ASTRONOMICAL PHENOMENA FOR THE WEEK 1889 *JANUARY* 6-12.

(FOR the reckoning of time the civil day, commencing at Greenwich mean midnight, counting the hours on to 24, is here employed.)

At Greenwich on January 6

Sun rises, 8h. 7m.; souths, 12h. 6m. 17·2s.; sets, 16h. 6m.: right asc. on meridian, 19h. 11·3m.; decl. 22° 26′ S. Sidereal Time at Sunset, 23h. 12m.

Moon (at First Quarter January 9, 1h.) rises, 11h. 2m.; souths 16h. 22m.; sets, 21h. 53m.: right asc. on meridian, 23h. 27·9m.; decl. 8° 22′ S.

Planet.	Rises.	Souths.	Sets.	Right asc. and declination on meridian.	
	h. m.	h. m.	h. m.	h. m.	° ′
Mercury..	8 39	12 30	16 21	19 35·5	23 46 S.
Venus.....	10 7	15 2	19 57	22 7·2	13 15 S.
Mars......	10 0	14 55	19 50	22 1·0	13 16 S.
Jupiter....	6 32	10 28	14 24	17 32·8	22 56 S.
Saturn....	18 55*	2 24	9 53	9 27·8	16 6 N.
Uranus...	0 54	6 17	11 40	13 21·6	7 55 S.
Neptune..	13 2	20 45	4 28*	3 52·0	18 27 N.

* Indicates that the rising is that of the preceding evening and the setting that of the following morning.

Saturn, January 6.—Outer major axis of outer ring = 45″·1: outer minor axis of outer ring = 11″·0: southern surface visible.

Variable Stars.

Star.	R.A. (1889·0)	Decl. (1889·0)			
	h. m.	° ′		h. m.	
U Cephei	0 52·5	81 17 N.	Jan. 8,	21 53	*m*
R Tauri	4 22·3	9 55 N.	,, 9,		*M*
ζ Geminorum	6 57·5	20 44 N.	,, 7,	19 0	*m*
			,, 12,	19 0	*M*
R Canis Majoris	7 14·5	16 11 S.	,, 11,	18 10	*m*
			,, 12,	21 26	*m*
U Geminorum	7 48·5	22 18 N.	,, 10,		*M*
X Boötis	14 18·9	16 50 N.	,, 7,		*m*
U Boötis	14 49·2	18 9 N.	,, 9,		*m*
δ Libræ	14 55·1	8 5 S.	,, 12,	22 53	*m*
R Herculis	16 1·2	18 40 N.	,, 10,		*M*
U Ophiuchi	17 10·9	1 20 N.	,, 11,	4 58	*m*
β Lyræ	18 46·0	33 14 N.	,, 12,	6 0	*M*
R Aquilæ	19 0·0	8 4 N.	,, 6,		*M*
T Vulpeculæ	20 46·8	27 50 N.	,, 8,	20 0	*M*
			,, 12,	4 0	*m*
Y Cygni	20 47·6	34 14 N.	,, 6,	5 40	*m*
		and at intervals of		36 0	
δ Cephei	22 25·0	57 51 N.	Jan. 7,	2 0	*M*
			,, 10,	20 0	*m*
S Aquarii	22 51·3	20 56 S.	,, 7,		*M*

M signifies maximum; *m* minimum.

Meteor-Showers.

	R.A.	Decl.	
Near ξ Virginis	173°	9° N.	Swift; streaks. January 11.
,, ζ Boötis	218	14 N.	Very swift; streaks.
,, β Boötis	222	42 N.	,, ,,

NOTES ON METEORITES.[1]

VII.

Possible Connection between the Jets and Envelopes seen in Cometary Swarms.

THE jets observed in comets when near the sun are very various in form. The concentric envelopes seen at times are much more regular; an idea of their appearance will be gathered from the accompanying illustration of Donati's comet.

