

## REVIEWS.

- I.—AN ESTIMATE OF THE GEOLOGICAL AGE OF THE EARTH.  
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THE paper consists of an introduction and these nine sections :—

- I. The estimate of geological time.
- II. The original condition of the ocean.
- III. The supply of sodium by the rivers.
- IV. The saline deposits.
- V. The alkalis of the rocks.
- VI. The potash of the rivers.
- VII. Uniformity of denudation by solution.
- VIII. The alkalis of sediments, and the geological age of the latter.
- IX. The solvent denudation of the ocean.

And two appendices.

Appendix 1 is generally useful. It contains a list of numerical quantities adopted in the calculations. Appendix 2 is a list of sources of error which may modify the conclusions.

The matters treated of in the nine sections are epitomized in the introduction.

The first point argued is, that so much of the removal of the land surface as is due to solution may be accepted as a uniformitarian process; and this being granted, if we take the one element of sodium, which is dissolved out of the rocks and enters the ocean through river discharge, and if we assume that there was no sodium in the primæval ocean, the amount of sodium in the ocean divided by the amount annually brought down by rivers will give the length of time during which the accumulation has been going on, and will be a measure of the age of the world.

Professor Joly claims that the amount of sodium in the ocean agrees very well with that which must have been lost by the crystalline rocks in the process of their being converted into the existing volume, as usually estimated, of the sedimentaries. This would decidedly support his view that the sodium of the ocean has been derived from the crystalline rocks, and that the primitive ocean was devoid of that element.

I. The data upon which the calculations are made are as follows :  
“The absolute masses of the ingredients of the ocean” are :

|                           | Tons. |     |                           |
|---------------------------|-------|-----|---------------------------|
| Sodium chloride ... ..    | ...   | ... | $35,990 \times 10^{12}$ . |
| Magnesium chloride ... .. | ...   | ... | $5,034 \times 10^{12}$ .  |
| Magnesium sulphate ... .. | ...   | ... | $2,192 \times 10^{12}$ .  |
| Lime sulphate ... ..      | ...   | ... | $1,666 \times 10^{12}$ .  |
| Potassium sulphate ... .. | ...   | ... | $1,141 \times 10^{12}$ .  |
| Magnesium bromide ... ..  | ...   | ... | $100 \times 10^{12}$ .    |
| Lime bicarbonate ... ..   | ...   | ... | $160 \times 10^{12}$ .    |

"Of the sodium chloride 39.32 per cent. is sodium. In the sea, there is therefore a mass of sodium amounting to  $14,151 \times 10^{12}$  tons."

The materials in tons per cubic mile of nineteen of the principal rivers of the world (after Sir J. Murray) are next given, and from these it is calculated that they contain 24,106 tons of sodium per cubic mile. "The total volume [of water] discharged by the rivers into the ocean is 6,524 cubic miles per annum."

The mass of sodium in the ocean divided by the mass annually brought down by the rivers gives the length of time in which, at the present rate, the mass in the ocean can have accumulated. The result is 89,565,000 years. But Professor Joly prefers to use a later estimate of the volume of the ocean, which would lengthen the "period of geological denudation to 94,800,000 years nearly."

The foregoing gives the pith of Professor Joly's very ingenious theory of the age of the earth. The remaining sections are subsidiary to it, and are apparently intended to meet possible objections, and to render the first estimate more accurate.

II. "On the Original Condition of the Ocean." This is a necessary inquiry; for unless it can be premised that there was no sodium in it, the argument clearly fails, and the earth's age will be proportionately shorter by an unknown amount. The author assumes that the earth was once molten, and considers that, upon cooling, "the upper part of what is now the earth's crust must have contained as silicates, in the form of slag, lava, or rock, the alkaline earths now appearing chiefly as carbonates, the alkalis now distributed between the salts of the sea and the alkali silicates of the rocks, along with iron and alumina. The early hydrosphere must for want of other known alternative be supposed to have contained a quantity of hydrochloric acid, roughly represented by the chlorine now in the ocean."

