of the alveolus, whilst the extent of the uncalcified part increased with each successive layer, but less rapidly than in the typical form, then the removal of the uncalcified portion during fossilization would produce a guard having a more or less funnel-shaped alveolar end (Fig. *c*), of which the apical or posterior portion only would form part of the alveolus, whilst the anterior part of the cavity would have a greater angle than that of the alveolus or of the phragmocone. This form of alveolar end is illustrated by *A. quadratus*.¹

It may also be noted that the alveolar end is frequently less dense and more friable than the rest of the guard, having probably been originally less perfectly calcified; it is therefore easily broken, causing the alveolar end to present the foliaceous appearance by no means uncommonly found in *A. quadratus*.

It would therefore seem that during the progress of development calcification of the alveolar end extended further and further forward, producing a progressive deepening of the alveolar cavity. This course of development is indicated also by the observations of Dr. Rowe,² who points out that in the examples which he refers to *A. granulatus* there is a progressive deepening of the alveolar cavity as the Belemnite ascends in the zone.

VI.—THE DESCRIPTIVE NOMENCLATURE OF RIPPLE-MARK.

By A. R. HUNT, M.A., F.G.S.

OVER twenty years ago, in 1882, I ventured to controvert a doctrine which was at the time maintained with remarkable unanimity by all geologists, and which was taught in all the current textbooks. It was that the ordinary ripple-mark of the seashore was formed by continuous water-currents of some kind; the current of water taking the place and performing the office of the current of wind which ripples the surface of sand-dunes.

As it was a question of authority and textbooks I ventured to join issue with those of perhaps the greatest weight, viz., the series of which several editions were published by Mr. Jukes and Sir Archibald Geikie. I stated my thesis, and the object of my paper, in the following plain words:—

“I shall endeavour in the present paper to prove that ripple-marks formed under water are, as a rule, completely independent of the rise and fall of tides, of tidal currents, and of sea beaches; and that they have little in common with the current-mark, that owes its origin to a continuous current of air or of water” (Proc. Roy. Soc., 1882, p. 2).

¹ This is the type-species of Bayle's *Gonioteuthis*. Explication de la carte géologique de la France, publiée par ordre de M. le Ministre des travaux publics, Tome quatrième, Atlas, Première partie—Fossiles principaux des terrains, E. Bayle, 1878, pl. xxiii, figs. 6–8.

² Proc. Geol. Assoc., vol. xviii, pt. 4 (1904), p. 271, fig. 12.

In my recapitulation I wrote, "Marine ripple-marks are formed by alternate currents set up by waves" (Proc. Roy. Soc., 1882, p. 18).

In 1883 three very important papers were published on the subject by MM. De Candolle and Forel and by Professor G. H. Darwin, F.R.S. Thus, in March, 1884, less than two years after the publication of my own pioneer paper, I was able in a paper on Sea Beaches and Sea Bottoms to direct the attention of students of wave-action to the three important papers referred to above, and also to some earlier observations of Professor Forel published in the *Bulletin de la Société Vaudoise*, etc., for February and March, 1878. The last-named publications give Prof. Forel the right of priority so far as wave-current ripple-mark is concerned.

Professor Darwin went further than any previous experimenter by demonstrating the action of eddies and vortices in collecting loose sand into ripple-mark, as soon as the incipient ripple-marks are established. Previous observers had indicated the agents, viz. wave-currents, but Professor Darwin demonstrated their mode of action.

As soon as the above papers appeared Sir Archibald Geikie allowed them their full weight, as will appear by a comparison of the third and fourth editions of his textbook with earlier works. For instance, to be as brief as possible, in the Manual of 1872 (Jukes & Geikie) we read:—Ripple-mark "is produced on the sea-beach . . . because of the moving current of water as the tide advances or recedes" (p. 192).