It has not yet been clearly ascertained whether the jets and envelopes are connected phenomena—that is, whether the jets are true whirls of the meteorites themselves—or whether they represent volatilization of the vapours of the nucleus in a particular direction, which vapours subsequently assume a concentric form. In Halley's comet, at all events, this was not

Fig. 21.—Concentric envelopes as illustrated by Donati's comet.

observed. Sir John Herschel writes concerning this: "The bright smoke of the jets, however, never seems to be able to get far out towards the sun, but always to be driven back and forced into the tail, as if by the action of a violent wind rolling against them—always from the sun—so as to make it clear that this tail is neither more nor less than the accumulation of this

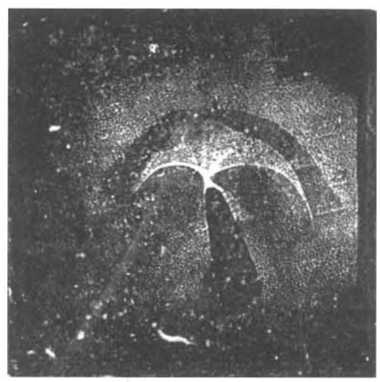

Fig. 22.—Combination of jets and envelopes (comet of 1861).

sort of luminous vapour, darted off in the first instance towards the sun, as if something raised it up, as if it were exploded by the sun's heat, out of the kernel, and then immediately and forcibly turned back and repelled from the sun."

The Concentric and Excentric Envelopes.

While in Donati's comet we get perhaps the finest exhibition of concentric envelopes successively thrown off from the nucleus towards the sun, in Coggia's comet, on the other hand, we had the most striking instance which has been yet observed in which the envelopes put on an appearance as if they belonged to two different systems of concentric envelopes cutting each other.

It is important here to enter into some details. In Coggia's comet (as observed with Mr. Newall's 25-inch refractor, with a low power), next to the nucleus the most brilliant feature was an object resembling a fan opened out some 160°. The nucleus, marvellously small and definite, was situated a little to the left of the pin of the fan—not exactly, that is, at the point held in the hand. If this comet, outside the circular outline of the fan, offered indications of other similar concentric circular outlines, astronomers would have recognized in it a

[1] Continued from p. 142.

great similarity to Donati's comet with its "concentric envelopes." But it did not do so. Envelopes there undoubtedly were, but instead of being concentric they were excentric, and of an entirely unique arrangement.

To give an idea of the appearance presented by these excentric envelopes, still referring to the fan, let us imagine a circle to be struck from the left-hand corner with the right-hand corner as a centre, and make the arc a little longer than the arc of the fan. Do the same with the right-hand corner. Then with a gentle curve connect the end of each arc with a point in the arc of the fan half-way between the centre and the nearest corner. If these complicated operations have been properly performed, the reader will have superadded to the fan two ear-like things (as of an owl), one on each side. Such "ears," as we may for convenience call them, were to be observed in the comet, and they at times were but little dimmer than the fan. It will be observed that there is a central depression between the ears.

At first it looked as if these ears were the parts of the head furthest from the nucleus in advance along the comet's axis, but careful scrutiny revealed, still further forwards, a cloudy mass, the outer surface of which was convex, while the contour of the inner surface exactly fitted the outer outline of the ears and the intervening depression. This mass was at times so faint as to be almost invisible. But at other times it was brighter than all the other details of the comet which remain to be described, now that I have sketched the groundwork. Occasionally to be seen outside all was still another fainter mass, both the surfaces of which were convex outwards, the inner one having a greater radius. This exterior envelope or "umhullung" was the faintest part of the head.