We next find speculations as to the sequence of events preceding and following the first condensation of water on the surface; and it is considered improbable that a uniform ocean ever covered the entire globe; and the author inclines to the opinion that the sub-oceanic crust is more dense than the continental, and that ocean basins have been permanent. This part of the essay is of much interest, but does not very closely concern the main question of the age of the earth.

We have here quoted an important analysis by Mr. F. W. Clarke (Bull. U.S.A. Geol. Surv., 1897), "which may fairly represent the composition of the older crust of the earth."

|                                       |       |                                      |       |
|---------------------------------------|-------|--------------------------------------|-------|
| " Si O <sub>2</sub> ... ..            | 59.77 | Na <sub>2</sub> O ... ..             | 3.61  |
| Al <sub>2</sub> O <sub>3</sub> ... .. | 15.38 | H <sub>2</sub> O ... ..              | 1.51  |
| Fe <sub>2</sub> O <sub>3</sub> ... .. | 2.65  | Ti O <sub>2</sub> ... ..             | 0.53  |
| Fe O ... ..                           | 3.44  | P <sub>2</sub> O <sub>5</sub> ... .. | 0.21  |
| Ca O ... ..                           | 4.81  |                                      |       |
| Mg O ... ..                           | 4.40  |                                      | 99.14 |
| K <sub>2</sub> O ... ..               | 2.83  |                                      |       |

"Such a rock, or lava, attacked by a heated solution of hydrochloric acid, must ultimately yield its iron, calcium, magnesium,

potash, and soda as chlorides. The atomic percentages of Clarke's average are given by himself as follows:—

|               |      |     |     |                                     |      |
|---------------|------|-----|-----|-------------------------------------|------|
| Iron ...      | 4.71 | ... | ... | } take up<br>units of<br>chlorine { | 9.0  |
| Calcium ...   | 3.53 | ... | ... |                                     | 6.3  |
| Magnesium ... | 2.64 | ... | ... |                                     | 7.6  |
| Potassium ... | 2.35 | ... | ... |                                     | 2.14 |
| Sodium ...    | 2.68 | ... | ... |                                     | 4.1  |

Having given the composition of the crust, the author next considers how the chlorine of the heated hydrochloric acid, which he supposes then to have been in the ocean, would have been distributed among the bases.

It is evident that any sodium which was obtained by rock solution from the floor of the primæval ocean must be deducted from that supplied by the rivers, otherwise the age of the world will be reckoned too long. Professor Joly proposes to estimate the former by considering the chlorine in the ocean. Of whatever chlorine there was in the primitive ocean the sodium would take 14 per cent. (reckoning from the proportion of sodium to the other bases in the crust). But some chlorine is also supplied by the rivers, and by rain upon the land. He allows for this at a guess 10 per cent. Deducting this, the total supply by rivers is  $97.8 \times 10^6$  tons of sodium chloride per annum. There are other chlorides (lithium  $16 \times 10^6$ , ammonium  $6.5 \times 10^6$ ) in the rivers. Thus we find  $76 \times 10^6$  tons of chlorine discharged into the ocean annually by rivers.

"If we assume that the final result as to the duration of denudation will not be far from  $86 \times 10^6$  years, we arrive at a total deduction of  $6,536 \times 10^{12}$  tons [of chlorine] as a correction on the amount of chlorine contained [at present] in the sodium chloride of the ocean." This, however, seems to *postulate* the period of  $86 \times 10^6$  years, which is the thing to be found. The calculation will be—

|  | Tons.                   |
|--|-------------------------|
| Chlorine in the sod. chl. now in the ocean ... ..                  | $24,155 \times 10^{12}$ |
| Chlorine in the mag. chl. now in the ocean ... ..                  | $4,161 \times 10^{12}$  |
|  | <hr/>                   |
|  | $28,316 \times 10^{12}$ |
| Deduct chlorine introduced by rivers in $86 \times 10^6$ years ... | $6,536 \times 10^{12}$  |
|  | <hr/>                   |
|  | $21,780 \times 10^{12}$ |