In Sir Archibald's first edition of his Textbook we read:—"Water (or air) gently agitated in a given direction [*italics mine*] throws the surface of sediment into ripples. . . . Their general direction . . . suffices to indicate the quarter whence the chief movement of the water has come" (p. 483).

In the Textbooks of 1893 and 1903 there is a complete revolution. We now read: "They have been produced by an oscillation of the medium (water or air) in which the loose sand has lain. In water an oscillatory movement, sometimes also with a more or less marked current, is generated by wind blowing on its surface. The sand grains are carried backwards and forwards. By degrees inequalities of surface are produced which give rise to vortices in the water. . . . In regular ripple-mark the forms are produced by water oscillating relatively to the bottom and the consequent establishment of a series of vortices."

No one without a minute study of ripple-mark could appreciate the extreme accuracy of phraseology and description in the above few lines. I may, however, remark that the 'alternate currents,' for which I contended single-handed in 1882, are the actual currents in opposite directions set up by waves, and not the reversal of the direction of a steady current of wind or water created locally by vortices.

I need scarcely express my deep sense of gratitude to Sir Archibald Geikie for having so promptly recognised the importance of very unorthodox doctrines at a time when it was almost impossible to obtain a patient hearing for them in England.

In the present article I propose to call attention to the extreme ambiguity of the phraseology in common use in the discussion of sand-ripples and cognate phenomena.

With reference to the meaning of 'breadth' and 'amplitude' a distinguished mathematician writes, "I cannot regard these questions of phraseology of much importance." It no doubt matters nothing when the ideas are clear, but I feel sure that inaccurate or inadequate terms, and especially when they are avowedly descriptive terms, must end in confusion of thought.

In the case of 'ripple-mark,' Sir Archibald Geikie summarily disposes of the difficulty by rejecting all such expressions as 'current-mark' and 'ripple-drift,' which, though accurate as far as they go, are calculated to mislead. Both expressions might lead the reader to suppose that ripple-mark can only be produced by the drifting action of a continuous current of air or water, whereas current-mark and ripple-drift might well be regarded as specific forms of the genus ripple-mark.

The foregoing three terms, together with 'wave-marks' as used by Dana, are a truly misleading quartette. 'Ripple-marks' are collections of sand in the form of water-ripples. There is no pretence that they are made by water-ripples. But current-mark, a completely parallel expression, professes to describe collections of sand in the form of ripples made by a current. The 'current' here is avowedly the agent, whereas the 'ripple' is merely the illustration of the effect. In Dana's 'wave-marks,' an expression even more closely allied to 'ripple-marks,' the 'wave' is the agent and not merely the illustration. In 'ripple-drift' we have a still further element of confusion, as here 'ripple' is not the illustration, but has come to mean the actual sand, which has been collected in ripple-like forms by drifting.

'Wave-mark' would be an excellent term descriptive of ordinary marine ripple-mark were it not that 'wave' would indicate the agent, whereas 'ripple,' which is no more than a small wave, would be used in an entirely different sense. Moreover, Dana has used 'wave-marks' for a very unimportant marine phenomenon, viz., the faint mark which is very occasionally left by a wave on a sandy beach.

If ripple-marks and waves are to be subjects of discussion, it is absolutely necessary that some definite meaning should be attached to descriptive terms such as height, length, breadth, and amplitude.

We will now inquire how these terms are actually used in the case of real waves.

What do we understand by the height of a sea-wave? A sailor undoubtedly measures height from trough to crest. For instance, in October, 1887, the Admiralty communicated to the Press a letter from Captain Fisher descriptive of a voyage of the battleship "Inflexible." He mentioned that "the waves were occasionally twenty-four feet high and three hundred feet in length." This height is obviously from trough to crest, and even so, very high for the wave-length.

