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Artikel: H.B. de Saussure : James Hutton's obsession
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which carved this valley. They are nevertheless not exactly of the same nature and, above all, not of the same structure; the hill of *Saint Tryphon* consists of regular layers, either horizontal or more or less so, whereas that of *Charpigny* has very inclined layers which are often in great disarray." [S. II. §. 1090, 1091, pp. 539, 541]

Hutton concludes [H. II. 432] at the end of Chapter XI: "In M. de Saussure's Journey to the Alps, we have now seen a description of the shape that had been given to things, by those operations in which strata had been consolidated and elevated above the sea...

Chapters XII and XIII refer to examples "from the different Quarters of the Globe," followed by a summary of Hutton's doctrine. At the end of vol. II, [H. II. 567], Hutton says : ..."in pursuing this object [physical dissertation] I am next to examine facts, with regard to the mineralogical part of the theory, from which, perhaps, light may be thrown upon the subject; and to endeavor to answer objections, or solve difficulties, which may naturally occur from the consideration of particular appearances."

Hutton's conclusion to Vol. II seems to indicate that Hutton's goal was to continue his *Theory of the Earth*. However, it is unknown whether the discovered manuscripts of Volume III were actually meant to be published. We shall discuss next Hutton's comparison of Saussure's observations in the Alps with those of the granite mountains of Scotland.

Volume III

INTRODUCTION

Volume III consists of six chapters, entitled: IV. *Observations made in a Journey to the North Alpine part of Scotland in the year 1785;* V. *Observations made in a Journey to the South Alpine parts of Scotland in the year 1786;* VI. *A comparison of M. de Saussure's observation in the Alps with those made upon the granite mountains of Scotland;* VII. *The Theory confirmed by observations made upon the Pyrenean Mountains;* VIII. *An illustration of the Theory from the natural history of Calabria; VI. An Examination of the mineral history of the Island of Arran.*

My translation concerns only Chapter VI and follows the same rules as in Hutton's vols. I and II, with the difference of the abbreviations for Hutton which will be, for example: [H. III. 333]

A comparison of M. de Saussure's observations in the Alps with those made upon the granite mountains of Scotland

Hutton had long waited for the second volume by Saussure, published in 1786. After having judged it, he was disappointed that Saussure had so rarely described

junctions between granite and schistus in the Alps. "It is true," Hutton said, "that our author's view of this natural phenomenon is in some measure diametrically opposed to mine." [H. III. 92] He also mentioned--not in a very flattering way--"I think myself fortunate in having written the histories of my mineral [rock] observations before I had read the second volume in which those of M. de Saussure are recorded; for it will thus be seen what natural correspondancy there is to be observed between these mineral appearances of Scotland, in the history of which no influence of description had intervened, and those of the Alps, in the observation of which such different views of cosmogony had occupied the mind of the naturalist." [H. II 93-94]

Hutton was above all interested in "...the junction of the two different rocks and the manifestation of fluidity or fusion in the granite mass, from this body breaking and invading the alpine strata. M. de Saussure had in his description no such object in his view, but on the contrary, if there is any particular point to be ascertained, it is that of the stratification of granite in general, notwithstanding those appearances of masses in which no distinct mark of stratification appears."

[To understand the reaction of the two naturalists, we must refer again to the difference between their two countries. In the Alps, any unconformable junction between the Hercynian basement (granites and metamorphics) and the overlying Secondary rocks were mostly obliterated by the Tertiary main folding and compressional phase when overthrust planes took advantage of that particular zone of weakness. Ironically, the only "Huttonian angular unconformity" (comparable to Siccar Point, Scotland) between vertical Hercynian reddish metamorphics and horizontal Triassic sandstones, that Saussure could have seen, is at the summit of the Aiguilles Rouges which he did not visit. In short, while the geology of Scotland was only weakly affected by post-Caledonian orogenies, the Alps underwent their major overthrustings much later, during the Tertiary, in which all previous rocks were involved.]

