation of granite and gneis from a common origin. Now this conclusion is quite separable from the ulteriour speculation as to the nature of the origin, and in the present advanced state of our knowledge it seems to require us to substitute a plutonic for an aqueous, without the intervention of the metamorphic, theory. Let me not be understood however as desirous of embracing a direct plutonic theory in the place of the metamorphic. All I maintain is that there is a limit where it ceases to be a theory and becomes an hypothesis, and this limit is narrow compared with the vast province over which its leading exponents extend it. As an hypothesis it is highly valuable, having already guided investigations which have been rich in results. Its legitimate domain, of which the boundaries are defined by geological demonstration, is constantly enlarging; and, in the present palmy condition of the science, we may hope that geologists, in a few years, will be able to determine whether the bulk of what are termed the primary or hypogene stratified rocks be semi-plutonic (i. e. metamorphic) or entirely plutonic, in the same sense in which granite is.

At the present day it is not so much dogmatism, prejudice or a reckless spirit of speculation in men, that maintains rival theories in geology, as that higher metamorphic power of nature which is ever reproducing the elements of

We have seen that von Buch refers these beds to contraction of the substance of the granite at a time when it had a degree of consistance »which in most cases was far removed from the condition of fluidity." But may not the internal structure of granite and other hypogene rocks be primarily due, not to the merely mechanical effect of contraction on cooling, but to the original conditions of crystallization? Reversing the Neptunian theory of the deposition of the primary rocks from a state of chemical solution in a hot fluid upon the *upper* surface of the earth's crust, may or rather must we not conceive them to have been gradually deposited on the *under* surface of the crust? We must suppose that crystallization did not at once extend throughout the whole of any mass of plutonic fluid, but commenced in a layer nearest the refrigerating surface of the superincumbent rocks, and thence slowly extended by accretions from below. Dr. Lardner says that »sudden expansion in freezing is particularly conspicuous in the crystallization of solids which shoot into prismatic forms. The process of crystallization in laboratories is for this reason frequently attended with the fracture of the vessels in which it is conducted. It may be taken as a general truth, to which however there may probably be some exceptions, that bodies which crystallize in freezing undergo the sudden expansion here mentioned, and that bodies which do not crystallize in freezing for the most part suffer a sudden contraction" (1). *A priori*, therefore, it might be predicated as probable that the granitic fluid, like water, expands on congelation. This predication seems to be verified by observed phenomena. If the granite contracted on crystallization, the crystals formed at and near the surface of refrigeration would sink, the hot fluid from below would constantly ascend to the surface, and when the central heat of the earth was so much lowered as to allow the crystals to reach the centre of gravity in a solid state, a nucleus would there be formed which would gradually increase until the globe was solidified from the centre to the circumference; or, at all events, no permanent solidification would take place until the temperature of the whole fluid was reduced to the point of congelation (2). Under such conditions, if the globe were originally a homogeneous fluid,

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matter in different shapes, and which so often assimilates her most diverse processes in the phenomena which result from them. We may seek to isolate particular processes, set the stamp of a name and a theory upon them and extend their exclusive dominion, but still the ministers of nature work together and in harmony, or rather in them the unity of the absolute will still manifest itself. We term some rocks plutonic and some volcanic, and presently we are forced to say that they pass by insensible gradations into each other. As our knowledge extends all this will probably appear but a play of words. Restraining speculation, we may consider it as established that the plutonic and volcanic rocks are the produce of the same process; that congelation and deposition may alike cause the stratified structure; and that by a chemical action, often slight, igneous rocks may, *in situ*, become assimilated to sedimentary, and sedimentary rocks may, *in situ*, become assimilated to igneous. Observation alone can reconstruct the history of any given rock, and determine the limits within which transmutations are effected in nature.

(1) *Treatise on Heat*, p. 131.