Physicists, on the other hand, regard height as from mean water-level to crest, unless the height from trough to crest is distinctly stated. In a letter to me in 1884, the late Professor G. G. Stokes refers to "the elevation or depression above or below mean level"; and again, "Taking it [the wave] as eight feet above or below mean level in the shoal, sixteen feet from crest to trough in all" (Trans. Devon Assoc., vol. xix, pp. 513, 514). Yet in the paper to which Professor Stokes' letter was appended, I, from force of habit, whenever I used the term height, referred to height from trough to crest. The one measurement is of course treated as being exactly double the other, though it is not necessarily so with breakers in shallow water.

What is understood by the 'length' of a wave? In the case of sea-waves, which are fairly uniform in size at the same time, English writers mean by 'length' the distance from crest to crest. If, however, we have to regard a wave as isolated, it has then but one crest, and we may treat the total length as the length of the elevated water added to the length of the depressed water, both at the level of repose of the water. What, then, is understood by the 'breadth' of a wave? This is a term rarely met with, but would probably mean the extent of a wave measured along its crest. We now come to 'amplitude.' What is the amplitude of a wave? So far as I am aware, 'amplitude' with physicists is always connected with the idea of motion, the amplitude of a wave of ether, air, or water being regarded as the extent of the oscillation or vibration of the medium, caused by the passage of a wave.

In the course of my correspondence with Lord Rayleigh and Sir G. G. Stokes on the question of sea-waves, although both those eminent physicists supplied me with much information, I do not remember a single instance of their use of the term amplitude. If used for 'height' it would be redundant, and for shore-breakers inaccurate, as in shallow water the crests contract in length, and the height of the wave from trough to crest greatly exceeds the relative height in deep water, where it is equal to the amplitude of vibration of the water itself. The increasing height of the shortening crest came out clearly in tank experiments.

We note, then, that even in the well-studied case of sea-waves, which are real waves, we have to be careful that we do not confound the height from mean level with the height from trough, and that we do not confound amplitude with either of those terms.

A difficulty has arisen owing to the indiscriminate application of the simple terms height, length, and amplitude (which in the case of true waves are technical terms with stereotyped meanings) to forms which simulate waves, such as ripple-mark, snowdrifts, and even mountains and valleys. And even so, the terms are not always used in the same sense by different authors. It is always necessary to ascertain the exact meaning of each author.

Professor Forel, in describing his ripples and experiments, speaks of the 'longeur' of his tank, and of the 'hauteur' and 'largeur' of his ripple-mark, but strictly limits 'amplitude' to the extent of the

water-oscillation which forms the ripple-mark. What to an English observer is the crest to crest *length* of ripples, is to Professor Forel their 'largeur' or 'breadth.'

Professor Darwin speaks of a "rotational oscillation with a jerking motion of small amplitude";¹ of the height of ripples, and of the 'wave-length' of ripples. With him also 'amplitude' expresses the idea of motion.

Ripple-marks so closely imitate in form motionless water-ripples (such as may be seen in a sharp current) that it is most natural to describe them by the phraseology used for true waves, such as 'height' and 'wave-length.' But even here we do well to remember that the height of a sand-ripple can never be synonymous with the height of a water-ripple, since the latter is referred to the level of repose of the water. The sand-ripple reposes corrugated as comfortably as it does flat. In fact, the height of ripple-mark is from trough to crest, and therefore does not even correspond with the 'height' of water-ripple, which is from crest to mean level.

In 1900 I was nominated by Section C a member of a joint committee with Section E to investigate 'Terrestrial Surface Waves.' I was reluctant to accept the nomination, which had been made in my absence, because, as I at once pointed out, I could see no geological bearing in the subject, which related in the first place to snow phenomena, and I knew nothing about it. On receipt of the first report I found that I was quite uncertain as to the meaning attached by the committee to the technical terms used in describing the dimensions of snowdrifts. In fact, I might go further, as I do not understand the terms used to describe the object of the committee's researches, viz. 'terrestrial surface waves.' I found that both snowdrifts and snow-ripples were described exactly as though they were real waves, and not merely wave-like forms. The following quotation will indicate my difficulty:—

"The height of these waves [of snow] was generally not more than six inches. They are flatter than the homologous æolian sand ripples, the wave-lengths being often forty or fifty times the amplitude. . . . There are also regularly undulating surfaces carved by the wind in more coherent snow . . . it is proposed to call them *undulates*" (Rep. Brit. Assoc., 1901, p. 398).

