III. *Of the FLEXIBILITY of the BRAZILIAN STONE.* By
JAMES HUTTON, M. D. F. R. S. EDIN. and Member of
the Royal Academy of Agriculture at PARIS.

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NO quality is more inconsistent with the character of a stone than flexibility. A flexible stone, therefore, presents an idea which naturally strikes us with surprise. For though among mineral bodies, we find flexible substances of the stony kind, such as mica, mountain leather, and amianthus, these minerals owe their flexibility, either to their thinness, or to the fibrous structure of their parts. Therefore, when a stone of any considerable thickness is said to have flexibility, we are led to think that here is something very extraordinary; and we wish to know upon what depends that quality, nowise proper to a stone.

SUCH, however, is the stone from Brazil, of which the Baron de DIETRICH read a description in the Royal Academy of Sciences, in January 1784. There is also at present, in the possession of Lord GARDENSTON, a specimen of stone, which corresponds with that description, inserted in the *Journal de Physique* for the year 1784*. The length of the stone which I have examined is twelve inches, the breadth about five, and the thickness half an inch. When this stone is supported by
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* Tom. xxiv. p. 275, 276.

the two ends in a horizontal position, the middle part bends by its own weight more than a quarter of an inch from the straight line. This species of flexibility may certainly be made a proper object of scientific investigation. I am therefore induced to lay before this Society what has occurred to me upon the subject.

HARD bodies are either on the one hand friable, or on the other ductile. If they are friable, they are elastic; if ductile, again, they preserve the change which has been forcibly induced upon their form, consequently are not in that sense elastic. Bodies, indeed, may be either friable or ductile in various degrees; but, so far as friable, they are not ductile; and, so far as ductile, they cannot be said to be elastic. But compound bodies may be flexible, without being either ductile or elastic; such are jointed bodies. In that case, however, it is not to the nature of the substance that the body owes its flexibility, but more properly to its mechanical construction. Of this kind, certainly, is the body which we have now under consideration; for it has a certain flexibility, to which neither the terms *ductile* nor *elastic*, will properly apply; although, having no degree of ductility from the nature of its substance, it cannot, in like manner, be said to have no elasticity. The flexibility of this stone is so easy, compared with the rigidity of its substance, and its elasticity so small, compared with its flexibility, that there must be in this body some mechanical structure, by which this unnatural degree of flexibility is produced; that is to say, a flexibility which is not inherent in the general substance of the body.

Now, the substance of this stone being chiefly quartz, the most rigid and inflexible of all materials, and the stone, at the same time, bending in such an easy manner, there is reason to conclude, that this arises from no principle of flexibility in the general substance of the stone, but from some species of articulation in the structure of it, or among its constituent parts; which
articulation

articulation, while it preserves the component particles in one entire mass, suffers the parts to move a certain space in relation to each other.

BUT before dissecting this stone, in order to see upon what principle it holds its flexibility, it may be proper to form a distinct idea with regard to that inflexibility or rigidity which is to be found in other strata.

WE do not now enquire into the means employed by nature for uniting the incoherent particles of which our strata have been composed; it is enough to know this fact, That strata are thus actually found, with their particles united in every possible degree, from the slightest contact to the most absolute confusion; that is to say, from a mass of incoherent particles, they become bodies of the most perfect solidity, and may be found in every sensible stage of that progress. If they are slightly cemented, the stone is tender and extremely friable; if much consolidated, the stone is strong, but inflexible, that is to say, with no more flexibility than the nature of the substance and the thinness of the body will admit of. It will here be evident, that with the same degree of cementation or consolidation, and with the same substance, the strength of the stone will depend upon the figure of the particles of which it is composed; the spherical being that in which the particles are least disposed to be firmly united. But of whatever form the particles may be, or in whatever degree they may be cemented, so long as their parts, which are in contact, are united, and so long as those particles are rigid, no flexibility, at least of that kind which is the subject of the present examination, can take place.