In the root of the excessively complex tail were to be observed prolongations of all the curves to which I have referred. Thus, behind the brightest nucleus was a region of darkness which opened out 45° or 60°, the left-hand boundary of which was a continuation of the lower curve of the right ear. All the boundaries of the several different shells which showed themselves, not in the head in front of the fan, but in the root of the tail behind the nucleus, were continuous in this way—the boundary of an interior shell on one side of the axis bent over in the head

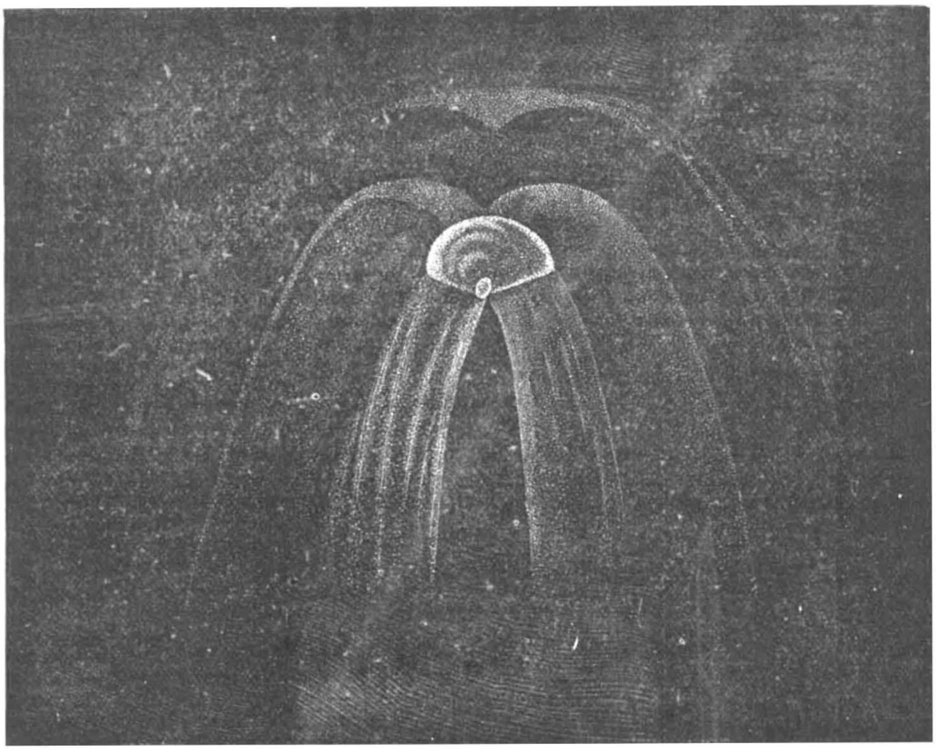

FIG. 23.—Rough outline sketch of head and envelopes of Coggia's comet as seen in Mr. Newall's 25-inch refractor on the night of July 12, 1874 (perihelion passage, August 27).

to form the boundary of an exterior shell on the other side of the axis.

I next draw attention to the kind of change observed. To speak in the most general terms, any great change in one "ear" was counterbalanced by a change of an opposite character in the other; so that, when one ear was thinned or elongated, the other widened; when one was dim, the other was bright; when one was more "pricked" than usual, the other at times appeared to lie more along the curve of the fan and to form part of it. Another kind of change was in the fan itself, especially in the regularity of its curved outline and in the manner in which the straight sides of it were obliterated altogether by light, as it were, streaming down into the tail.

There was nothing which in the slightest degree resembled the giving off of vapour.

The only constant feature in the comet was the exquisitely soft darkness of the region extending for some little distance behind the nucleus. Further behind, where the envelopes, the prolongation of which formed the tail, were less marked, the delicate veil which was over even the darkest portion became less delicate, and all the features were merged into a mere luminous haze. Here all structure, if it existed, was non-recognizable, in striking contrast with the region round and immediately behind the fan.

Next, it has to be borne in mind that the telescopic object is, after all, only a projection, from which the true figure has to be built up, and it is when this is attempted that the unique character of this comet becomes apparent. There were no jets, there were no concentric envelopes; but, in place of the latter, excentric envelopes indicated by the ears and their strange backward curvings, and possibly also by the fan itself.

It seems impossible that we can be here dealing with the mere volatilization of the materials of which the nucleus is composed; for, assuming that it is possible, as has hitherto been imagined, that shells of vapours can be thrown off to form concentric envelopes, and that the heads of comets like Donati's are thus built up, it is difficult at first to see how such appearances as here described could be thus produced.

On the Forces which produce the Various Forms and Parts of Comets.