It will be observed that the geographers have captured the entire wave-nomenclature, e.g., ripples, wave-length, height, amplitude, and undulating. If we refer to Murray's Dictionary we shall find that the primary meaning of amplitude is width or breadth; that its astronomical meaning is angular distance; and that its physical meaning is the vibration of a particle. With regard to the word 'undulating,' we have Pope's line "Through undulating air the sounds are sent." The geographical and geological use of 'amplitude' to express height forces the word into a meaning in direct conflict with both its ordinary use and its derivation. Professor Lapworth, in his address to Section C, points out that the form of the "wave or fold of the geologist resembles that of the

¹ Proc. Roy. Soc., 1883, p. 2.

wave of the physicist, as also does the form of the surface-wave of the geographer" (Rep. Brit. Assoc., 1892, p. 701). No doubt geographers and geologists have as much right to the dictionary as physicists, but in the present case, the investigation of ripple-mark, the result is inconvenient for the following reason, viz., that as it is now admitted that marine ripple-mark is to a great extent made by waves, if we attempt to discuss the formation of ripple-mark in any detail the waves will require their own terminology for their own use.

The following incident illustrates the importance of exact phraseology. My Ripple-mark paper, though promoted to the rank of a much cited authority, survived eighteen years scatheless, until in 1900 my friend Dr. Vaughan Cornish stated in Section C that an error therein had misled German students. I was not surprised at the detection of an error, but at its having escaped so long. I pointed out that the alleged error was in a quotation. Dr. Cornish replied that I was held responsible for it. On referring to Professor Forel's paper I noted that he had actually quoted the censured passage, but only on the authority of its author, the Rev. John Gilmore, as cited by me. The passage had clearly not misled Prof. Forel, nor did he hold me responsible for it. What, then, had misled the German students? It was simply this. The Rev. John Gilmore, in describing the struggles of the lifeboat men on the Goodwin Sands, wrote, "The heavy seas have driven the sands into high ridges, and the gullies between these are waist-deep and full of running water with the sand soft and quick at the bottom." And again, "On the Goodwins where . . . the waves break and the tide rushes with tenfold power, the little sand ripples of the smoother shore become ridges of two or three feet high." In referring to these ridges and gullies made by "heavy seas" and rushing tides in quicksands, I used the expression 'wave-marks,' carefully avoiding the technical term 'ripple-mark.' But, alas! I was unaware that the German equivalent for ripple-mark is 'wellenfurschen,' or wave-furrows, so the German students must naturally have concluded that when I described ridges and gullies as 'wave-marks' I meant to describe their own German wave-furrows, which are no more than the ordinary English ripple-mark and Professor Forel's 'rides du fond,' otherwise wrinkles on the bottom. I was unaware that Dana had previously appropriated the term 'wave-marks' for another purpose. No doubt it would have been more accurate to have described the ridges and gullies on the Goodwins as wave-and-tidal-current-marks; but the quotation of a record of a fact, far too valuable to lose, could not have misled experimentalists, and in fact did not do so.