"The result is  $21,780 \times 10^{12}$  tons" of chlorine in the original ocean. Of this, 14 per cent. will have been combined with sodium as already explained, the remainder combining with the other bases of the magma. This gives  $1,972 \times 10^{12}$  tons of sodium in the original ocean. Hence we have—

|   |                         |
|---|-------------------------|
| Tons of sodium in the present ocean ... ..      | $15,627 \times 10^{12}$ |
| Tons of sodium in the original ocean ... ..     | $1,972 \times 10^{12}$  |
|   | <hr/>                   |
| Difference given as brought in by rivers ... .. | $13,655 \times 10^{12}$ |

This, divided by the annual supply of sodium by rivers, viz.  $15,724 \times 10^4$  tons, gives as a final result  $86.8 \times 10^6$  years for the age of the world.

III. In this section some slight modifications of the supply of

sodium by rivers to the ocean are considered. The estimate of 39.3 millions of years is finally arrived at as "based on the most complete estimates of probabilities."

IV. We next have a short geological discussion on the origin of beds of rock salt; but the author concludes that these have scarcely any bearing upon his theory.

V. In this section the rates of percentages of soda and potash in igneous and sedimentary rocks respectively are considered. Seeing that the sedimentaries have been ultimately derived from the igneous, the difference needs to be accounted for. The difference is considerable; for while in the igneous the percentages are of potash 2.83 and of soda 3.61, in the sedimentaries they are of potash 2.49 and of soda 1.47. "If now the inference is right that the missing alkalis [i.e. the deficiency of soda in the sedimentaries] were supplied to the ocean, we should expect to find, on a rough approximation of the bulk of sedimentaries, and hence of the original rocks giving rise to them, that such a mass of parent rock would be adequate to supply the sodium in the ocean." This the author claims to be the case, allowing for the sodium retained in beds of rock salt. The weight of this argument clearly depends upon what reliance we can place upon the estimate of the bulk of the sedimentaries, which is taken from Mr. Mollard Reade.<sup>1</sup> Professor Joly accepts his estimate of a layer 2 miles thick over the land area, which on deducting the calcareous rocks is reduced to 1.6 miles. This, however, is reduced still further by a course of somewhat complicated reasoning to 1.1 miles, and the conclusion, accentuated by italics, is thus stated:—

*"Hence it appears that, if a thickness of 1.1 mile of rock spread over the land area represent the bulk of the entire detrital siliceous sedimentary rocks, inclusive of submarine detritus, and this constitutes 67 per cent. of the entire sedimentaries of the earth, including matter in solution in the sea, the sodium contained in the sea, added to what is left over in the detrital sediments, would suffice to restore to the entire mass a soda percentage almost equal to that in the eruptive, igneous, and crystalline rocks; the deficiency, about 0.4 per cent., exists partly in rock-salt deposits."*

The bearing of this section upon the general argument is, that the sodium in the ocean may be regarded as having been all of it derived from the original rock magma.

VI. The ratio of potash to soda in the ocean is 1 to 31 nearly, whereas in the river discharge it is 1 to 2.8, that is, there is about eleven times as much potash compared to soda in the rivers as there is in the ocean. It is therefore clear that at this rate the present ratio of these alkalis in the ocean could not have been contributed by the rivers. "We must then suppose that the rivers are now supplying more potash relatively to soda than formerly; or that some process of abstraction of the potash from the ocean is in continual progress." The author comes to the conclusion that there is no reason to suppose that the ratio of the alkalis in the river supply differed in

<sup>1</sup> GEOL. MAG., Dec. III, Vol. X (1893), p. 97.

times past from what it is now, but attributes the deficiency of potash in the ocean to a continual abstraction of that alkali in deposits which have always been, and still are, going on upon the sea bottom, especially in the form of glauconite. Moreover, while the soda brought by rain from the ocean is returned to it again, much of the potash is retained by vegetation, and finally deposited in the strata.

[Is it certain, however, that the primæval ocean did not contain soda? If it did, the excess would be at once explained.]

VII. The uniformity of denudation by solution throughout geological time is a first requisite of Professor Joly's calculation. The objection which would be probably made is, that the sodium supply by rivers will have been greater in early times. To meet this he first argues for a nearly equable distribution of land and sea all along, so that there would not have been formerly much larger areas exposed to denuding agency than now. This portion of the present section is very interesting from a geological point of view, and is well reasoned. No claim is made to settle definitely the ratios of rainfall during successive epochs.