Before we proceed further with any detailed description, it is necessary to inquire into the causes of the cometary phenomena with which we have so far become acquainted—namely, nucleus, jets, envelopes concentric and excentric, and tails.

We shall best do this by referring to the various memoirs with which Roche, of Montpellier, has enriched science. He dealt first with the atmospheres of planets; and, in concluding the third part of a memoir on the figure of a fluid mass subjected to the attraction of a distant point,[1] remarked that the inquiry might possibly apply to the theory of comets, if we suppose such an object, fluid and homogeneous, falling in a straight line towards the sun.

We have seen that a comet when it first makes it appearance at its greatest distance puts on a form resembling a planetary nebula. It is at this point that M. Roche closes with it in order to see what its change of form must be supposing it to be as above stated fluid and homogeneous.

As it approaches the sun, a tidal action will be set up, as the solar attraction will be greater on the particles nearest to it; hence there will be an elongation of the swarm, and possibly even one or more separations along a radius vector.

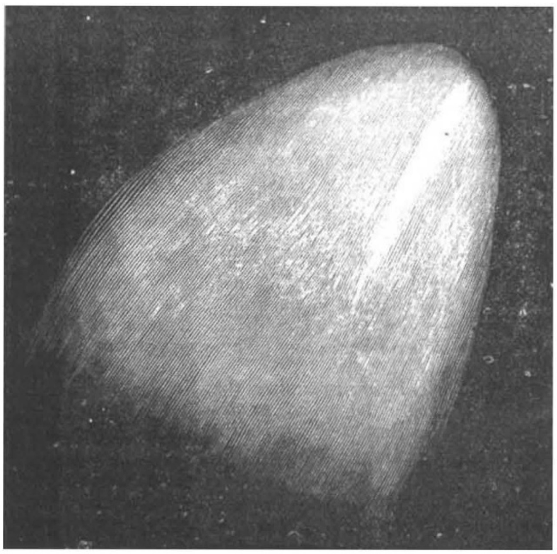

Fig. 24.—Elongation of a cometary swarm. Comet 1882 *b*, Washington equatorial.

If gravitation alone is concerned, the comet will remain symmetrical, it will reduce its size as it approaches the sun,[2] and part of its outer portions will be successively lost along the radius vector both towards and away from the sun; there, in fact, will be two outpouring streams—one directed towards the sun, the other away from it. There will be the greatest elongation and the greatest loss at perihelion.

M. Roche makes this out by considering the form of the envelope in which particles will be equally attracted by the sun and the general mass of the comet.

One chief point of the mathematical investigations was, in fact, to determine the surface on which the gravity of a small particle was *nil* in consequence of the solar and cometary attractions. This is called the limiting surface. On this point I quote from M. Faye:—[3]

"There exists, for every body placed within the sphere of action of our sun, a surface limit beyond which its matter may not pass, under pain of escaping to that body and falling within the domain of the solar action. This surface limit depends on two things—the mass of the body, and its distance from the sun. For a planet like the earth, whose mass is so considerable, this surface limit is very distant, and yet, within the still terrestrial region of its satellite, the moon, a child could lift, without much difficulty, a body which would weigh for us 36,000 kilogrammes, so feeble does the attraction of our globe become at that distance of 60 terrestrial radii. A little beyond the lunar orbit, a body would cease to belong to the earth, and would enter the exclusive domain of the sun. But for a comet this surface limit is much nearer the nucleus, and, moreover, it draws nearer and nearer in proportion as the comet approaches the sun. . . . The surface which so limits a body in the vicinity of the sun presents two singular points in the direction of the radius vector, setting out from which this surface is widened out into a conical network, in such a manner that the dissolution of a body the matter of which reaches or passes beyond these boundaries is effected principally in the vicinity of the points referred to, flying, so to speak, into two pieces, thus obeying at once the attraction of the comet and especially, the thenceforth preponderating attraction of the sun. . . .