(2) This appears in granite to be about the same as that of iron (De la Beche's *Report* p. 191) which is stated in the table appended to Dr. Lardner's *Treatise on Heat* (p. 415) to be 21637° F. but which appears by the improved pyrometer of Professor Daniell to be only 2786° F. (*Penny Cyclopaedia* Art. *Freezing and melting Points*.) It should be observed however that granites vary very greatly in fusibility. Trappean rocks were found by Sir H. de la Beche to fuse at the same temperature with copper or 1996° F.

and granite be the constant result of the internal congelation of that fluid, no solid *crust* could ever have been formed. But assuming the existence of the crust apart from all theories of its origin, and limiting our view to the great lakes or oceans of fused rock beneath particular portions of the crust or occupying great cavities in a solid globe, which are all that Mr. Lyell will recognise as necessary to explain plutonic and volcanic phenomena, it is obvious that, until the temperature of the whole lake or ocean were reduced to that of incipient congelation, the upper layer would retain its heated fluid condition. If so, the igneous fluid would have time to penetrate fissures to great distances in the same way as that of trap. But granite veins are generally found to be short and sinuous, a circumstance which contradistinguishes them from dykes of trap, and which seems only explicable on the assumption that the injective tendency of the fluid was counteracted by its tendency to congeal at the surface from contact with the rocks above and to remain there in that state in consequence of its expanding or becoming less dense when it assumes the solid form (1). The phenomena which have been discussed in this paper disclose two structures in hypogene rocks, the laminar, and the globular passing into the cuboidal. Now the first may be due, in the case of gneiss, simply to excess of mica or to this in combination with other causes which have been adverted to. The second is clearly the original mode of crystallization, if the above views are correct, or if it be granted, without reference to them, that granite solidifies from the surface downwards. In the upper layer of the granite fluid, nuclei are formed, which gradually enlarge till their mutual expansion prevents further increase, and the layer, bearing the form of its mould (2), is complete. This layer is the upper bed or stratum of the granite, and others are successively formed beneath, each, of course, conforming to that above it. The spheres not only when first formed, but during the long

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(1) The granite veins of *Cornwall* and *Devon* seem to demonstrate that a crust must have been formed while the granite beneath retained its fluidity, for it not only sends veins into the slates but is itself traversed by veins of the same kind of granite. These are also sometimes continued in the slate above. (De la Beche's *Report* p. 171, 2).

From the point of fusion of granite being very high compared with volcanic rocks, and, I presume, as high as that of any sedimentary rocks, it follows that so long as the temperature of granite is above that point, it will continue reducing the incumbent rocks at the plane of contact into its own substance, and will only cease to do so when it is on the point of ceasing to be a fluid. Hence, probably, the shape of the veins. They were filled with granite when its temperature was reduced to that of incipient congelation and when the fluid had, consequently, become thick. They shew, as it were, its last efforts in its fluid state to melt into the rock above it. Even where the granite fluid at a temperature above 2786° entered a straight mechanical fissure or crack in any rock, it would immediately begin to melt the sides. The veins are therefore more pyrogenous than mechanical. Trappean fluid, on the other hand, might remain in a fluid state long after its heat was inadequate to melt the adjacent rocks. It might therefore be forced into fissures without altering their previous form. Trappean veins might thus be considered as generally mechanical,—granite, as generally dyrochemical, for the irregular distribution of chemical ingredients in a rock would affect the course of granitic veins in it. From the great difference in the fusing point of granite and trap, it probably also results that the former is never found as an overlying rock, whereas the later from its retention of fluidity 790° lower in the thermometric scale, admits of being impelled through fissures and spread over the surface.

(2) See note in appendix.

period in which their ingredients retain a viscid consistency, will, from the expansion consequent on crystallization, be exposed not only to mutual lateral pressure but to pressure from beneath, and this will tend, according to the rate of refrigeration and other circumstances, more or less to obscure or even obliterate the spherical form. Where there is a considerable proportion of mica the concentric laminar arrangement will still be preserved. I cannot follow out this view here; but the experiment on the gradual cooling of molten rock first made by Mr. Gregory Watt, and frequently repeated since, would seem to explain all the gradations of igneous rocks. With reference to the hypogene rocks, in order to conceive how the different species may be produced from igneous fluid beneath the earth's crust, we need only consider under what different conditions the fluid must have existed as to tranquillity, agitation, or motion, — the extent and form of refrigerating surfaces, — the nature, thickness, and pressure of the refrigerating masses themselves, whether rock, or sea, or both, — the rate of diminution of temperature, — and the proportions of chemical ingredients. Many of these conditions may have varied in different portions of the same great fluid mass, and at different stages in the process of its crystallization and solidification. The phenomena attending Mr. Watt's experiment even seem to shew that the globular, cuboidal, or prismatic *concretionary* structure of micaceous granite might pass into the laminar gneissose structure merely through oscillations in temperature during solidification. An analogous passage from nodules into layers, and, in the latter, the arrangement of the crystals of one of two or more different minerals in continuous parallel laminae, characterises some volcanic rocks.