In the next place the author meets the possible objection, that it might be thought that formerly greater areas of the land surfaces were occupied by crystalline rocks, which, containing a larger percentage of sodium than the sedimentaries, would have supplied that element at a quicker rate. In later times the sedimentaries would occupy a larger proportion of the exposed surface, but the balance of supply would, he thinks, be rectified by the greater ease with which the sedimentaries, aided by disintegration into soils, yield up the alkalies they contain.

VIII. In this section "a very interesting but difficult line of enquiry is suggested in the probable facts of geological denudation" referred to in the previous section. The object in view appears to be to support the theory of uniformity of sodium supply.

IX. By "the solvent denudation of the ocean" is meant its action upon the coastlines. This is believed by the author to be small compared with what goes on upon land surfaces. Moreover, experiment has shown that sea-water has little effect in decomposing felspars, and similarly the volcanic products which are so abundant in deep-sea deposits have the alkali ratio of igneous, not of sedimentary rocks—"a plain proof that the waters of the ocean do not affect them as would terrestrial rain and rivers." The correction on the world's age on account of the solvent denudation of the ocean will be sufficient if half a million years is allowed. The final conclusion is that "*our present knowledge of solvent-denudation of the earth's surface points to a period of between eighty and ninety millions of years having elapsed since water condensed upon the earth, and rain and rivers and the actions continually progressing in the soils began to supply the ocean with materials dissolved from the rocks.*"

As Major Dutton has somewhere remarked, "If we enquire of Mother Earth her age her face is the face of a sphinx." Has

Professor Joly read her riddle aright? The suggestion of some criticisms may be excused.

In the first place, it does not appear safe to take the intensities of actions now going on as a measure of those in past ages, because the earth has been losing energy; and, as Professor Darwin has pointed out in his book on "*The Tides*," meteorological agencies must have formerly been more powerful than they are now. In the writer's opinion, in dealing with events of long past ages the interaction of the moon upon the earth ought not to be lost sight of. This is inversely proportional to the cube of her distance, which distance was once much less than it is now, if, indeed, the moon was not once a portion of the earth suddenly detached. If such was the case, the primæval condition of the earth's surface may have been profoundly modified by the stupendous event.

The assumption made that the primitive ocean did not contain alkalis appears to require that the alumina in the original magma was exactly proportioned to the alkalis, so that when the felspathic minerals were formed there was neither alumina left nor alkalis, as there certainly was silica in abundance, still uncombined. If this proportion did not hold, there would have been either alumina uncombined in the crystalline rocks, or alkalis over to combine with the acids in the ocean—presumably the latter, seeing that alkaline salts abound in it at present. That this due proportion should have existed does not seem probable. If there was soda in the primæval ocean, that would shorten Professor Joly's estimate of the earth's age.

The various sodium salts in the rivers are in the proportion of sulphate 32, nitrate 27, chloride 17, nearly. The decomposition of iron sulphide would supply the sulphuric acid. Bacteria in the soils would supply the nitric. But whence came the chlorine? The amount of 0.01 per cent. stated to occur in crystalline rocks seems insufficient. Sodium occurs as carbonate rather abundantly in some rivers and artesian wells, which, Sterry Hunt remarks, "has its source in the decomposition of felspathic minerals."<sup>1</sup> This shows that the direct product of these rocks is the carbonate rather than the chloride. Is it not probable that the chlorides of sodium, and to a small extent of lithium, are derived from sedimentary rather than from crystalline rocks; not from the decomposition of these rocks, but from what Sterry Hunt calls the "fossil sea water still to be found imprisoned in the pores of the older stratified rocks,"<sup>2</sup> and presumably in the younger as well?

This idea had occurred to the writer before referring to Sterry Hunt's book, and he had already begun to examine a specimen of the Silurian rock (Wenlock shale) obtained from the depth of 880 feet in the New River Company's borehole at Ware; for it seemed probable that this rock has never yet been exposed to atmospheric influences, so that it would contain all the salts which were present in the mud of the very early ocean from which it was

<sup>1</sup> "Chemical and Geological Essays," p. 85.