THUS we may see, that in order to give any degree of the present flexibility, it is necessary the particles should not be all equally united, but be united in some parts, and disunited in others. By this means, a certain species of articulation may be formed; an articulation which must be of a complicated nature,

ture, depending upon many circumstances ; and one which it may be very difficult to investigate among the small particles of this stone.

WE are now to endeavour to discover the peculiar structure or constitution of this Brazilian stone, by examining, as minutely as we can, the form and substance of its constituent parts, and that particular texture by which they are united.

UPON the upper and under surfaces of this thin stratum of stone, there is to be perceived a certain structure, which has a resemblance to a fibrous structure, but which is truly not fibrous. From more accurate inspection, it appears to arise from the reflection of longitudinal specular plates, which are all regularly arranged in one direction, consequently are parallel to each other. This gives some resemblance to a fibrous structure.

WHEN I examined these places with a microscope, I could perceive nothing like mica in them ; but they seemed to me to be the impression of mica which had so formed the transparent substance of the stone. In examining the transverse section of the stone, there appears nothing heterogeneous in its constitution, nothing micaceous, nor any distinct mark of stratification. The stone is porous or spongy, seemingly composed of nothing but pure transparent quartz, and shows neither a fibrous nor a laminated structure. It resembles nothing so much as a compressed stratum of snow. I now almost gave up every suspicion of mica in the composition of this stone ; and this will serve to show how deceitful may be certain appearances.

MY next operation was to split this stone in the direction of its stratification, by pressing in the point of a knife. Here I found that this stratified body has truly a foliated structure, and a certain tenacity in the direction of its stratification, which admits of flexure before it breaks. The same striated appearance is here to be perceived in the internal horizontal section, as was observed upon the upper and under surfaces of this stratum ;

tum ; and this appearance likewise proceeds from the same kind of specular longitudinal plates, arranged in the same order.

I NOW bestowed some pains in endeavouring to discover, by the power of the lens, what was the nature of those reflecting specular laminæ ; but I could not say assuredly, that there were two different substances in the construction of this stone. The irregular quartz particles, and these specular bodies, seemed both to be of a perfectly transparent crystalline-like matter. I then had recourse to the blow-pipe, in order to resolve my doubts ; and this indeed soon made a distinction of the different substances contained in this stratum. Where the fragment of the stone had received the intense heat of the flame, the foliated specular structure totally disappeared ; and here the irregular quartz particles remained seemingly without change. In the other part of the fragment, which had been heated to incandescence, the doubt with regard to the specular bodies was entirely removed, and the transparent mica had now assumed its natural appearance ; it had become opaque with regard to the transmission of light, at least comparatively, and it gave an argentine appearance by reflection, as may be perceived in the specimens which I have here laid before the Society.

I NOW could see, most evidently, the connection of the irregular structure of the quartz particles, with those stratified parallel plates of mica ; and I also understood the reason why I could not before distinguish the proper connection of those two substances, which was no other than their perfect transparency. But being thus satisfied of the thin flexible plates of mica, we may now consider the particles of quartz, which have little cohesion, as being bound together by these thin plates of transparent mica ; and these connecting plates being flexible, this allows a certain motion of the rigid particles among themselves, without the fracture or general separation of the stone.

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WERE I to form a conjecture in relation to the natural history of this flexible Brazilian stone, I would suppose, that it had been originally, like many similar strata, attendant upon the Alpine limestones, consolidated with calcareous spar; and that the consolidating substance had been afterwards dissolved out, as it always is in stones sufficiently exposed to the influences of the atmosphere. This supposition is also countenanced by the report, which I have received, with regard to the situation in which this solitary stone was found. It is said to have been in the soil or upon the surface of the earth. But without allowing ourselves to be led into any hypothetical speculations upon the subject, we may now reason from what appears more evident in the construction of this mineral.