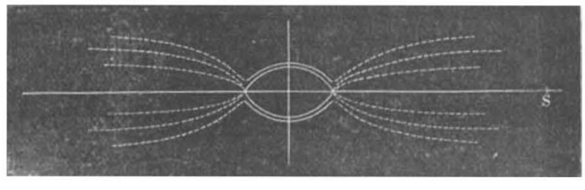

Fig. 25.—Showing how a comet approaching the sun, gravity alone being in question, loses its constituent particles beyond its free surface, which is constantly diminishing, by an outflow in both directions along the radius vector.

"All the conditions of instability are found united in comets. Their mass is extremely small, and, consequently, the surface limit is very near the centre of gravity. Their distance from the sun diminishes rapidly in the descending branch of their trajectory; consequently this surface limit becomes more and more contracted. Finally, their enormous volume tends unceasingly to dilate, because of the increasing heat of the sun, and to cause the cometary matter to shoot out beyond this surface limit.

"What becomes of this matter after it is set free by the action of the sun? Having escaped from that of the comet, it will none the less preserve the original speed, *i.e.* the speed which the comet itself had at the moment of separation; this speed will scarcely be altered by the feeble attraction of the cometary nucleus, or by the internal movements of which I have spoken, since these are measured by a few metres per second, while the general motion round the sun takes place at the rate of 10, 15, 20 leagues and more per second. The molecules, separated and thenceforward independent, then describe isolated orbits around the sun, differing very little from that of the comet. Those which are found in advance go a little faster and take the lead; those which are behind remain a little in the rear; so that the abandoned materials are divided along the trajectory of the comet in front and in rear of the nucleus. In time these materials are separated considerably from the body from which they emanate, and are more and more disseminated; but, considered at the moment of emission, they will form two visible appendages, two sorts of tails opposed and stratified on the orbit of the comet."

So much for the state of things if gravitation alone is in question.

But is gravitation alone concerned in building up a comet's form? That this is not so was fully recognized long ago, and it was suggested by the fact that the tails always appeared to be driven away from the sun; Seneca, indeed, was possibly acquainted with this fact, as he wrote: "Comæ radios solis effugiunt."[1] Kepler was the first to suggest that the matter of the tails was transported to the regions opposite the sun by the impulsion of the solar rays; Euler and Laplace accepted this explanation; and Newton was the first to give a complete explanation of the curve of the tail.

Olbers, whose researches dealt with the phenomena presented by the comet of 1811, considered that the approach of a comet to the sun might develop electricity in one or the other of these bodies, and to this were ascribed both the repulsive action of the

[1] *Mémoires* of the Academy of Montpellier, vol. ii. p. 23.
[2] *Annales de l'Observatoire de Paris*, vol. v. p. 376.
[3] "Forms of Comets," Nature, vol. x p. 247.

[1] See Pliny, Book II. chap. xxii. *et seq.*, for many references to more ancient authorities.

sun on the materials of the comet, and that of the comet on the nebulous atmosphere by which it was surrounded.

Olbers was driven to consider the repulsive action of the comet on its atmosphere in order to explain the many luminous sectors visible in the comet in question. To this he also ascribed the gradual rise of successive envelopes, so well illustrated subsequently by the comet of Donati.

The energy of electrical repulsion depends upon the amount of surface of the bodies concerned, whereas the attraction of gravity depends upon the masses of the bodies. Small things have more surface in proportion to their masses than large ones, and there will therefore be attraction or repulsion between the sun and the particles composing comets according as the differential effect of the two opposite forces is repulsive or attractive. In the very small particles, the electrical repulsion will be stronger than the attraction due to gravitation, while in the larger particles the two forces may balance each other, or gravitation may preponderate. Only the finest particles composing the head of a comet are therefore repelled to form the tails.

Bessel[1] considerably modified this hypothesis. He considered that the action of the sun on the comet represented a polar force.