In this chapter, Hutton [H. III. 102] had naturally chosen descriptions that were of interest to him, such as the foot of the Aiguille de Blaitière with the famous granitic pyramids. There Saussure had undertaken a trip to Chamonix to examine these pyramids, forming the highest needles of the central chain, from as close as possible. Here is Hutton's citation:

> [S. II. §. 660, pp. 67-70] "From this place I had a very extended view; however, what stroke me the most, namely, the center of my needle (pyramid), did not provide much satisfaction. The granite of which it is made--perfectly similar to the one I described above with respect to its composition (§. 659)-- showed no regularity in its structure: its fissures which divided them, went indifferently in all directions, here they appeared parallel; farther away, they were seen to converge and cut the rock into large cuneiform masses, elsewhere they were curved, cutting [H. III. 103] the rocks into parts, concave on one side and convex on the other. The only general fact that could be observed was the constant shape of the crevasses, which were always clear-cut, without indentations, without smears, so that the faces of the resulting blocks were always at least smooth, if not polished.

I descended the glacier on the opposite side to the one I had climbed, on a slope so steep that, if the snow had not been so hard, it would have been impossible not to be pulled down. The hat of Pierre Balme, my faithful guide, fell by accident and rolled all the way down on the edge of its rim. We were certain it was lost because it had to fall naturally into a large crevasse underneath of us. Nevertheless, it turned around it and escaped the danger with a lightness and a very unusul appearance of intent and skill.

§. 661. As soon as I came out of the glacier and the snow which extended still much lower, I searched for [H. III. 104] a place to rest and have something to eat. I found a comfortable seat on a grass spot at some higher place which provided a vast view of these debris which I had crossed that day. At first, my eyes neither discovered nor searched for anything interesting among these debris. However, when the rest and the diminution of the intensive cold, which had seized my legs during at least 2 hours, rendered some activity to my senses and my intention, I seemed to see some kind of regular shape in the chaos; I believed to see well-followed bands of rocks which rose their heads above the surface of these debris. The hope of making some interesting observation completed my well-being. I was in a hurry to get down there. My hopes were not dashed; I observed there a very rare and interesting fact, namely beds of granite enclosed between layers of foliated rocks. The highest was a perfectly regular and well characterized bed of massive granite [en masse]. Its overall [H. III. 105] uniform thickness was 12 to 15 feet. The layers that surrounded or enclosed this granite belonged to foliated granite, between 1 foot and two or three inches in thickness. These layers were perfectly regular and extended from NE to SW, as does the valley of Chamonix, [they are] in a vertical position. A little lower, was a second bed of granite, similar to the first, although less characterized, enclosed by layers which were no longer veined granite, but a quartzose and foliated white rock. The direction and the location both of the granite and the foliated rock was the same as the preceding ones. Below the second bed, I found a third one, and others yet down to the vertical layers I had crossed in the morning above Blaitiere (§. 658). But the farther away the beds were from the high needles [blades], the more they lost their granitic nature, approaching that of ordinary rocks mixed with [H. III. 106] quartz and mica with which they finally merged.

§. 662. These degradations and enclosures seem to show with the outmost evidence that granite had been formed exactly like foliated rocks. Indeed, how could one suppose that these beds or these thick granite layers, enclosed by layers of another rock, preserving the same thickness and following the same direction, could have another origin ? And if one adds to this consideration that of the nature of the rock itself, if one ponders about the veined granite which encloses the first of these beds and differs from the enclosed massive granite only by the arrangement of the blades of mica, which are confusedly dispersed in one, and arranged on parallel lines in the other; and that furthermore everything is similar between them, I must

admit that I cannot assume that they are bodies of absolutely different nature. Indeed, as I previously observed, [H. III. 107] we can very often notice in mountains of a different order, beds of massive rocks, such as limestone for example, in which we cannot perceive the slightest appearance of a foliated rock alternate with foliated layers, of the same kind or a different one. Nobody doubts that in spite of the difference in the textures, these beds and layers have had the same origin.

