

ART. XLIV.—*Bacteria and the Decomposition of Rocks*; by
JOHN C. BRANNER.

HAVING had occasion recently to study certain features of rock decomposition, I was frequently told that bacteria were important agents of rock decay. I here indicate as briefly as possible the evidences considered and the conclusions reached in regard to this subject.

The *bacteriaceæ* or *schizomycetes* of the botanists are a group of the simplest microscopic fungi. Fermentation and putrefactive processes are the results of the growth of certain of these bacteria.*

The discovery that organic decay was a process of bacterial growth seems to have given rise to the idea that this decay extended to minerals and rocks as well. In 1890, Muntz, speaking of decomposed or disintegrated rocks said,† “In applying to rocks in this condition the word *decayed*, which, since the work of M. Pasteur is so clearly explained as *facts connected with the growth of microscopic organisms*, we unconsciously establish between these two orders of ideas a correlation confirmed by the researches mentioned above.” The italics are in the original. In this article Muntz speaks of having found bacteria “in the denuded rocks of the Alps, the Pyrenees, the Auvergne, and the Vosges, comprising the most varied mineralogical types: granites, porphyries, gneiss, mica schist, volcanic rocks, limestones, sandstones.† Often the action of the micro-organisms is not confined to the surface, but extends into the depth of the rock mass. This is the case with the so-called *rotten* rocks of which the particles become disengaged and separate as is often seen in limestones, schists and granites. In decomposed rocks I have always verified the presence of the nitrifying organism.”

This statement of Muntz seems to have given rise to the somewhat prevalent idea that rock decay is, like organic decay, a process of bacterial growth. It appears to have been accepted without question, and one finds occasional references to the work of bacteria in rock decay as if it were a fact as well established as their work in organic decay.‡

Accepting the statement of Muntz that bacteria are found

* A. De Bary, Comparative Morphology and Biology of the Fungi, etc.; translated from the German by Garnsey and Balfour, Oxford, 1887. (Contains bibliography.) Duclaux, Chimie biologique, Paris, 1883. Cornil et Babes, Les Bacteries, 2d ed., Paris, 1886. Hueppe, Die Methoden der Bacterienforschung, Wiesbaden, 1885. Writings of Pasteur, Koch, Lankester.

† Comptes Rendus, cx, 1890, 1372.

‡ Robert Warington, U. S. Dept. of Agriculture, Exp. Sta. Bull., No. 8, p. 70; H. W. Wiley, Yearbook of the U. S. Dept. Agriculture, 1895, p. 71.

in decayed rocks, let us inquire into the possibility of their finding conditions favorable to their existence in undecayed ones.

There is a great difference among bacteria with regard to the conditions under which they thrive. For example, those called *aerobiotic* by Pasteur require a large supply of free oxygen, while the *anaerobiotic* thrive best when the oxygen is kept from them.

The kind found by Muntz in decayed rocks are what are known as nitrifying bacteria, that is bacteria that reduce nitrogenous matter to nitric acid, or nitric acid to lower forms of oxidation. To most forms organic food is absolutely indispensable, but several authorities have demonstrated that the nitrifying bacteria may live without organic food.* This fact seems at first to place the statement of Muntz beyond question, for if bacteria can live in inorganic media, why can they not live in the rocks? But these bacteria are composed principally of carbon and nitrogen and in order to live they must take up these substances with their nourishment, either from the air or from some other source. It is known that the carbon of the bacteria may be derived from organic sources. De Bary says that "as far as we fully and certainly know, the parasitic mode of life is always indispensable to the complete development of the *facultative saprophytes*," which is understood to mean that organic matter is necessary to that existence.†

Warming, a thoroughly trustworthy authority, definitely states that "*organic carbon* compounds are indispensable for all bacteria (except, as it appears, for the nitrifying organisms), as they can only obtain the necessary supplies of carbon from this source."‡ Note his exception. He also says that "the bacteria are unable to assimilate carbon from the carbonic acid of the air." Berthelot says that the carbon and hydrogen of the atmosphere does not appear to be capable of supporting the life of the nitrogen-fixing bacteria, and that they are nourished by substances furnished by higher organisms.§

Experiments by Monro in 1886,|| by Frankland in 1885–6 and by Winogradsky in 1890¶ have demonstrated that bacteria of more than one kind can be propagated in inorganic media. These media, however, of a necessity contained carbon and

* Phil. Trans. Roy. Soc., 1890, B. 107; Nature, xlv, 1892, 136–138; Annales de l'Institut Pasteur, 1890, 268; Exper. Station Bull. 8 U. S. Dept. of Agriculture, 1892, 42 et seq; Comptes Rendus, 1893, cxvi, 842–849.

† Comparative morphology and biology of the fungi, mycetozoa, and bacteria, by A. de Bary; revised by Isaac B. Balfour. Oxford, 1887, 356.

‡ A handbook of systematic botany, by Dr. E. Warming. Translated by M. C. Potter, London, 1895, 31–32.

§ Nature, May 4, 1893, xlviii, 23; Compt. Rend., 1893, 842, for April 24.

|| Jour. Chem. Soc., 1886, 651.

¶ Annales de l'Institut Pasteur, 1890, 268.

nitrogen in some available form. Frankland used a solution of ammonium chloride, potassium phosphate, magnesium sulphate, calcium chloride and calcium carbonate.* Here the carbon was supplied by the calcium carbonate and the nitrogen by the ammonium chloride (NH_4Cl). Winogradsky used ammonium carbonate, from which both nitrogen and carbon could be derived.

