

bottles a residue rich in manganese. He argues that the manganese exists in the water in the form of carbonate, and that at the surface gaseous exchanges take place transforming the carbonate into oxide, which falls to the bottom of the sea where it takes a concretionary form.¹

In 1891 Irvine and Gibson² pointed out that sulphide of manganese could not be formed in the manner maintained by Buchanan, as it is readily decomposed by the action of carbonic acid, whether free or loosely combined as in the bicarbonates of sea-water, carbonate of manganese being formed, which would go into solution as bicarbonate of manganese.

These various opinions as to the mode of origin of manganese nodules may be summarised as follows:—

1. The manganese of the nodules is chiefly derived from the decomposition of the more basic volcanic rocks and minerals with which the nodules are nearly always associated in deep-sea deposits. The manganese and iron of these rocks and minerals are at first transformed into carbonates, and subsequently into oxides, which, on depositing from solution in the watery ooze, take a concretionary form around various kinds of nuclei (Murray).³
2. They are formed under the reducing influence of organic matters on the sulphates of sea-water, sulphides being produced and subsequently oxidised (Buchanan).
3. They arise from the precipitation of manganese contained in the waters of submarine springs at the bottom of the ocean (Gümbel).
4. They are formed from the compounds of manganese dissolved in sea-water in the form of bicarbonates, and transformed at the surface of the sea into oxides, which are precipitated in a permanent form on the bottom of the ocean (Boussingault, Dieulafait).

Without discussing these diverse opinions it may be stated that we accept the

¹ We have been unable, in all our attempts, at the laboratory of the Scottish Marine Station at Granton, to determine even approximately the amount of manganese present in solution in surface waters from the Atlantic, Mediterranean, Red Sea, and Indian Ocean. Nor have we been able to detect the presence of manganese in the boiler deposits of several ocean-going steamers; we have detected carbonate of manganese in the muds of the Clyde sea-area (Murray and Irvine).

² "Manganese Deposits in Marine Muds," *Proc. Roy. Soc. Edin.*, vol. xviii. pp. 54–59. Mr Irvine and Dr Gibson say:—"From the behaviour of manganese, we have come to the conclusion that the formation of sulphide of manganese cannot be a result of the animal life, or the decomposition of animal matter at the sea-bottom, as supposed by Buchanan, inasmuch as sea-water containing excess of carbonic acid must be always present. Buchanan does not give any evidence whatever to show that sulphide of manganese is formed, but appears to rely upon the supposed analogy in the behaviour of iron and manganese. Under conditions such as those referred to by him, sulphide of iron is necessarily formed. Unlike sulphide of manganese, sulphide of iron is readily formed in the presence of sea-water, whether mixed with carbonate of lime or not, and solutions of carbonic acid or bicarbonates do not decompose it or prevent its formation. Thus in all cases where, through the life processes of animals, sulphide of iron is formed as a result of the reduction of sulphates the excess of carbonic acid necessarily formed at the same time must prevent the formation of sulphide of manganese. This holds equally in the case of the decomposition of the dead bodies of animals at the sea-bottom."

³ While admitting that a part of the manganese accumulated at the bottom of the ocean may be derived from the decomposition of volcanic rocks, in the manner described above (No. 1), it appears to me that the greater part must have been derived from the manganese in solution in the sea-water (A. Renard).