the twin-line is 5° . These observations agree precisely with Michel Lévy's results for oligoclase of composition $Ab_3 An_1$. The green mineral in this rock forms distinct slender rods and skeleton-crystals about 0.03 inch long, with occasionally a stouter crystal or pseudomorph. Most of it seems to be hornblende, but some is a feebly polarising chloritoid substance: possibly both represent an altered pyroxene. The specific gravity of this rock is 2.663.

Another specimen, richer in the green mineral [1757], gave 2.763, and yielded 59.8 per cent. of silica.¹ Oligoclase of composition $Ab_3 An_1$ has a specific gravity 2.659 (Tschermak) or less (Goldschmidt), and contains 61.9 per cent. of silica: the higher density and lower acidity of our rock is sufficiently accounted for by the considerable quantity of a ferro-magnesian mineral which it contains. A similar mineral occurs more richly in a six-inch dyke traversing the gabbro of Iron Crag [1881], and this rock has a specific gravity of 2.906. Here, however, the little feldspar-fibres have lost their radiate arrangement.

Readers familiar with British and foreign "variolites" will recognise in the preceding short descriptions features characteristic of those curious rocks, or perhaps more accurately features often found in intimate association with the more typical variolitic structures. But while such structures have usually been described in distinctly basic rocks, we have them here reproduced in rocks of intermediate chemical composition. Other veins and dykes in the neighbourhood are of thoroughly basic rocks, and if, as seems probable, the whole group had a common origin, we have here another problem in the differentiation of rock-magmas in this very interesting district.

V.—ON THE APPLICATION OF THE SAND-BLAST FOR THE DEVELOPMENT OF TRILOBITES.

By H. M. BERNARD, M.A., Cantab., F.L.S., F.Z.S.

MY endeavours to establish a genetic relationship between the Annelida and the Phyllopod Crustacean *Apus*² led me, very naturally, to the study of the Trilobites. Specimens were kindly lent me by Dr. Woodward, F.R.S., Prof. Judd, F.R.S., and by Prof. G. B. Howes, it being my privilege at the time to be working in the Huxley Research Laboratory, which is under his direction.

Picking at the fossil with a steel point taught me, what every worker soon finds out for himself, that the limbs which, under such a dorsal shield, would probably have been thin-walled structures, could not be differentiated from the matrix by any such method. Was there, then, no mechanical method of revealing the under-surface? At first I thought, among other things, of a stream of water, mixed with emery powder, forced through a rose; this idea

¹ This was kindly determined for me in the laboratory of the Yorkshire College of Science under the direction of Dr. J. B. Cohen.

² "The Apodidæ," *Nature Series*, 1892, and the *Systematic Position of the Trilobites*, *Quart. Journ. Geol. Soc.* August, 1894, Vol. L. pp. 411–432.

led, very naturally, to the sand-blast. A visit to the "London Sand-blast Works" (58A, Gray's Inn Road) gave some promise. The proprietor was kind enough to express interest in the idea, and showed me blocks of granite which had been treated with the sand-blast, and in which the harder elements stood out in good relief. A very short application of one of the sand-blasts belonging to the Works to the under-surface of a Trilobite from the soft Wenlock cleared away a large portion of the matrix, and revealed a small area of the under-surface of the carapace completely cleaned. In this specimen there was no trace of any under membrane having been cut through, and the carapace was probably the last remnant of a cast skin.

I then applied to Mr. W. I. Last, the keeper of the Machinery Division of the South Kensington Museum, for advice and assistance. He suggested several methods by which a constant stream of sand might be obtained, very kindly allowing me to make use of the air

Reproduction of drawing (on greatly reduced scale) to show Sand-blast Apparatus for developing fossils, invented by W. I. Last, Esq. (Keeper of the Machinery Division), Science and Art Museum, South Kensington.

pressure (about 5lbs to the square inch) by means of which the beautiful series of model engines in his charge are kept in motion or set working by the visitor on pressing a button. I take this opportunity of thanking Mr. Last very sincerely for the friendly assistance he rendered, for whatever is of value in this paper, viz. the description of the apparatus, is entirely due to him.

The sand was first thrown up from the bottom of a deep funnel by the air current rising in its base, always falling back again to

be again shot up. Under these circumstances it was not easy to manipulate the fossil, and the cutting action was not sufficient.

The sand was then allowed to run out through the funnel, which was connected by a short india-rubber tube with the nozzle of a blow-pipe apparatus. The air was forced through a small aperture just behind the feed, which, in this case, was sand instead of gas, and further, the aperture of the nozzle itself was narrowed by inserting a short piece of fine bore india-rubber tubing. The sand was shot out by this arrangement, with much greater velocity, but yet not with the highest possible, under the available pressure.

Enlarged section of part of Apparatus for developing fossils by means of the Sand-blast. Apparatus invented by W. I. Last, Esq. (Keeper of the Machinery Division), Science and Art Museum, South Kensington.

“The action, being partly due to induced currents, the amount of inert air carried along considerably reduced the velocity of the combined jet.” Various other difficulties also had to be contended with—the dispersal of the sand, the clouds of fine dust, and, again, the manipulation of the fossil.