Furthermore, this difference in texture can be explained in a very natural way by the most generally adopted principles on the formation of mountains. Indeed, who could doubt that liquids of any kind, in which or with which mountains were formed, were not subjected to variations, that they did not carry here certain materials, and there others? These changes in movement and rest alone suffice to explain alternating massive and foliated rocks.

I am therefore convinced that the large masses of granite devoid of any traces of foliation or [H. III. 108] of regular divisions are nothing else but very thick layers that were deposited during intervals of stagnation of the fluid in which mountains were formed.

It even seems that the masses of these pyramids--of which we cannot know the thickness--are interspersed by beds of veined granite. Indeed, at the foot of these needles I have found everywhere numerous fragments of veined granite and of foliated rocks at heights where I could see above me nothing but massive granite. And these fragments could originate only from the middle of these same granits."

Hutton interrupts, stating [H. III. 109]:

"Here M. de Saussure inclines to make the central masses of the Alps to be of the same formation with those regular bodies of granite which he had found placed among the alpine strata. I am perfectly agreed with our author, only with this difference that I suppose those regularly formed granites to be of the same nature with the central mass ; this will require some explanation.

M. de Saussure supposed that he understands the formation of those granites which he found inclosed between the alpine strata ; consequently, it is by this means that he would explain the central masses, the formation of which he does not comprehend. I, again, suppose that I understand the formation of those irregular masses of granite ; it is by means of this knowledge that I am inclined to explain those regularly formed or apparently stratified granites, which I do not suppose to have been stratified originally along with the *granit feuilleté* with which they are inclosed. In the light in which M. de Saussure considered the subject, he had no distrust of those inclosed granites being strata ; consequently, it is possible that he may have neglected making some observation by which this question might have been absolutely decided. But it is probable that there was not enough of the solid strata seen to lead a person who had not this particular view in his head, to make a conclusion so very different from that which the first appearance must suggest.

[H. III. 110] In the present state of things, I am disposed to believe, that those apparently stratified granites were truly great veins interjected between the alpine strata; and therefore that they differ or, at least, in this respect from the stratified granite with which they are inclosed, while they perfectly agree with the granite mass of the pyramid or mountains, in having been produced at the same time or in a similar manner. "

[Geikie added in a footnote [H. III. 110] that "Hutton looked on the successive sheets of granite interposed among the schists as so many intrusive apophyses from the main body of that rock in the central part of the mountain."]

Hutton [H. III. 111] then returned to Saussure's description of the fourth pyramid: [S. II. §. 663, pp. 70-72]:

"§. 663. The following day, August 30, I started to examine the fourth pyramid, the closest to the *aiguille du midi* and named *aiguille du Plan*. To arrive at its foot, I took more toward the west than I had done the day before and in three quarters of an hour I passed in front of the chalet of the *Tapie* which was located in an extremely secluded bottom, at the foot of the glacier of the *Nantillons*, completely surrounded by debris of rocks which had been carried by that glacier.

At a good quarter of a league above the chalet, I passed near a small but rather deep lake, named *Lac du plan de l'aiguille*. Its water, although perfectly pure and limpid, appeared in the color of a green emerald. The temperature of the water in the shade, close to the surface, is 4 1/5 degrees, whereas that of the air is 7 1/5 degrees. The rocks along the western border of the lake consist of thin sheets, mixed with quartz and [H. III. 112] mica, running NE-SW and rising toward the NW. All those I crossed today have the same general trend (§. 656).

A little above the lake, one finds in the same foliated rock a bed of yellowish talc, soft to the touch, but mixed at times with quartz nodules.

