ences," by R. C. Archibald; "Notes"; "New Publications."

THE April number of the *Bulletin* contains: "Simon Newcomb," by E. W. Brown; "A new proof of Weierstrass's theorem concerning the factorization of a power series," by G. A. Bliss; "On some theorems in the Lie theory," by L. D. Ames; "On the discontinuous ζ-groups defined by rational normal curves in a space of n dimensions," by J. W. Young; "A new analytical expression for the number π, and some historical considerations," by G. Vacca; Review of Hermite's Works, Volume II., by James Pierpont; "Shorter notices": Serret-Scheffers, Differential- und Integralrechnung, third edition, Volume III., by A. R. Crathorne; Richter's Kreis und Kugel in senkrechter Projection, by D. D. Leib; Granville's Plane and Spherical Trigonometry, by Jacob Westlund; Lecornu's Dynamique appliquée and Boulanger's Hydraulique générale, by J. B. Shaw; Schafheitlin's Besselsche Funktionen, by A. R. Crathorne. Correction; "Notes"; and "New Publications."

REFLECTIONS ON JOLY'S METHOD OF DETERMINING THE OCEAN'S AGE

As is well known to all geologists, the very important method of estimating the age of the ocean devised by Mr. J. Joly consists substantially in dividing the total sodium content of the sea water by the yearly contribution from the land, this annual tribute being ascertained by analyzing river waters and gauging the streams. It is assumed on uniformitarian principles that what variation there has been in the annual salt tribute is undiscoverable.[1] In a long-forgotten memoir Edmund Halley[2] made a very similar suggestion and anticipated Lyell in propounding a strictly uniformitarian doctrine of the accumulation of salt.

Oceanic sodium is at least chiefly derived from lime-soda feldspars, which as essential constituents are practically confined to Archean and later igneous rocks. The original surface of the earth must have consisted of such rocks to the exclusion of all others, while at the present day the greater part of the land area is covered with sedimentaries. Now the rate of decomposition of rocks is chiefly dependent on exposure. Even in areas of ancient feldspathic massives decomposition does not seem to penetrate to great depths. Thus in the southern Appalachians great areas of gneiss and allied rocks are now covered by a blanket of saprolite (rotten rock in place) which is in many localities 50 feet in thickness, but at all the points where I have observed it less than 100 feet thick. Immediately below the saprolite blanket there is incipient decomposition and the feldspars are milky, but not many yards lower down the feldspars are characteristically translucent and the rock bluish in tint. A layer of decomposition products 100 feet thick seems to arrest decay. Corresponding statements are true of Tertiary volcanics excepting where the decomposition is solfataric. On the other hand Mesozoic and Paleozoic massive rocks deeply buried under sediments are not seldom found to be very free from decomposition. In short, buried massives decompose at a rate which is scarcely sensible.

It is quite conceivable that in the far distant future all the massive rocks might be thoroughly decomposed down to sea level or a trifle below. The continents would then be exclusively detrital. Under such conditions there could be no further important additions to the sodium content of the ocean, for there would then be no leaching, while mere diffusion to any considerable distance is too inordinately slow to produce any noteworthy result even in millions of years.

Thus in the distant past there must have been a time when a far greater mass of massive rock was decomposed each year than now decays in the same period; and a limit to this process can also be foreseen. The total area of exposed massives has surely diminished and will continue to diminish. Climate and temperature may perhaps have been in the past much what they are to-day; the rate of chem-

[1] *Trans. R. S. Dublin*, Vol. 7, 1899, p. 23, and Brit. Assoc. Rep., 1900, p. 369.

[2] SCIENCE, Vol. XXXI., March 25, 1910, p. 459, and *Phil. Trans.*, Vol. 29, 1715, p. 296.

ical denudation per unit area may not have changed considerably, but the most rigid uniformitarian would not maintain that the total area of exposed massive rocks has been constant. The inference seems unavoidable that sodium accumulation is an asymptotic process which progressed more rapidly (though possibly not with greater intensity) in the distant past and will come substantially to an end when a certain very finite layer of surface material has been exhausted. It seems worth while to attempt some rough estimates based on this conception of the saltness of the ocean.

There is a great deal of evidence for the elder Dana's generalization as to the permanence of continental areas. Dana would have been the last to assert absolute invariability of the land area but, just as it seems less hazardous to assume a uniform areal rate of decomposition than any uncertain or fanciful variation of that rate, so it seems safest for the present purpose to suppose the total area constant.