The final method planned and carried out by Mr. Last was the most ingenious: in order to get still more force, the sand was confined in a large bottle, but instead of being drawn into the air stream as before, it was forced in by the air pressure within the

bottle. This happy device brought the whole available force of the air upon the sand, and its cutting action was much increased. Mr. Last has kindly furnished me with a couple of sketches explaining the apparatus as it was used. In the section, *a* represents the level of the sand, nearly run out; *b*, the feed-pipe; *c*, the tube carrying the air above the sand; at *d* is a wire ring which, by contracting the air passage between the two vertical pipes, secures a slight excess of pressure within the bottle. Without this excess of pressure the sand was not fed into the jet in sufficient quantity; *e* is the nozzle, formed by a piece of fine bore india-rubber tubing; *f* is the wire clip to keep the cork from being blown out.

A considerably larger bottle might have been used with advantage. The one figured only lasted about five minutes; although it was easily filled, yet, when there was much matrix to be cut away, it would have been more convenient had it lasted 15 to 20 minutes.

The fossil was embedded in paraffin, for convenience of manipulation and for the ready protection of exposed parts, the under-surface alone being exposed. It was then fixed in position by screw clips in front of the nozzle of the sand-blast, and the whole covered with a large glass shade, to prevent the dispersal of the sand. The shade stood on feet so as to allow the air to escape. Parts which at any moment required protection were covered with the paraffin by means of a hot knife or needle. Various other methods of protection were tried, such as collodion, india-rubber solution (this applied by a fine brush), strips of gum-paper, small cardboard screens, but none of them helped much.

Although I devoted many hours to the process, I was too busy with other things to be able in any way to exhaust the method; on the contrary, I did but make a beginning, and cannot, therefore, pretend to give a final judgment on its merits. At the same time, my experience of it, as far as it went, may not be without interest.

The differential action is not so great as I expected it would be, still it undoubtedly exists. Many times structures appeared which looked very like fragments of limbs. These I did not care to try to save. I was looking for a series of segmentally arranged processes which ought to appear in more or less regular rows on each side, hence single fragments were of little use to me. The interesting question unfortunately remains to be solved: "Had such rows of limbs come into view, would the sand-blast have differentiated them, or would it have cut them away together with the matrix?" My experience, as far as it goes, makes me believe that this would depend entirely upon the hardness of the matrix. In one partly rolled specimen (such specimens, inasmuch as they must have been complete animals when they rolled up, are the most hopeful to experiment with), I found with a pocket lens, a regular row of dots close under the lateral edge of the head-shield. I worked away the matrix, commencing near the middle line and working slowly outwards towards these points so as if possible to reveal the limbs along their lengths. As I suspected, the points were the tips of structures which were almost certainly limbs, but the matrix was

so hard, that no differential action was possible, and further, the faint ridge of darker material which represented the limb first revealed was too thin to protect with paraffin.

On the other hand, if the matrix is not very hard, the sand-blast would almost certainly differentiate fine structures, provided, of course, they were not exposed too long to the action of the sand. My final plan, therefore, was to work away till I discovered by means of the sand-blast the existence of a serial row of limbs in a specimen, and then to blast away the matrix on all sides of these limbs, even through the dorsal surface, always stopping as soon as they showed as ridges, and then to work in some other way to clear the limbs further. Unfortunately, I never found such a specimen, and believe that it would be very difficult to find. The rolled-up or partly rolled-up specimens get filled with a substance too hard for the sand-blast to yield any result, while the limbs of the open specimens were probably flattened down against the dorsal carapace into a tangled mass. I did not, however, give up hope that, if I could work long enough at it and had sufficient material, the sand-blast would reveal something worth finding, if not a complete series of limbs. As above stated, many mysterious fragments and membranes appeared which kept me for a few days or hours in a state of tension. For instance, a fragment of the ventral membrane was very clearly shown in one specimen (figured in the paper above quoted).

The absence of nearly all tangible result from my own researches need deter no one from repeating the attempt. It must be remembered that a very large portion of the time I devoted to it was given to getting an apparatus which would work, and then when this was overcome by the mechanical skill and kindly assistance of my friend Mr. Last, other and more pressing duties called me away, so that on the whole I did not apply the method to more than six specimens in all. From every one of them I think I learned something, and I firmly believe that if anyone with more leisure and sufficient material would repeat the attempt, he would sooner or later certainly be rewarded. We have not by any means exhausted all that could be learned from a study of the inner surface of the dorsal shell, which the sand-blast is well able to clear out. In these cases, it is well to take care that the carapace is firmly bound together by strips of gum-paper, or by embedding in paraffin, otherwise it is very likely to fall to pieces as soon as the matrix is removed.

It may be said, in conclusion, that when the matrix is soft as compared with the fossil—and this would apply to all fossils—the sand-blast cleans the objects very beautifully, and for this alone, as an accessory method of investigation, it might be of great use to palæontologists. It is only with great regret that I have felt myself compelled, on account of other duties, to drop this method of investigation, and I hope that some one with sufficient leisure and opportunity will be tempted to carry it on.