ART. XXVI.—*An Analysis of Moa Eggshell.* By Prof. LIVERSIDGE, F.C.S., University of Sydney. Communicated by Prof. VON HAAST, F.R.S.

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I AM indebted to the kindness of Dr. Julius von Haast, F.R.S., director of the Canterbury Museum, New Zealand, for the specimen which is the subject of this note. The little packet of fragments was labelled "Moa-hunter kitchen-midden, Sandhills near Moa Cave Point, Sumner."

All the fragments appeared to be more or less weathered, and the edges, except where freshly fractured, were smooth and rounded, and their general appearance seemed to indicate that they had been subjected either to the action of blown sand or to that of water charged with carbonic acid gas; both influences may, of course, have been at work together.

The fragments were all very brittle, the fractured edges plainly showing, without the aid of a lens, the presence of two distinct layers. In most of the fragments the inner or concave layer, *i.e.* the one facing the interior of the shell, possessed a pale brown colour, the middle portion being quite white whilst the outer surface of the shell presented a pale tint of brown. Judging from the different depths of tints, the varying thicknesses and appearance, the pieces were apparently fragments of several different shells.

It is unnecessary for me to give any account of the microscopical structure of the shell, since that has been so ably done by Prof. F. W. Hutton, of Canterbury College, New Zealand.*

The pores are readily seen to penetrate right through the substance of the shell, on account of the brown-coloured matter which most of them contain; some appear to penetrate only to a certain limited distance, but this is because the direction of the pores is not straight and a portion of their length is cut off in the section; their apertures can easily be seen on the inside of the shell as well as on the outside, the outer openings, however, are considerably larger and are funnel-shaped,—many of these pores can be seen to pass through from side to side by the unassisted eye.

The middle portions of the eggshell are shown to be of softer material than the two surfaces, since most of the weathered pieces show a groove running along the edges.

On ignition all the pieces of shell experimented upon blackened and emitted an ammoniacal odour, thus plainly showing that they had by no means lost the whole of their organic matter, and on dissolving portions in acetic acid flocculent particles of organic matter were left floating in the solution. This organic residue was collected and found to be a readily com-

* *Vide* "Trans. N.Z. Inst.," Vol. IV., p. 166.

bustible nitrogenous body; under the microscope it presented traces of an organized structure.

A careful qualitative analysis was made of a portion of the shell, and, in addition to calcium carbonate, alumina (with traces of iron), phosphoric acid, magnesia, sulphur, potash, and soda, were found to be present; the latter three were in very small quantity, and no estimation of the amounts was attempted.

ANALYSIS.

Moisture driven off at 100° C	·20
Carbonic acid	40·05
Phosphate of alumina, with traces of iron	·29
Lime	53·65
Phosphate of magnesia	·17
Phosphoric acid	·59
Organic matter	4·90
Undetermined, including traces of sulphur, potash, and soda	·15
	100·00

The above results calculated out to the proximate constituents give the following:—

Calcium carbonate	91·02
„ *phosphate*	1·29
Magnesium phosphate ($Mg_3(Po_4)_2$)	·17
Aluminium phosphate, with traces of iron ($Al_2(Po_4)_2$) ..	·29
Lime	1·98
Organic matter	4·90
Traces of sulphur, soda, and potash, undetermined ..	·15
Moisture driven off at 100° C	·20
	100·00

The amount of organic matter was determined by the loss on ignition, after deducting the carbonic acid and moisture present, thus,—

Loss on ignition (carbonic acid, moisture, and organic matter) = 45·15 per cent.
Less carbonic acid 40·05 per cent., and moisture ·20 per cent. = 40·25 „

∴ Organic matter = 4·90 „

This organic matter probably in part consisted of albumen, since both sulphur and soda were present; the acetic acid solution also, from which the flocculent organic matter had been filtered, became turbid on boiling, thus affording an additional confirmatory reaction for albumen. I much regret that the small quantity of shell at my disposal did not permit me to prosecute this part of the enquiry further.

The phosphates of magnesia and of alumina were determined by dissolving out the phosphate of magnesia, by means of acetic acid, from the precipitate containing the mixed phosphates thrown down by ammonia; the amount of iron present was so small that it was disregarded.

It will be noticed that 1·98 per cent. of lime in the above results is uncombined with any acid; it therefore probably existed as an organic compound, perhaps as an albuminate. The amount of carbonic acid found in the shell itself was 40·05 per cent., but on treating the ignited residue (of quick lime) with ammonium carbonate and again determining the carbonic acid 41·48 per cent. was found, or an excess of 1·43 per cent. over and above that furnished by the original shell itself; this 1·43 per cent. of carbonic acid would, by calculation, require 1·82 per cent. of lime, whilst the actual excess of lime found was 1·98; the difference, ·18 per cent., between the calculated amount and that found is quite within the range of experimental error.

It was thought that perhaps it was just possible, although not very probable, that the shell had been subjected to the action of fire, and that part of the lime might still be in the caustic state, but nothing was found to confirm this momentary idea; the powdered shell turned red litmus blue paper, but not to a greater extent than does powdered marble; and, moreover, the presence of the organic matter found in all the fragments examined completely negatived the supposition that they had lost part of their carbonic acid by the action of fire.

The specific gravity of the shell was found to be 2·706 when taken in the form of powder; the uncrushed shell, after long soaking in water, gave a specific gravity of 2·530, and after warming until air-bubbles ceased to be expelled it was found to be 2·610. The difference between the first and second determinations gives a rough estimate of the amount of air-space in the substance of the shell.

On comparing the results of the analyses of the moa eggshell with the analyses of recent eggshells, it will at once be apparent that the composition of the moa eggshell differs but little from them; hence it has, in all probability, undergone but a slight amount of change.

The following analysis of the eggshell of the domestic fowl, made by Vauquelin, is quoted in Watts' Dictionary of Chemistry, vol. II., p. 363:—

Calcium carbonate	89·6
,, phosphate with a little magnesium phosphate ..	5·7
Animal matter containing sulphur	4·7
	100·0

In the Supplement to Watts' Dictionary, p. 549, the following analyses by W. Wicke, are also cited:

	Heron.	Gull.	Pheasant.	Goose.	Hen.	Duck.
Calcium carbonate	94·60	91·96	93·33	95·26	93·70	94·42
Magnesium ..	·69	·76	·66	·72	1·39	·50
Phosphates ..	·42	·83	1·37	·47	·76	·84
Organic substances	4·30	6·45	4·64	3·55	4·15	4·24