The simplest law compatible with the conditions set forth is that the proportionate decrease in the sodium-producing exposures of massive rocks has been constant. This is of course the familiar compound-interest law. In other words the hypothesis proposed is that the area of exposed sodium-bearing rocks can be represented approximately by the descending exponential which is so characteristic (in Mr. Walcott's words) of cases in which "an entity is subject to gradual extinction or absorption."

If A is the total constant land area and y the exposure of sodium-bearing rocks when the ocean had an age of t years while c is a certain constant to be determined from limiting conditions, then the hypothesis to be examined is

$$y = Ae^{-t/c} \qquad \text{or} \qquad t = c \log A/y.$$

Suppose the total sodium content of the ocean at time t to be N and let my be the increment of N in any one year. Then m being constant

$$N = \int_0^t my\,dt = Amc(1 - y/A).$$

Here N is pretty well known, and so is A, or at least its present value, while m and the value of y for the present time are known to a certain degree of approximation. Hence c can be found. If t were infinite, y would become zero, and therefore Amc represents the total sodium which can possibly be supplied to the ocean if the hypothesis fits the case. From this total it is easy to compute the thickness of the layer of average massive rock which would yield it.

Mr. Joly's assumption expressed in this notation is that, subject to minor corrections,[3] the age t would be given by N/my. His data are

$N = 14{,}694 \times 10^{12}$ and $my = 155.42 \times 10^{6}$

tonnes (or metric tons) and I shall adopt the same values in order to obtain strictly comparable results. The ratio N/my is 94.544×10^{6}.

A careful study of the areas of exposure of the principal geological formations was made by the late distinguished physical geographer Lieutenant-General Alexis von Tillo. This includes the Archean and the younger eruptives, the results being expressed in hundredths of the total surveyed area. The following is an extract from von Tillo's table.[4]

Continent	Archean	Eruptives	Total
Europe	20.6	1.3	21.9
Asia	17.7	4.7	22.4
Africa	18.4	2.2	20.6
Oceanica	20.0	4.8	24.8
North America	27.2	5.5	32.7
South America	18.7	4.6	23.3
Mean	20.3	4.0	24.3

The most recent geological map of North America (compiled by Mr. Bailey Willis) shows that the relative area of exposed feldspathic rocks on this continent is not so large as was supposed when von Tillo wrote, and, though I have made no minute measurements, this exposure as now mapped seems not to exceed 25 per cent. With this emendation von Tillo's table shows a truly remarkable uni-

[3] Especially for marine denudation and uncertainty in the volume of the ocean.

[4] *Comptes Rendus*, Paris, Vol. 114, 1892, pp. 246, 967.

formity throughout the world, all the figures lying between a fourth and a fifth of the total area. He too was impressed by the smallness of the variation in the relative areas of Archean exposures.

It seems well established that at the present day the relative area of y/A lies between two tenths and three tenths. The values for the constant c, the ultimate sodium accumulation, Amc, and the present age, t, as computed from the formula are given in the following table for these extremes and also for $y/A = 1/4$.

y/A	0.20	0.25	0.30
c	23.636×10^6	31.515×10^6	40.519×10^6
Amc	$N\,5/4$	$N\,4/3$	$N\,10/7$
t	38.0×10^6	43.7×10^6	48.8×10^6

It can also be computed from the formulas at what rate the area of massive rocks is diminishing. This is expressed by $dy/dt = -y/c$. Substituting for y its value in terms of A and taking A at 134.38×10^6 square kilometers gives the mean annual net decrement for each of the three cases at almost exactly one square kilometer in spite of additions due to vulcanism, a result which is certainly not startling.

Mr. F. W. Clarke[5] has shown that a shell of average igneous rock enveloping the globe and 2,225 feet (678.2 meters) thick would furnish all the salt of the ocean. The ultimate thickness of the decomposed shells corresponding to the three values of y/A would be proportional to Amc, that is, 848, 904 and 969 meters, respectively, so that Clarke's shell would never assume improbable dimensions, or exceed three fifths of a mile.

Much the weakest point in this speculation seems to me to be the assumed constancy of the land area. This has assuredly fluctuated, yet when shallow seas flooded portions of the continents, marine denudation took the place of erosion in part, at least, and was possibly an equivalent. A is taken as constant only because there seems no way at present in which its variations can be rationally represented. The present marine denudation is offset to some extent by wind-borne or cyclic salt. It seems to me needless to consider the sodium content of sedimentaries as a source of supply for the ocean. Limestones contain a mere trace of sodium. Shales—which are the prevalent detrital rocks—(including clay, clay-slate and phyllite) contain sodium, but seemingly in a stable form, since ancient phyllites and modern clays are indistinguishable by their sodium content. Sandstones do not contain enough sodium to affect the problem of the earth's age, considering the greater uncertainties. Possibly some massives underlying thin layers of sedimentaries yield a little sodium, but, per contra, areas properly mapped as Archean or massive are in many localities protected by saprolite. This is true locally even in glaciated Alaska. Considering such protection, I believe the effective value of y/A to be nearer a fifth than a quarter.