It is safe to assume, without demonstration, that some such source of supply of these two substances must always be at hand or else these organisms cannot live.

Leaving aside the carbon, the only known mineral sources from which nitrogen could be derived are the nitrates and nitrites and a few others, such as teschemacherite, (acid ammonium carbonate ($\text{H}\cdot\text{NH}_4\text{CO}_3$)), from guano deposits, and sal-ammoniac (ammonium chloride (NH_4Cl)), which occurs about volcanoes.† But while these minerals all occur in nature, sometimes in great quantities, as in the great niter beds of the world,‡ so far as known, they are all produced by organic agencies, and can scarcely be regarded as what geologists know as “rock-forming minerals,” that is, minerals that enter into the composition of crystalline, eruptive, metamorphic or widespread sedimentary rocks. It is true that these minerals may be carried into the soil and into the rocks by infiltration, and Mrs. Frankland points out that some forms thrive in carbonated waters.§ But even then bacteria carried in with such waters could not attack the rock-making minerals directly, but only by the formation of organic acids by their own decay. But this simply puts them back in the position of other forms of life which yield organic acids upon decomposing.

Attention is also called to the statement of Storer|| that Warington, who found “nitric ferment in loam at various depths, was no longer able to detect it with constancy and certainty at depths greater than 36 inches In none of his experiments was nitrification excited by soils taken from depths of seven and eight feet.”

Again he says “In order that nitrates may form in the soil there must be free access of air, as well as a certain amount of humidity and warmth.”

* Micro-organisms in their relation to chemical change, by Percy F. Frankland. *Nature*, xlvi, 1892, 136-138.

† W. L. Watts in his “Across the Vatna Jökul,” pp 110, 154, mentions considerable deposits of this mineral about volcanoes. Mr. Watts tells me, however, that he doubts the correctness of the determination.

‡ Stutzer and Burri are said to have found bacteria feeding on saltpeter: *Deutsch. Landw. Presse*, 1894, xxi, No. 63, p. 610.

§ Bacteria and carbonated water, by G. C. Frankland. *Nature*, August 20, 1896, 375-376.

|| Agriculture in some of its relations with chemistry, by F. H. Storer, i, 299 and 305, N. Y., 1892.

Warington also shows* that subsoil nitrification is more active during dry periods because the opening of the soil by cracks admits the air, without which it cannot take place.†

In other words nitrifying bacteria not only do not penetrate the rocks themselves to considerable depths, but they do not even penetrate the soil to a depth of more than three or four feet. In the face of this fact, and of the other fact that our granites are often decomposed to depths of more than 100 feet, it seems quite improbable if not impossible that bacteria are responsible for this deep decay or for any considerable part of it.

Prof. G. P. Merrill in his paper on the principles of rock weathering,‡ summarizes the subject well when he says of bacteria that "the depth below the surface at which such may thrive is presumably but slight, and their period of activity limited to the summer months."

It may be asked whence came the nitrates now in the soil, if not from the rocks of the earth. I do not undertake to answer this question, and only suggest that the nitrogen is contributed to largely by the nitric acid produced by electric discharges in the atmosphere, and by the union of ozone and ammonium in the air.§

It will not be out of place here to refer to other statements regarding the presence of bacteria in the rocks.

Trouessant speaks of Béchamp as holding that the organic substance of the rhizopoda of the chalk has retained its vitality in the rocks, "since a freshly cut piece, taken from the quarry with all possible precautions to exclude air-germs, is able to furnish microbes (bacteria) which multiply rapidly in a favorable medium."|| This he is said to have demonstrated. I have not seen this statement, which is probably made in Béchamp's large work.¶ I am disposed, however, to believe that there is some mistake about this. It is difficult to believe that plants have preserved their vitality in the rocks for thousands of years. It is not difficult to believe that such forms may have been washed into cracks in the rocks, or that they may have been introduced in some of the many ways in which these organisms elude our watchfulness.

But even if there were no mistake about the matter, the existence of the original bacteria in chalk beds and the decom-

* Jour. Chem. Soc., li, 118.

† U. S. Dept. of Agriculture, Exp. Sta. Bul., No. 8, p. 70.

‡ Jour. Geol., iv, 857.

§ Bericht. deuts. Chem. Gesel., viii, 1481.

|| Microbes, ferments, and moulds, by E. L. Trouessant, the International Sci. Ser., N. Y., 1892, p. 125, 292.

¶ Les Microzymes dans leurs rapports avec l'hétérogénie, etc.; par A. Béchamp, Paris, 1883.

position of rocks through the agency of bacteria are different questions, except in so far as the supposed bacteria of the chalk may be able to attack the surrounding materials. Trouessant also speaks of Parize finding organisms in plaster and of his belief in their power to disintegrate "schistoid rocks."*

Dr. Bernard Renault recently published a paper on the geologic work of the bacteria† in which he tells of, and reports finding bacteria in several coals.

It should also be remembered in regard to all bacteriological questions that the methods employed in such investigations are not at the command of us all alike. We are compelled to rely upon the statements of specialists, and we need to be more than ordinarily cautious in our discriminations. I am therefore disposed to look with much doubt upon the finding of bacteria in rocks by anyone else than an experienced bacteriologist. Only those who have worked at bacteriology can fully appreciate the difficulties to be encountered and the precautions to be taken in dealing with these organisms in order to prevent being misled by faulty manipulation.

* Op. cit., 123-4.

† Les bactéries et leur œuvre géologique, *Revue Générale des Sciences*, Oct. 15, 1896; abstr. *Nature*, Nov. 12, 1896, 40.