<sup>2</sup> *Ibid.*, p. 41.

consolidated. And it is distinctly salt to the taste. On submitting a fragment of this rock for examination to Mr. Purvis, of the Cambridge University chemical laboratory, he found that it contained 0.568 of soluble matter, of which 0.042 per cent. consisted of chlorine calculated to sodium chloride. Now the specific gravity of this rock is 2.59. Consequently, since a cubic foot of water weighs 1,000 ounces, there are 1.08 ounces of chlorides in a cubic foot of the rock and 2.27 ounces of other soluble salts. In like manner a piece of Devonian shale from Meux Brewery in Tottenham Court Road at the depth of 1,070 feet was found to yield 1.11 per cent. soluble in water, but the amount of chlorine was too small to determine.

It is interesting to compare these old rocks with such as we might suppose would now be forming. Accordingly it was found upon squeezing dry some mud from Southampton Water that the matter soluble in water was 0.495 per cent., and of "chlorine calculated to sodium chloride 0.074 per cent." This mud was derived from Middle Bracklesham sands, and yielded a soft sandstone rock when consolidated in a hydraulic press.

Some mud from the Fleet near Weymouth, when treated in the same manner, yielded 0.9 per cent. of soluble matter, of which chlorine calculated to sodium chloride gave 0.29 per cent.

It is remarkable that the total amount soluble in these hypothetical recent rocks is closely analogous to that in the ancient rocks examined, and also that the proportion of sodium chloride in both cases is comparatively small; whereas in sea-water it is very much greater than that of any other salt. Mr. Purvis adds: "This pressed mud also contains probably mixed sulphates, such as magnesium sulphate, sodium sulphate, potassium sulphate, and calcium sulphate." It is natural to conclude that the decomposition of iron sulphide in the original sands may have converted much of the chloride into sulphate. Sulphuric acid is also a product of the combustion of coal, which would account for the presence of a certain amount in localities like those from which these muds were obtained. But the point of interest is the probable substitution of sulphates for chlorides, from whatever source the acid may have come. This consideration shows that there may have been originally more sea salt in a sedimentary rock than is indicated by the quantity of sodium chloride it now contains.

Another point to be noticed is, that the amount of salts in the ancient rocks being so near that in rocks now presumably being deposited, shows that the ocean was about as salt then as it is now, and consequently not much additional sodium can have accumulated in it during the long ages since Silurian times.

In the 18th annual report of the U.S.A. Geological Survey<sup>1</sup> upwards of sixty analyses of well waters are recorded in Indiana and Ohio. In the artesian wells sodium chloride is very abundant, to the amount of 1,000 to 3,000 grains to the U.S.A. gallon. These waters appear to be found in sedimentary rocks. In the 19th report<sup>2</sup>

<sup>1</sup> 1896-7, pt. iv, p. 500.

<sup>2</sup> 1897-8, p. 650, "Rock Waters of Ohio."



we read: "Water from a greater depth [not specified] holds dissolved chlorides as well. Chloride of sodium is by far the most common, but chlorides of magnesium and calcium are often added. Such waters are usually called saline. The presence of chlorides is seldom shown in waters at less than 100 feet in depth. . . ." "It is very rare that the drill descends to 300 feet without encountering saline water." These waters are from Silurian beds.

The conclusion to be drawn from these remarks is, that some of the sodium found in river waters may probably be derived from the "fossil waters" of old sea muds, and if that is the case, it is in circulation from the ocean to the stratified rocks and back again. No doubt much sodium may find its way into rivers immediately from the felspar of rocks, but we are not justified in crediting all the sodium conveyed to the ocean as having been supplied *de novo* in that manner. This consideration would lengthen Professor Joly's estimate of the world's age by an unknown period.