If expansion on crystallization be attributable to the nether hypogene fluid masses, and they are gradually solidified from above downwards, a slow upheaval of the superincumbent crust must attend their solidification when they are of sufficiently great extent. This may be the cause of the elevation of *Scandinavia* and other countries, at present in progress.

Whatever may be the origin of the bedded structure of the hypogene rocks, it is to a similar stratification, combined with the vertical joints, that the forms assumed by the exposed masses on *Pulo Ubin* must probably be referred, and to these I now finally return.

The blocks protruding from the hills or ranged along the shores of *Pulo Ubin* are more solid and less decomposable masses and nuclei, of which the forms, and the directions of the sides and axes, have, in almost every instance, been determined by structural planes, and which remain after the surrounding rocks have disintegrated and been washed away. With respect to the latter, it is obvious that while the Island has been extending by the growth of alluvium in its bays, its more open coast has been slowly retreating, so that what was once a part of the solid land is now a band on its border washed by the sea, but still exhibiting numerous rocky remnants. The larger masses still evidently occupy their original positions. Frequently their seaward face is curved. Sometimes another mass stands behind merely separated from that in front by a chasm whose sides are parallel. With respect to the decomposition of the rocks on the hills, the soil is entirely derived from this source with the exception of a very slight superficial mixture of vegetable matter, which in many places is absent. In general, however, the blocks that remain are decomposing with exceeding slowness. One exception I noticed in the NW.—SE. side of the rock described at

p. 12. The laminae being inclined inwards, in disrupting by their own weight fall some feet in front of the base, where a long mound of earth has consequently accumulated.

I have now only to revert to the grooves. The circumstances attending them which any hypothesis of their origin must explain are these: their general prevalence; the existence, however, of exposed rocks devoid of them; their being commonly confined to the sides facing the exteriour of the Island, although sometimes found on other and even on all sides of a rock; their great depth and regularity; their general coincidence with divisional lines; their conformity to the course of rain; and their antiquity. It is this last circumstance which, presenting at the outset a great difficulty, leads, on further consideration, to what I consider the true explanation. That meteoric influences have been the great agents of erosion I have already suggested. But the antique, permanent, character which is impressed on the great majority of the rocks, their vegetable coatings, the hardness and sharpness of the external edges of the grooves, and the absence of all indications of the process of excavation being at present in progress, prove that the rocks must have existed under very different conditions from the present, to enable atmospheric forces to produce results of such magnitude. The considerations which have hitherto occupied us in the concluding portion of this paper appear to me to indicate what those conditions were. The composition and structure of the external rocks, unveiled by the action of the sea on the beach, shew zones of soft rock (1), rows of globular decomposing masses, and of harder ferruginous spheroids etc. susceptible of being detached, and a general tendency to perpendicular division. If, therefore, we conceive the external layer of the Island, when it first became exposed to decomposition, to have resembled in character the zone that has been laid open for our inspection along the beach, it is easy to comprehend how the wasting away of the more decomposable parts might at last leave exposed masses, including bands of the less stubborn material already partially softened or disentegrated underground, and that the action of the atmosphere and rain torrents would gradually excavate the more yielding portion until the solid remnants exhibited their present shapes.

The grooved and striated rocks of *Europe* are by some geologists supposed to have been caused by the action of the great and rapid waves called waves of translation induced by the sudden elevation of the sea bed and loaded with detritus. Now although in *Singapore* there is ample evidence of violent movements in the position in which we now find the stratified rocks (2), we can hardly conceive the *Pulo Ubin* rocks to have been subjected to

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(1) Some rocks may be seen along the beach with chasms 2 or 3 feet wide, the sides being quite hard and the bottom a soft decomposed substance. In such cases a zone of rock differing in composition from that adjoining has evidently been gradually decomposed and washed out.