§. 664. Leaving the lake behind on my left, and continuing to climb, I found beds that gradually resembled the nature of granite and finally a bed of true massive granite. These beds are most probably an extension of those I saw the day before (§. 661); at least, they run in the same direction and are intercalated like some of those mentioned before, between sheets of quartzose and micaceous rocks. Athough this bed is only two to three feet thick and does not preserve the same nature throughout its extension-- because, while trending toward the SW-- it changes into foliated rock. This is a remarkable characteristic of rocks formed by crystallization, and a very natural consequence of the nature of this [H. III. 113] process, to lack consistency of rocks which owe their origin to deposits.

Very close-by, I found beautiful pieces of specular iron attached to fragments of quartz.

Higher up, and still in the debris, I found a superb bed of massive granite, forty to fifty feet thick, hemmed in, on its upper side, by layers of massive granite, precisely of the same nature, and six inches to a foot thick. These beds are *vertical*

and oriented NE-SW as all the others of these mountains. Nevertheless, they are not of the same irregularity as those that precede them. Although they preserve well all along their extent the nature of granite, their divisions do not continue in a constant fashion over the entire length of the rock; here they disappear while two distinct beds join to form only one; there, new ones are formed by subdivision of one of them. This is still a natural effect of crystallization. However, what is most important to the question [H. III. 114] of the existence of layers is the fact that these divisions keep one and only direction.

From here to the needles all is granite, but so much covered that one only rarely sees the bottom of the soil. I found, nevertheless, at the foot of the needle itself, beautiful vertical sheets of massive granite of different thickness, from two inches to four feet, running NE-SW as all the layers in these mountains."

Hutton remarks:

"Here I do not see any evidence for the stratification of those masses of granite. M. de Saussure, in whose judgment we may confide, is clearly of opinion that they are not stratified in the usual manner, as having been formed by subsidence in water, but that they had been formed in a different manner. Therefore, I must still be inclined to suppose that it is the mountain or massy granite which is here injected among the alpine strata, and that this granite mass had only been stratified in flowing between those regular bodies. [H. III. 116]

Having after much pains arrived at the foot of the Aiguille du Midi, M. de Saussure thus continues his description."

"§. 674. I was well rewarded for my efforts, this rock is one of most extraordinary [H. II. 117] I have ever seen : a strange mixture of true massive granite with a heavy gray rock recalling hornstein which has no resemblance at all to granite and shows a rusty weathering color. Here is a bed of granite encased between layers of this rock, elsewhere, the same bed is in some places of granite and in others of this rock. Further on are transverse veins, elsewhere nodules of granite included in that same rock. Moreover, the rocky mass is divided into well-defined vertical beds, trending NE-SW. Only crystallization can explain such unusual mixtures. In a fluid containing in solution different matters which undergo crystallization, the smallest accident compels the elements of one of the materials to concentrate in great abundance in certain parts of the container : another accident changes this arrangement and forces the elements of the same kind to congregate at another place.

However, the entire needle is not composed of this singular mixture: the entire center and the [H. III. 118] upper part consist of beautiful pure granite, resembling that of the other needles. It is only this portion of its foot and that of the SW, which I see very distinctly, that appears to consist of these mixed rocks."

Hutton remarked: "The interesting fact, with regard to this valuable observation, consists in this, that there is a certain mixture or confusion of granite and the alpine

strata. It would have been still more interesting, indeed had M. de Saussure distinguished in this mixture which of the two different rocks was the containing and which the contained body; that is to say, which of those bodies had broken and invaded the other."

[H. III. 120] A footnote by Geikie explains :

[Among the phenomena attending the "granitisation" of rocks, or their absorption and transfusion by granitic magma, laminae, veins and nodular lumps of granitic material seem to be separately enclosed within the metamorphosed mass. De Saussure's observation was therefore no doubt accurate, but Hutton had not seen much of the phenomenon of extreme granitisation and did not realize how exceedingly complex the junctions of granite with the surrounding rocks sometimes are.]

Hutton then refers to Saussure's description of the other side of the central granite mass where granite "is found continuous with the alpine schisti."

