Molybdenum, manganese and iron in lake muds

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With 1 table in the text

Iron and manganese are well known to move more freely in anaerobic than in aerobic soils, and release of these elements from profundal muds into overlying lake waters has frequently been demonstrated during summer reduction of the mud surface in fertile lakes (HUTCHINSON 1957). Such migration along redox gradients is sufficient to greatly enrich iron and manganese in the oxidized microzone at the mud surface of Windermere and Esthwaite Water in the English Lake District (Table 1). Semi-quantitative spectrographic analyses of molybdenum reveal that this element is also markedly concentrated in the surface oxidized mud, following manganese according to geochemical expectation (GOLDSCHMIDT 1954).

It further appears from Table 1 that manganese and molybdenum are on average lower in the muds of Esthwaite Water than in those of the less fertile Windermere. The profundal Esthwaite muds differ from those of Windermere in having their oxidized microzone reduced during summer (MORTIMER 1941—42), and there is evidence that this reduction allows escape of manganese from the lake at overturn (MACKERETH and HERON 1959, 1961). The data in Table 1 suggest that molybdenum may be lost in the same way. By analogy, the high levels of acid-soluble manganese in Esthwaite surface waters, compared with those of Windermere and other less fertile lakes (HARVEY 1949), suggest that Esthwaite may also be high in soluble molybdenum.

Iron, which is also released into the bottom waters of Esthwaite in large quantities during summer (MORTIMER 1941—2), is much less easily maintained in the reduced and mobile condition than is manganese; and it appears not to be lost at overturn in the same way as manganese, for the Esthwaite muds exhibit about the same iron concentrations as those of Windermere. Moreover, the levels of acid-soluble iron are slightly higher in Windermere than in Esthwaite surface waters (PEARSALL 1930).

If molybdenum does migrate from mud to water in Esthwaite, its release could conceivably be of some biological importance. This element plays a part in the reduction of nitrate, which is much more abundant than ammonia in surface waters of the English Lakes (PEARSALL 1930, GORHAM 1958); and is concerned in the fixation of molecular nitrogen. Blue-green algae, many species of

Table 1. Molybdenum, manganese and iron in oxidized and reduced lake muds.

Site	Depth in mud (cm)	Molybdenum (parts per million of oven-dry mud)	Manganese	Iron
Esthwaite Water				
Deep water (c. 15 m)	Surface	4	13 800	83 000
11 October, 1954	5	< 1	800	48 000
	10	< 1	900	53 000
Deep water (c. 15 m)	Surface	1	600	51 000
29 November, 1954	5	< 1	300	44 000
	10	< 1	600	44 000
Windermere North Basin				
Shallow water (c. 4 m)	Surface	6	7 100	60 000
7 October, 1954	5	4	600	36 000
	10	3	800	39 000
Deep water (c. 60 m)	Surface	6	23 000	71 000
29 November, 1954	5	1	3 600	54 000
	10	2	3 600	54 000

which fix nitrogen (FOGG 1956), are particularly abundant in Esthwaite, one of the most productive waters in the English Lake District (LUND 1957). At times this lake also develops large populations of photosynthetic bacteria (COLLINS 1959), which may likewise prove to be sometimes important in nitrogen fixation (HUTCHINSON 1957). The possibility that molybdenum could be one of the factors controlling nitrogen metabolism and affecting general productivity (cf. GOLDMAN 1960) might therefore repay investigation.

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References

- COLLINS, V. G. 1959. *Rep. Freshw. biol. Ass. (U. K.)* 27, 24.
- FOGG, G. E. 1956. Nitrogen fixation by photosynthetic organisms. — *Ann. Rev. Plant. Physiol.*, 7, 51—70.
- GOLDMAN, C. R. 1960. Molybdenum as a factor limiting primary productivity in Castle Lake, California. — *Science*, 132, 1016—1017.
- GOLDSCHMIDT, V. M. 1954. *Geochemistry*. Oxford: the Clarendon Press.
- GORHAM, E. 1958. The influence and importance of daily weather conditions in the supply of chloride, sulphate and other ions to fresh waters from atmospheric precipitation. — *Phil. Trans.*, ser. B, 247, 147—178.
- HARVEY, H. W. 1949. On manganese in sea and fresh waters. — *J. mar. biol. Ass. U. K.*, 28, 155—164.
- HUTCHINSON, G. E. 1957. *A Treatise on Limnology I. Geography, Physics, Chemistry*. New York: J. Wiley and Sons, Inc.

- LUND, J. W. G. 1957. Chemical analysis in ecology illustrated from Lake District tarns and lakes 2. Algal differences. — *Proc. linn. Soc. Lond.*, **167**, 165—171.
- MACKERETH, F. J. H., and HERON, J. 1959. *Rep. Freshw. biol. Ass. (U. K.)*, **27**, 15.
— 1961. *Ibid.*, **29**, 17.
- MORTIMER, C. H. 1941—42. The exchange of dissolved substances between mud and water in lakes. — *J. Ecol.*, **29**, 280—329, and **30**, 147—201.
- PEARSALL, W. H. 1930. Phytoplankton in the English Lakes I. The proportions in the waters of some dissolved substances of biological importance. — *J. Ecol.*, **18**, 306—320.