(2) The nearest point at which this displacement can be observed is in the vicinity of *Singapore Town*, about eleven miles to the south west of *Pulo Ubin*. But the whole intermediate country is broken up in the same manner, so as to present the appearance, in many places, of a tempestuous sea, and the billowy hills are throughout so connected and similar, that there can be no doubt that the forces which elevated them operated during the same period over a wide area, including the southern portion of the *Peninsula* and its outlying Archipelagoes. This

these movements since their consolidation. The first hurried view of a portion of the masses at the quarries left the impression that the rocks had been shattered and separated by such forces. But I am now satisfied that, with some slight exceptions due to decomposition and consequent alteration in the balance of the different parts of some of the larger rocks, they all occupy their original relative positions, and even their original absolute positions with reference to the horison, although the level of the whole Island and adjacent tract has probably shifted. At all events no violent vilbratory movement has affected the Island since the joints were formed and the mass stood above the surrounding tract. I cannot think that a wave of power adequate for the excavation of the channels could have been generated by a movement which would have left the projecting rocks undisturbed, or even that the force of the wave itself could have met with such resistance from the smaller rocks as to enable it to grave the channels instead of displacing the rocks. No doubt a large proportion of these rocks were formerly firmly wedged into the mass of the Island, but many must have been more or less isolated, as the channels embrace more than one side. The undulations, if any, attending the elevation of the Island and inducing waves of translation (if they were sufficiently violent, and the upheavals sufficiently great) would probably be in the direction of the *Peninsula;* and, after the Island and the adjacent hills of *Singapore* and the mainland rose above the sea, waves might act on both sides of the Island transversely to the line of undulation. But as the principal fissures and soft bands are in the same direction, the circumstance of the grooves mostly coinciding with it does not peculiarly fovour the application of the wave theory. But in rejecting its applicability, we may, at the same time, allow that the action of the waves, whether ordinary or extraordinary, as the Island gradually, or by abrupt steps, rose above the sea, may have assisted to a considerable degree both chemically and mechanically in wearing the channels. On the coast of *Singapore* opposite the eastern extremity of *Pulo Ubin*, and only a mile distant, there is a layer of pebbles evidently marking the last step in the elevation of the land. Such pebbles driven to and fro by the waves against the rocky beach of *Pulo Ubin* would be instrumental in deepening hollows.

Since a portion of this paper was written I have seen, in the number of the Quarterly Journal of the Geological Society of *London* for May last, in the Presidents annual address to the Society, a notice of the observations made on the coasts of *Sweden* and *Norway*, last year, by M. Durocher. M. Durocher found along a portion of the coast, and particularly in the Islands off it, deep channels and furrows in directions from NW. to SE., some 10 to 20 inches wide and 5 to 10 feet deep, »effects of erosion," says the President, » on a much greater scale than I remember to have read of before." The resemblance of these channels to those of *Pulo Ubin* is not confined to their unusual size, but is carried out in the circumstance of the sides of the interiour of many of the channels being grooved in the directions of their longer axes, of their sometimes dividing into two

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tract, I have already said, is probably but a small section of a vast region, embracing *India* on the one side and *Australia* on the other in which similar forces were in activity during the same period, and produced similar effects.

or more branches which afterwards re-unite into one, of many being rectilinear but many being undulating and bent in short waves, and lastly of the axes of the channels and the striae in their interiour having the same general direction as the depressions of the neighbouring country. Mr. Hoasea refers to the Bulletin of the Geological Society of France (tome III p. 65) for some important views as to the causes of these phenomena. I have not access to the Bulletin, and cannot venture in my ignorance of the rocks and all other details, to make any further remarks on the analogy between the channels described by M. Durocher and those of *Pulo Ubin;* but it is probable that the structure of the rocks will be found in the one case as in the other to have facilitated the erosion of the channels, and partly given them their directions.

Singapore, *1st.* Oct. *1846.*

APPENDIX.

Note to p. 33.