"§. 860. This pass reaching 1195 toises [H. III. 121] above sea-level, according to my observation of the barometer, faces the *Col de la Seigne* and is located at the opposite end of the same valley. This valley continues to separate here the primitive central chain from the first secondary chains. There are indeed some mixtures, for instance, slates and limestones at the foot of these primitive mountains, and even at the entrance of some of their gorges, as one finds also here other primitive mountains behind the first line of the secondary ones. However, in general, the peaks on the right side are granitic and those on the left calcareous.

The general direction of the valley, following a straight line from the Col Ferret to the Col de la Seigne, is from NE-SW, but it curves in the middle where it becomes slightly convex toward the SE.

All the secondary mountains which limit the left - or SE side of this valley, have their inclined layers rising against the primitive chains. This situation can be seen distinctly from the top of the col and even better from slightly below. [H. III. 122].

The primitive chain does not show here a distinct organization. The Mont-Blanc is not visible, but is hidden by less elevated but closer peaks. The attention of the observer is attracted by two large glaciers flowing down from the primitive chain very close to the Col Ferret. The closest to this col is called the glacier of the *Mont Dolent*. Its highest plateau is a large cirque surrounded by high sheets of granite of pyramidal shape. The glacier flows from there through a gorge in which it becomes narrower. But as soon as it emerges, it opens up again in a fan-shaped manner. In summary, its shape is that of a sheaf, narrow in the middle and open at its two extremities. The second glacier is that of the *Triolet*, smaller and covered by debris of a high mountain of granite. About sixty years ago a considerable rockslide fell from the top of this mountain which, in one night, buried the chalet, located at the foot of this glacier, together with the cattle and the shepherds. Since then, these landslides have continued uninterruptedly. [H. III. 123]

These two glaciers are separated by a mountain called the *Mont-Ru*. It consists of granite, and as it seemed to me accessible toward its foot, I decided to examine it after having reached the bottom of the valley.

§ 861. The col Ferret itself consists of foliated sandstones and soft slates whose sheets move away from the vertical position only to lean against the primitive mountains. Their directions is toward the S-SW like that portion of the valley. These slates are intermingled with layers of quartz, either thick or thin, or whole here and decayed there in thousand different shapes.

§ 862. The descent is very steep, even dangerous for mules after rain, because the altered slates on which one walks form an extremely greasy and slippery surface. This slope, like the summit of the col, consists of slates and foliated sandstones, but one finds furthermore beds of a calcareous rock of a slaty color, while the latter rock builds alone the lowest part [H. III. 124] of the mountain on the side of the central chain. The layers of all these rocks have consistently the same structure as those on the top of the col....

§ 866. From the chalets I descended to the bottom of the valley, and from there, in order to observe the foot of the *Mont-Ru*, which separated the two glaciers (§ 813), I left the regular road and forded on my mule, not without some difficulties, the torrent which flows from the glacier of the *Mont-Dolent*. Having reached the foot of these rocks, I found them to consist of a granite whose structure I was unable to figure out. Upon close observation, I saw merely small fissures whose directions were not parallel among themselves. I saw the flank of the mountain facing the valley, coated in different places by a hard yellowish and foliated rock, whose surface trended S-SW as that portion of the valley. These sheets adhered to the granite but could be separated from it with a blow of the hammer. Upon close observation, they consisted of very thin sheets [H. III. 125] of a whitish quartz, separated by even thinner layers of yellow and shiny mica. This rock, when exposed to the flame of the blow-pipe, became covered by a shiny varnish produced by the vitrification of mica, whereas quartz remained white and intact. I can assume that these layers are the remains of a foliated rock which serves as a transition between slate or limestones of the secondary chain, and the granites of the primitive one."