An enquiry not without interest may be made as follows:—Supposing the whole of the land area to consist of granite; for how many years would a foot thickness of the land supply the sodium as carried down by the rivers at the present rate? Mr. Merrill's book supplies the data to answer this question.<sup>1</sup> He describes a section where solid granite occurs at the bottom, and, after passing through an intermediate stage of weathering, is disintegrated into sand at the surface. It appears legitimate to assume that this process of disintegration keeps pace with the denudation of the surface. Mr. Merrill says that the solid granite, in the process of disintegration into the residual sand, loses 28·62 per cent. of its soda. Now the weight of the sodium is the weight of the soda *minus* the weight of the combined oxygen, so that it will be 23/31 the weight of the soda. Also he tells us that the weight of the soda is 2·68 per cent. of the solid granite; and according to Mallet a cubic foot of granite weighs 198·34 pounds.

With these data it appears that the weight of the sodium in a cubic foot of granite is 0·00047029 of a ton.

Accepting Professor Joly's figures, the land area in square feet will be  $55,814,000 \times (5,280)^2$ , which gives us the volume of a layer a foot thick covering the land area; also the weight of the sodium annually discharged by the rivers is 157,267,544 tons. Dividing this by the volume of the one foot layer multiplied by the weight of sodium in a cubic foot, we get 1/5000 of a foot of granite as competent to supply the sodium of the rivers in the annual process of disintegration.

We may hence conclude that, if the land area consisted of granite, the rate of denudation would be one foot in 5,000 years. Sir A. Geikie, in his "Text Book of Geology" (p. 444), accepts one foot in 6,000 years as a probable mean for the rate of denudation. It is certainly remarkable that the result we have obtained comes near this. But when we remember that but a small portion of the land surface consists of crystalline rocks, and that the mean

<sup>1</sup> "On Rocks and Rock Weathering," p. 209.



percentage of soda in sedimentary rocks is only 1.47 (p. 44), it is obvious that a much higher rate of denudation would be required to yield annually by decomposition of such rocks the amount of sodium carried down by the rivers. The conclusion will be that, if one foot denuded in 6,000 years is near the truth, the sodium in the rivers must have some further source than the soda which forms a mineral constituent of the surface rocks, and that this additional soda is probably derived, as already suggested, from "fossil" seawater. Ought not also some allowance to be made for the soda introduced into rivers by human agency?

The style of the paper leaves here and there a little to be desired in respect of clearness; for instance (p. 47), "We can apply to the mean analysis of the sedimentaries on the one hand, and to that of the original crust on the other, to arrive at a rough estimate of the loss of entire rock by solution in the process of formation of the former." Again (p. 46), "We accept one mile deep of these [detrital sediments] on the land, and confining ourselves to purely detrital siliceous sediments, assume that as much as 10 per cent. of what is on the land is in the sea [?], or say a total of 1.1 mile deep over the land area."

In this important essay Professor Joly has opened up an entirely new line for the investigation of geological time. It is too soon to pronounce whether his numerical estimate is fully to be relied upon, until it has been a little while before the scientific world. His period of between 80 and 90 million years will perhaps satisfy geologists as being sufficient. The leading physicists, on the other hand, are disposed to grant us a good deal less time.

O. FISHER.

HARLTON, CAMBRIDGE.  
January 22, 1900.

## II.—THE FAUNA OF THE SILURIAN OF PODOLIA.

Fauna siluriiskikh otlozhenii podol'skoï gubernii. Die Fauna der Silurischen Ablagerungen des gouvernements Podolien. By P. N. VENYUKOV (Wenjukow). Mater. Geol. Russlands, XIX, pp. 21-266, pls. i-ix; November, 1899.

**P**ODOLIA, which lies to the south-west of Kiev, is bounded on the south by the Dniester and on the west by Galicia, and is drained by a river beloved of every schoolboy—the Bug. The Silurian rocks are all in the south-west of the province, adjoining the similar formations of Galicia. The present work by Professor Venyukov of Kiev describes the fauna of these rocks, unfortunately for us, in Russian; but the broad results may be gathered from the short abstract in German, while the new species, of which there are not a few among corals, brachiopods, molluscs, and ostracods, may to some extent be identified from the plates. The Silurian geologist will certainly have to read the abstract, and the specialist in palæontology must get the Russian descriptions translated for him. Here we give only the main conclusions.