It is by no means always easy to distinguish offhand true ripple-mark from corrugations in fine-grained rocks caused by pressure, and in a well-known case at the east end of Meadfoot Sands, Torquay, the evidence is conflicting. If only a squeeze it is a remarkably good imitation of the genuine article. If genuine, and a case of ripple-mark complicated by pressure in finest grits associated with slates, it is interesting as occurring in the Lower

Devonian rocks without a trace of shallow-water conditions. Associated with these corrugated rocks there is a band of some inches of badly preserved shells suggestive of some great destruction of the submarine fauna; what Gwyn Jeffreys would have described in modern seas as a charnel-house of shells. The currents were clearly sharp, but transitory, as the grit and slate beds are not confused, and the thickness of the shell band very regular. The corrugations are symmetrical, so must be wave-formed and not continuous current-formed, that is, if they are ripple-mark at all. Now in considering such a case as this we have to realise the presence of waves heavy enough to disturb depths at which fine silt and mud can accumulate. This depth, disturbed only on rare occasions, will depend on the height (crest to trough) of the waves. The amplitude of the reciprocating currents over the bottom will depend on the height (crest to trough) of the waves and the depth of the water, while the number per minute of the double currents, or their frequency, will depend on the period of the waves. Now the technical terms required for this description are height (crest to trough), length, amplitude, period, and frequency. The terms height and length will apply to ripple-marks equally well; but with amplitude, period, and frequency ripple-marks have nothing to do. If we use amplitude for the height of a ripple-mark we use a stereotyped wave-term in a different sense; while, if we use the term wave-length for the ripples, our thoughts are at once directed to the true waves which formed them, waves which really possessed wave-length, which the ripple-marks only possess by courtesy.

My own work in ripple-mark, which was undertaken solely to establish the doctrine of alternate wave-currents, received its full fruition when Sir Archibald Geikie accepted the doctrine of the "oscillation of the medium" in his textbook of 1893. That fact accepted, all the rest, the interesting consequences, must follow in time. But they will follow sooner if we can avoid confusion of ideas being perpetuated by ambiguous and even conflicting nomenclature. Were this a paper on ripple-mark itself it would be easy to run through the great textbooks and manuals and indicate where the different authors have followed the wrong trail. I will, however, quote one very useful and popular dictionary of scientific terms. In Webster's Dictionary, ed. 1876, we read, "Ripple-mark. (Geol.) A mark on the surface of a rock resembling that made by receding waves on a sea beach." Now waves on a falling tide have often effaced ripple-marks on the flats of a sea beach, but have never created them. The efficacy, or even the existence, of a *receding* wave is as imaginary as that of the efficacy of the advancing or receding tide, moving towards or from the shore at the rate of a few hundred feet or less in some six hours. The wave has ceased to exist before any water recedes from off the beach.

So far as I am aware, no paper on ripple-mark has appeared in any geological publication since Dr. Sorby's "Structures produced by the Currents, etc.," in the *Geologist* in 1859. The literature is scattered far and wide. Sir Archibald Geikie has given the

references to the papers of Messrs. Sorby, De Candolle, Forel, and Darwin. To these I would add the shrewd observations of that king among observers, De la Beche, in his "Geological Observer," and several papers by Dr. Vaughan Cornish in the publications of the Geographical Society which have appeared since I retired from the fray.

In May, 1903, I concluded a paper on Vein Quartz with a quotation from a letter written by Dr. Sorby in 1889—"There are many things connected with it [granite] about which we know much less than is desirable." Let me conclude this paper with the last few lines of the same author's 1859 paper on the "Structures produced by Currents": "Those [experiments] which I have made already, though not nearly sufficient to clear up many highly important questions, are still sufficient to give very great encouragement; and I therefore feel anxious to induce others to turn their attention to this branch of research, being convinced that it cannot but yield a bountiful harvest of fact when studied with perseverance and zeal." To this conviction, now forty-five years old, we may still add our fervent *Amens*.