With reference to the views in the text it may be said that no congelation could take place till the temperature of the whole mass was at that of fusion, because until then there would be a constant interchange of level between the successive upper or denser layers and the lower. Without resorting to the supposition that gradual expansion as in water may begin prior to congelation, it seems clear that in such a dense fluid as molten granite under great pressure, the passage of one portion through another must be effected with difficulty and very slowly. Between the level at which the maximum temperature ceases, and the refrigerating surface, there must, in such a fluid, be an insensible and very gradual diminution of heat, and deep masses may be viewed as consisting of layers of considerable thickness in any one of which the temperature is almost uniform and between which and the adjacent layers the transfer of heat is exceedingly slow. It may be proper to examine this further, because when the text was written I overlooked the chapter in Mr. LYELL's Principles (Ch. XIX of Book II) in which he controverts the doctrine of the internal fluidity of the globe by an argument which is partially opposed to some of the above views, although it does not interfere with my general inferences. Its object is to prove that no consolidation at the surface of a fluid mass like the globe could take place, till the whole had been reduced to a uniform heat or about that of incipient fusion. It appears (note p. 440) that M. POISSON had, independently, adopted the same argument, and that he imagined that if the globe ever passed from a liquid to a solid state by radiation of heat, the central nucleus must have begun to cool and consolidate first. The principal facts on which Mr. LYELL relies are, that so long as a fragment of ice remains in water the temperature of the water, cannot be raised above 32°, and that Professor DANIELL found that while a solid piece of iron etc. remained immersed in a molten mass of the same substance, its temperature could not be raised above the melting point. The remarks in the text relating to the origin of granitic structure do not require me to assume that the temperature of a granitic mass was ever much above that of its melting point, a temperature, it should be recollected, higher by 790° than that at which basalt can exist in the fluid state; and as Mr. LYELL does not seem to deny, with M. POISSON, the possibility of a crust being formed when the general temperature is near that of fusion, his remarks are not inconsistent with the hypothesis that granite has crystallized in successive layers. Even if the granite fluid approached to the condition of water, instead of being comparatively very dense, the congelation of the first layer would tend to maintain the fluidity of the next for some time, not merely by arresting the interchange of particles by which its heat had thitherto been transferred to the surface, and substituting for it the process of conduction, but by adding to it the large quantity of latent caloric expelled in the act of congelation. With reference, however, to Mr. LYELL's argument, it may be remarked that the conditions to which a fragment of ice or iron are exposed when immersed in a fluid mass of the same substance, and heat constantly added from a source close to it, are very different from those of a crust resting on the same fluid, in contact on one side with a refrigerating surface, and on the other with one to which caloric slowly ascends from a source far below. The immersed fragment is enveloped in a rapidly heating medium. The floating crust is between two media, one slowly giving heat, the other abstracting it. The period, therefore, at which a crust can be formed is not determined simply by the fusing point (that is, necessarily postponed until the whole mass has reached its lowest fluid temperature) but is determined by the relative rates at which heat ascends through the substance in its fluid state, and is conducted from it when in its solid state. The latter is an indeterminate quantity, depending, as it in some measure does, upon the nature of the refrigerating body. But, laying that out of view, it is evident that as the heat diminishes, the rate of its passage from one level to another will also decrease, because the motion of the particles of the fluid amongst themselves will be impeded as the density increases. Now long before the mass generally is reduced to the temperature of fusion, the density of its higher portion may reach the point at which the rate of motion has subsided to that at which heat is given off by a solid crust. Refrigeration may come to a stage at which, while the upper layers are at and near the point of fusion, the lower may be far removed from it in proportion to the depth of the mass. Because in a receptacle of water exposed to a cold atmosphere we see a rapid interchange of particles, and the formation of ice postponed till all the lower layers have reached the temperature of about 40°, we are not entitled to conclude that in the successive layers of a deep abyss of dense molten granite there will be a similar rapidity and extent of mutual motion of particles. Even in the case supposed by Mr. LYELL of the globe consisting of water having at the centre a temperature of 6400° which gradually decreased towards the circumference where a crust of ice fifty miles in thickness existed, is it necessary that we should admit with Mr. LYELL that the ice would soon melt into an atmosphere of steam? In a layer a mile in thickness the temperature would not increase one degree. At 8 miles beneath the ice the temperature would be only 40°. Below that the counter currents would first be encountered, but the rate of their motion in a layer a mile in thickness in which the summit only differed from the base by 1° would be so extremely slow as to be insensible. But, to render the cases of a globe of water and a globe of granite more analogous, the globe of water should be supplied with a refrigerating atmosphere at a temperature more than 2000° below zero, for such is the difference of temperature between that of the atmosphere (even taking that of the equator) and the fusing point of granite. With such a medium, or even one of which the temperature was calculated according to the fusing point of trappean rocks, the heat given off on the upper side of the icy crust might exceed that received from below even with a central temperature of 6400°.