Possibly it may be worth while to refer to the evident fact that if the descending exponential properly represents the history of the accumulation of sodium in the ocean, this became highly saline much earlier than on Mr. Joly's theory. Thus when the earth was half its present age the law of linear increment would of course imply that there was half as much salt in the ocean as there is now, while if the exponential relation holds good and $y = A/5$, the ocean at that epoch contained seven tenths of the present amount. The fauna of the Paleozoic indicates a salt-water habitat. If the deep was then as briny as it now is, it must have taken in a vast amount of juvenile water in the mean time on either hypothesis.

The annual increment of N or the quantity here called my is susceptible of improved determination, as every one has recognized. Mr. Clarke is now engaged on a discussion of this subject based on far more extensive material than was at Mr. Joly's disposal, and his results will be available in a few months. When they are known, it will take only a few minutes to recompute the age of the earth on the hypothesis here discussed.

The foregoing speculation is based on the assumption that the area of sodiferous rocks has diminished by a constant proportion ($1/c$)

[5] "Data of Geochemistry," 1908, p. 28.

per unit of time—about a thirty-millionth part each year. This can not be precisely true, but I think it must be a better approximation than the hypothesis that this area has undergone no diminution at all. The results may err in either direction. Thus the rate of diminution may fluctuate; if it is now above the average the exponential relation would give too low a value for the earth's age, and *vice versa.* Whether the rate is actually above or below the average we have no means of discovering. Again it is wholly improbable that either intensity of decomposition or the average yield of sodium per square kilometer of sodiferous rocks has always been the same, and this yield may now exceed the mean or fall short of it.

It appears that Mr. Joly's linear relation between oceanic sodium and its increment must lead to an excessive estimate of the earth's age, at least when the increment is duly determined. Thus that method assigns a limit, a knowledge of which is very valuable as a check on other computations. On the other hand, the ages computed from his data by the exponential expression seem to me suspiciously low. Various trains of reasoning lead me, at least, to believe that 50 million years is not a maximum but a minimum age; if so and if the exponential hypothesis is applicable then Mr. Joly's datum for the annual sodium increment is too large.

George F. Becker

Washington, D. C.,
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BOTANICAL NOTES

RECENT STUDIES OF THE FUNGI

Dr. J. J. Davis's "Fourth Supplementary List of Parasitic Fungi of Wisconsin" in the *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* adds many new hosts, many species not hitherto reported, and some species new to science. All of the latter are Fungi Imperfecti. With this may be noticed the same author's "Mycological Narrative of a Brief Journey through the Pacific Northwest" (in the same *Transactions*) in which we are reminded of the itineraries of the earlier botanists, like Kalm and Pursch, or even the master traveling botanist, Linné, in which not only are we told of the plants observed and collected, but we are made delightfully aware of the botanist himself. Our younger botanists might profitably study the style of the paper before us.

In these days when all lichens are fungi, we may notice here L. W. Riddle's "Key to the Species and Principal Varieties of Cladonia occurring in New England," which appeared in *Rhodora* for November, 1909. It looks promising, and no doubt will be helpful to students.

Of quite a different nature is Professor Atkinson's paper on "Some Problems in the Evolution of the Lower Fungi," published in *Annales Mycologici,* 1909. It was first delivered as the presidential address before the Botanical Society of America. In a most ingenious manner the author argues for the origin of the Phycomycetes from the lower unicellular algae such as the Protococcoideae through Chytridiales, to Saprolegniales, etc. He discusses the "degenerative influence of parasitism" and comes to the conclusion that "there seems little in support of the theory." On the contrary, he builds up "a natural series from Chytridiales to the Oomycetes and Zygomycetes, showing progressive evolution of the vegetable body and sexual process." While the paper may not be conclusive, it is suggestive and should be read by every student of the lower fungi.

W. H. Brown, in a note on "Nuclear Phenomena in *Pyronema confluens*" in the Johns Hopkins University Circular, 1909, points out that "it seems probable that the fusion of the sexual nuclei originally took place in the ascogonium, but later was delayed until some point in the development of the ascogenous hyphae." In this way he suggests a reason for the disappearance of the functional sexual organs in many fungi.

Here may be mentioned several papers on the economic aspects of certain parasitic fungi; namely, H. T. Güssow's "Serious Potato Disease occurring in Newfoundland" (Bull. 63, Canadian Dept. Agric.), in which a