Hutton states: [H. III. 125]

"All that is to be said with regard to these observations is this, that they are strictly conform to the supposition of the central body of granite having been forced up among the stratified schisti, in those operations by which land was raised from the bottom of the sea, and horizontal strata changed to positions nearly vertical. We shall now see what occurred to M. de Saussure upon considering the situation of the stratified alpine bodies. It is in continuing to describe those objects with which we are now more immediately concerned."

§ 867. After having made this observation, I returned to the large road which is [H. III. 126] nothing but a miserable footpath that, at the beginning, is rather rugged; the bottom of the valley is arid, covered with blocks of granite. The glacier of *Triolet*, buried underneath debris, a dirty and bubbly torrent emerging from heaps of ice and rubble, and some sickly-looking larches, scattered in the middle of these rocks and ice, present the saddest picture and awake only ideas of desolation and ruin.

§ 868. After having advanced a little along this road, and when turning backward to see the *Mont-Ru*, one can perceive some regularity in the structure of this mountain. It is divided from top to bottom by large fissures which cut through this mountain from one side to the other. These fissures, parallel among themselves, cut the mountain into large and very thick layers which are themselves subdivided into thinner ones. These fissures represent the cross sections of the intervals of large pyramidal sheets of which this mountain is composed. The most exterior sheets are not as well separated; their summits [H. III. 127] are poorly separated one from the other, and the whole picture of these summits form an almost continuous crest. However, the interior sheets which reach a great elevation, have their tops separated and form pointed and distinct teeth.

The planes of these sheets do not resemble those of the *Allée-Blanche*, which are parallel to the valley that runs here toward the SE whereas these planes run toward the S-SE, which makes a difference of about 34 degrees.

The following mountains in the direction to Courmayeur present an almost similar structure, however, the planes of the slices [H. III. 128] seem to gradually turn backward and take the direction of the valley, becoming finally parallel with it.

All these layers--if they are really layers--because I cannot really confirm it as I was able to do of those whose nature I clearly recognized, I mean all these sheets overhang the valley.

§. 869. Finally, when I say that the large beds of rocks are similar to those which are *overhanging*, one must not imagine that they have no support at all, they do lean on others, and although those are also overhanging, but gradually diminish in elevation, the mountain as a whole is supported and does not overhang : all is supported as in a vault.

§ 870. It would be very difficult to understand these anomalies that are visible in the situation of layers. Even in secondary mountains, as for example in the Jura, it is possible to see layers that are very close to each other in completely different positions. Primitive mountains [H. III, 129] that are much older and have therefore been exposed much longer to agents and revolutions of all kind, must necessarily present even greater anomalies. And if these mountains-- as I am beginning to believe-- have vertical layers, then this situation is due to violent movements which

uplifted layers that were horizontal at the beginning. It is more natural even that during this violent uplifting, the mountains of the same chain did not all take perfectly similar situations."

Hutton's answer is sweet and sour:

"Here M. de Saussure enters perfectly into my views, at least, so far as regards the formation of those alpine strata which have been considered by other philosophers as original bodies of the globe. This testimony, at all times most respectable, is on this occasion of the greater weight, in that upon the most mature consideration and accurate survey of the facts, M. de Saussure here changes his opinion, if he had allowed himself to form one, before examining sufficiently the subject." [H. III. 130]

Hutton returns to Saussure to "make the observations with regard to the granite better understood":

"§ 872 Walking through these pastures, with my eyes always fixed on the primitive chain, I saw beds at the bottom of this chain that were similar to slates and leaning against rocks of granite. Since in my opinion nothing is more interesting for the theory than the junctions between mountains of different orders, I decided to go and look at that one. But since it was too late to do a good job during that same day, I stayed overnight at Courmayeur, 2 leagues away from the junction, and I returned the next day.