NOTHING is more common in our north Alpine country, as well as in every other extensive country of the same kind, than strata of granular quartz and mica; and in our low country, we have many micaceous sand-stones; yet stones of that kind, with palpable flexibility, have not been observed. Therefore we have reason to believe, that it requires many conditions, seldom to be found together, in order to produce that flexibility which is so remarkable in this Brazilian stone. It is not enough to be composed of filiceous particles and plates of mica; these must be duly proportioned and properly arranged. But when all the materials shall be justly proportioned and perfectly arranged, perhaps the most difficult part is still to come; that is, the giving a proper union to the parts, so as to form a cohering stone, at the same time that the proper separation among those parts is so preserved as to allow them to move in relation to each other. Were all the particles united or cemented where they are in contact, it is plain that the flexibility of this stone would be lost; and were there no union among the component particles, it would cease to be a stone; a term which implies a certain degree of consistency or strength. But between those two extremes, there are not only many degrees,

but also a certain variety, arising from different modifications of those conditions. Thus, for example, the plates of mica may be united with the particles of quartz, while these inflexible particles are not united with each other. Here is a modification which may also take place in various degrees; for part of the quartz particles may be cemented, while there is sufficient separation upon the whole, to admit of all the flexure which is here perceived.

I MAKE little doubt that something of this kind is the case with the present example; that is to say, that there is a sufficient connection among the parts to preserve the proper consistency of a stone, and a sufficient laxity in the composition to admit of many of its parts moving in relation to each other, at the same time that the whole is connected.

BUT if among the indefinite variety that may happen in the disposition of those materials, and in the still more various degrees in which the cementing or consolidating operation may proceed, there is but one in which the greatest degree of flexibility may be admitted of, we shall find reason to conclude, that while an example equal to the present may be extremely rare, yet that upon accurate observation, many stones of that kind may be found to possess small degrees of this species of flexibility, such as might pass unnoticed by common observation.

THE *stellsten* or *gestellstein* of the Swedes and Germans, which they employ for the building of furnaces, is a stone of this kind, being, according to CRONSTEDT, composed of quartz and mica. Let us now consider what is the quality in a stone which, besides being apyrous, is required in order to adapt it to that purpose, of being durable in a furnace. It is precisely the same quality that would procure a certain degree of flexibility to the stone. In proportion as a stone is solid and friable, it is improper for that purpose. But in a porous stone, there is also a certain texture that adapts it for resisting the alternate
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operations of heat and cold, or the effects of frequent expansions and contractions, partially applied. Now, it is precisely the same structure which is required for those two purposes, that of procuring flexibility, and that of resisting fracture by the partial application of heat and cold; and the two things here compared, the *Stellsten* and the Brazilian stone, are of the same construction, so far as composed of quartz and mica in the stratified structure of a *Schist*.

Now, though in comparing the common *Stellsten*, or quartz micaceous strata of the Alpine countries, with this Brazilian stone, the one may be said to be flexible and the other inflexible, this is but saying that the one of these is not sensibly flexible, as is the other. But how many degrees of flexibility may actually take place between that which may be sensible to common observation, and that at which flexibility must cease?

THEREFORE, in seeing the principle upon which the Brazilian stone possesses its flexibility, we may understand the quality of the *Stellstein* which renders it so proper for the construction of furnaces; and, conversely, in understanding the structure of the *Stellsten*, we may see the principle upon which the Brazilian fossil possesses flexibility in so eminent a degree.

BUT it would appear, that this is not the only species of stone which may have this remarkable degree of flexibility. M. le Baron de DIETRICH observes, that the marble tables, preserved in the Borghezé Palace at Rome, under the name of *Pietra elastica*, seem to have the same property. Now, M. FERBER found, that those tables were of a true antique white marble, the grains of which have but little cohesion; and the P. JAQUIER observed, among the grains of the marble, particles of talc. But among the Alpine strata, we find both those that are composed of granulated quartz and mica, and those that are composed of granulated calcareous spar and mica, so much resembling each other, that, without trying their hardness or their solubility in acids, it would be difficult to distinguish them.

them. While, therefore, the flexibility of those stratified bodies is considered as arising from a certain mechanical construction, in which flexible plates of talc or mica are united with the granulated body of the stone, it is of no consequence of what substance the rigid particles of the stone shall consist, since they do not alter their form during the flexure, but only move in relation to each other.