P.S.—Since the above was written, I received, on the 1st of July, *Nature* for June 30th, and Dr. Nansen's "Bathymetrical Features of the North Polar Seas," etc. Dr. Nansen observes (p. 137), "ripple-marks, however, are not merely formed by waves, but also by currents." *Nature*, referring to experiments made by Mr. F. Ayrton at the Royal Society conversazione, asserts, with the emphasis of italics, "It was also shown that ripples are *not* produced by a *steady* current of water flowing over sand." Dr. Vaughan Cornish writes: "The true current-formed sand-wave I find to be produced as soon as the velocity of the stream causes the water to be turbid with a heavy charge of sand in eddying suspension. The process can be watched in the shallow streams of sandy tidal foreshores" (*Geographical Journal*, August, 1901, p. 198). I have noticed this result myself.

In the same paper (p. 200) Dr. Cornish writes, "Professor Osborne Reynolds found that in his model estuaries the ripples 'formed by the alternating action of the tide' had a wave-length equal to twelve times their amplitude ($4 = 12 H$)."

If Professor Reynolds used the terms wave-length and amplitude I should have to retire discomfited, as I had the honour to serve on his committee; but I find that what Professor Reynolds wrote was, "Some of the ripples were from hollow to crest as much as one-fourth the mean-rise of the tide, the distance between them being twelve times their height" (*Rep. Brit. Assoc.*, 1889, p. 343). Professor Reynolds avoids the technical wave terms.

The apparent contradictions of writers on ripple-mark are so surprising that one fails to see how the student, or even the text-book writer, can find his way through the mist. However, the contradictions are easily explained, as there are several ways of producing rippled sand-surfaces. If not trespassing too much on

the patience of the readers of the GEOLOGICAL MAGAZINE I should like some day to make an attempt to show how the trick is done, and how ripple-mark concerns geologists, not as a mere unimportant detail of rock-structure, but as an important factor and index in the great problem of marine erosion. In the meantime I may refer to Dr. Nansen's admirable epitome of the evidence of marine erosion in his work above referred to, and also to Dr. Cornish's papers in the Geographical Journal.

VII.—CONTRIBUTIONS TO THE GEOLOGY OF CEYLON :

III. THE BALANGODA GROUP.

By A. K. COOMÁRASWÁMY, B.Sc., F.L.S., F.G.S., Director of the Mineralogical Survey of Ceylon.

THE name 'Balangoda group' is proposed for a series of granitic and pegmatite-like rocks, intrusive in, but distinct from, the Charnockite series; first met with in the Balangoda district, but evidently widely distributed over a large area between Balangoda and Hatton. The rocks are best described as granites, but occur most often in rather narrow dykes, after the manner of pegmatites. Yet there is no reason for separating the smaller from the larger masses, and the term granite is applied to both. The group (of which a more detailed account will ultimately be needed) includes in particular zircon granite, allanite granite, magnetite granite, and granite without conspicuous accessory minerals; as well as the probably similar rocks in which the hitherto unlocated minerals geikielite, baddeleyite, rutile, fergusonite, thorite,¹ thorianite, etc., may be looked for; and the vein of pegmatite at Gampola, which consisted of quartz, feldspars, and biotite, with apatite, ilmenite, tourmaline, and the new mineral described as thorianite² as accessory minerals.

These granites are intrusive in the Charnockite series, and though frequently occurring in lenticular masses (Denagama) with a disposition parallel to that of the foliation planes of the charnockites, have often been observed to transgress these foliation planes and to behave as intrusive rocks. Contact phenomena have not, however, been observed, except perhaps in a slight tendency to a peripheral fineness of grain in the intrusive rocks. At the junctions granite and charnockite are usually welded together, there being no absolutely hard line of separation, although the junction may be called sharp; in the case of the larger masses no good junctions have been seen.

A description of the rocks is given below, with special reference to the localities where they can be seen :—

Zircon granite.—This rock was seen *in situ* at several points, and is the best known member of the group. The finest and longest exposure is on Massena estate, six miles from Balangoda; here a considerable mass of granite, fully two miles in length and

¹ W. Dunstan, *Nature*, 1904, p. 510.

² "Spolia Zeylanica," vol. i, pt. 4 (1904), p. 112; and *Nature*, loc. cit.