From the bottom of the valley, it took almost three quarters [H. III. 131] of an hour of climbing to reach the point where the schists touched the granites. These schists, which from far away appeared only as a thin surface leaning against the foot of the mountain, are in fact a considerable mass of different layers. The material which forms most of these layers is remarkable by the fact that it makes a strong effervescence with acids and nevertheless melts very easily with the blow-pipe into light green and transparent glass which flows and collapses on the glass pipe on which it was welded. Its color is blackish and its grain resembles that of a calcareous rock...

The layers of these schists are intermixed with layers of a fine gray sandstone, weakly coherent, changing into a white sand which accumulates in great amounts at the foot of these same layers. The weak cement which unites these grains of sand is of calcareous nature.

These beds are a little arched, but their general situation--at least for those which are the lowest--is vertical or to a few degrees close, as they lean [H. III. 132] against the mountain. There can be no doubt on the situation of these beds of schists because they are exactly parallel to the sheets themselves of which they consist. But these layers are cut throughout and perpendicularly by fissures parallel to each other and which all curve in the same way while dipping toward the southwest under an angle of about 50°. These fissures leave between themselves intervals ranging from a foot to only a few inches. When these fissures are

observed from far away, it is impossible not to take them for the divisions of the layers of the rocks. This shows how important it is in this investigation to see closely and observe in detail because the internal structure of a rock alone can decide between these sections which intersect each other perpendicularly which one indicates the situation of the layers. I said previously what I thought of the origin of fissures cutting bedding and I shall return to that subject later on. [H. III. 133]

§ 873. I recognized in the transition of these schists to granites four well-marked nuances

The first layers of schists, where some weathering can be noticed, show sheets that are more wavy, more shiny, and more resembling mica, of which they have indeed the same properties.

The following ones are even more wavy; sheets of true mica can be recognized, and besides that a mixture of quartz that give sparks when struck with steel although the rock is always effervescent with acids. One can see in the same rock veins of black matter, shiny and consisting of small rhomboids, which seem to be the crystallization of the purest material of the schists; because these crystals dissolve with effervesce in acids without leaving any appreciable residue. Nevertheless they melt very easily under the blow-pipe into a transparent and greenish glass which collapses on the end of the glass pipe.

The third nuance is a true quartz [H. III. 134] mixed with some mica which does not effervesce.

The fourth is a gray granite with small grains of quartz, feldspar and mica.

This transition is generally of a rather small thickness. In some places, these four layers, taken together, are no more than one foot thick : however, granite reaches its perfection with clear and well-distinct grains only a few feet from this junction. The layers of this perfect granite are parallel to all those which form this transition.

At a rather great distance, while coasting along the mountain, I followed this junction of schists while sampling everywhere with a hammer the adjacent banks. I did not notice any appreciable difference in the nature of the beds which formed the transition between granite and schist. But I found a few changes in the position of the beds. Walking toward the SW, [H. III. 135] I saw the schists as well as the granites overhanging on the side of the valley, here at 35° and there at 47°. The direction of the beds changes also a little. Those which are closest to the Col Ferret trend S-SW, whereas those which are furthest away from the same col trend about 30° more to the west."

Hutton answers: "If I had not been acquainted with this subject of the junction of the granite and alpine schisti, I should have been inclined to think that here was an evidence of a gradation with regard to the original formation of those two bodies, when

these had been deposited in form of strata at the bottom of the sea. I am however almost persuaded from this description that the apparent gradations, here perceived, has for cause the contact of the granite in a fluid state of fusion with the schistus which it had been made to invade....

Upon the whole then, if it shall be allowed me to make this conjecture with regard to the observation of so able a naturalist, it would appear that here in the central granite of the Alps of Savoy and Switzerland, the same general fact is to be found which I have constantly observed wherever I could perceive the junction of the strata and granite masses; consequently that upon this occasion the body of granite in its present state is posterior to those invaded.

That this is truly the case, and that the granite really breaks and displaces natural strata of that alpine country, as well as those of Scotland, will appear from the facts which M. de Saussure relates in the former volume of his journey in the Alps. For there he gives an example, both in the Alps and at Lyon, of granite veins traversing [H. III. 137] the natural strata ... *[see below] Therefore, granite, in this particular place where it is mixed with the stratified bodies of the earth, is evidently of a posterior formation, and is the transfused body which had broken and invaded the regular strata."

* [Saussure's example in the Alps and in Lyon of veins of granite traversing schists is given in Chapter XII : "*Recherches ultérieures sur les Granits* ": [S. I. §. 597-601, pp. 530-535] Saussure describes debris of primitive rocks in the neighborhood of Vallorcine in a rich collection of rocks with fragments of granite fused together with schists (§. 598). The next paragraph (§. 599) mentions granite formed inside fissures of schists, giving the explanation of this phenomenon: infiltration of waters. Hutton, naturally, would not have mentioned this explanation and thus did not cite it. Saussure made a similar observation at Lyon, (§. 601) of a vein of granite, 21 inches large which cut layers of schists at an angle of 30°.]

Hutton continues: [H. III. 137]

"With regard to the stratification of granite in mass, I had formerly entertained the same idea with M. de Saussure, that they perhaps might be considered as stratified bodies of great thickness, consolidated by means of fusion. But since meeting with the most satisfactory evidence of granite having been made to flow in the manner of subterraneous lava, I have in some measure changed my opinion and am rather inclined to think that the apparent stratification, which may be: [H. III. 138] perceived in any of those granite masses, may be considered as a regular separation by the contraction of the mass."

Finally Hutton turns to Saussure's *resume*, in the last citation on the central masses of the Alps. [H. III. 139]

"§. 677. If one wants to gather all the observations presented in this chapter, it is necessary to consider that the mountains which border in the SE the valley of

Chamonix are composed of two distinct parts. One part is the uninterrupted and uniform massif which rises up to 7-800 toises above the valley (*first plate*) [facing p. 88 in Vol. I], the other consists of the pyramids or the isolated needles which tower above this massif.

The lower uniform masse consists of foliated rocks of different [H. III. 140] kinds, but mostly quartzose and micaceous. These rocks consist of very regular layers which run, as the valley, from NE to SW; these layers are not much inclined toward the foot of the mountain, but they rise gradually against the valley up to the summit where they are exactly vertical. These same layers approach the nature of granite the nearer they are to the summit of the mountain; and there they change into veined granites or even massive granite enclosed by layers of either veined granite or foliated rock.

The pyramids that tower above this massif consist of granite en masse. They are flanked, or even consist on the outside, of pyramidal leaves which are divided into large beds parallel to the planes of the leaves. The latter are almost vertical and are not rising against the valley as do the lower layers of the massif, but they lean against the pyramidal bodies themselves. Their direction is more or less the same as that of the massive layers. The center [H. III. 141] or the inner part of these pyramids, seem, in some places, to be without any regular structure and to be merely divided by accidental fissures.

Furthermore, one should not imagine that these pyramids are sitting on the massif that they dominate like a column on its base. The direction of the layers shows that the massif is leaning against the pyramids which have their own base and that it might rather be the massif which is partly sitting on the inner bases of the pyramids since the sheets of those descend toward this massif and seem to plunge underneath it."

Hutton's last answer: [H. III. 141]

"Here, in making a distinction of the central mass of granite and the erected strata of various species of alpine schisti, M. de Saussure has been at the utmost pains to inform himself that the central mass which is elevated to such a height, has its basis under those erected strata with which it is immediately connected. Now this could only happen in one of two ways; [H. III. 142] either the alpine schisti were superinduced upon the inclined granite in its present place; or the horizontal strata had been elevated by the rising granite. I suppose M. de Saussure's theory would lead him to conclude the first; mine again leads me to conclude the last."

CONCLUSION

Throughout this paper, we have encountered Hutton's great interest in Saussure's descriptions of the origin, structure, and composition of montains in general, and the Alps in particular. Why were those descriptions of such importance to him? The reason