M. Faye has more recently held that this repulsive action is due to the radiant energy of the sun, and that it has an intensity inversely as the square of the distance, and proportional to the surface and not to the mass of the moving particles. Its action would therefore be in the inverse ratio of the density of the particles upon which it acted; it would vary with every difference of cometary constitution; it would be inappreciable on the nucleus itself; (the idea being, of course, that the nucleus was a solid body); and it would be most effective in the case of the rarest vapours. The important part of M. Roche's later memoir consists in testing these views of repulsion, to determine whether the forms of comets could be explained by its introduction.

One result is very striking: the tail towards the sun demanded by gravitation alone at once disappears. The limiting surfaces which Roche's calculations demand are so very like some of the surfaces actually observed in the head of a comet, where they can be best seen, that it is suggested that the movement of the particles takes place in the precise direction where they would flow according to M. Roche's mathematical investigations.

Hence we are justified in attributing some cometary phenomena to the flow of matter acting under the influence of attraction and solar repulsion.[2] In concluding his memoir Roche points out (p. 393) that the hypothesis of a repulsive force acting along a radius vector, and varying inversely as the square of the distance, and only acting on matter reduced to a state of great rarefaction, gives figures identical with those observed. We see the germ of the tail is the part of the atmosphere the furthest removed from the sun, and it is easy to explain the enormous development of the emission of cometary particles near perihelion. The existence of a repulsive force which counterbalances the solar attraction M. Roche therefore considers established by his researches.

It must, however, be at once stated that much remains to be done before all the help that M. Roche's work can afford can be

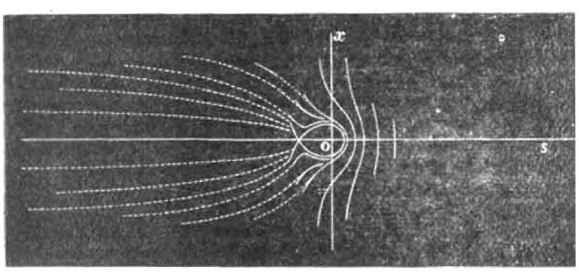

FIG. 26.—M. Roche's theoretical construction of the head of a comet, a repulsive force being taken into account.

utilized, and there is little question that the outflow in the solar direction has not been so entirely abolished as his figures indicate. This, however, may to a certain extent depend upon the fact that the observations of comets have been made at some distance from perihelion. But there may be another reason. If the outflow along the limiting surface is an outflow of solid particles, the solar repulsion will not be effective until collisions have reduced this dust to vapour. We shall still therefore have the quasi-conical surface *turned towards the sun*,[1] though it will be soon destroyed. Many of the phenomena presented by jets and excentric envelopes may be thus caused, and the very complicated phenomena presented by Coggia's comet, and others in which the section of the cone presents the appearance of birds with their wings more or less extended, do not seem opposed to this view.

J. NORMAN LOCKYER.

(*To be continued.*)

[1] Bessel's paper "On the Physical Constitution of Halley's Comet" is printed in the *Connaissance des Temps*, 1840.

[2] See *Annales de l'Observatoire de Paris*, vol. v.

[1] Although this does not figure in Roche's diagrams, Faye gives it in his lectures on the "Forms of Comets."

PRELIMINARY NOTE ON KEELING ATOLL, KNOWN ALSO AS THE COCOS ISLANDS.

MR. JOHN MURRAY, of the *Challenger* Expedition Office, has forwarded to us the following letter, which he has received from Dr. Guppy:—

DEAR MR. MURRAY,—

During my sojourn of nearly ten weeks in these islands, I was able to make a fairly complete examination of them. Here, I can only refer to some of the new features of this atoll which my investigations have disclosed, and must leave the details to be subsequently worked into a general description of the islands. Regarding myself as very fortunate in being able to examine the only atoll visited by Mr. Darwin—the atoll, in fact, which gave rise to the theory of subsidence—I at once set about making observations, without reference to any particular view of the origin of coral-reefs. I examined all the islands and islets, more than twenty in number, making a separate description of each, and reaped the benefit of the fact that this atoll has been occupied for more than half a century by residents interested in their surroundings. The result has been to convince me that several important characters of these islands escaped the attention of Mr. Darwin, partly owing to his limited stay, partly also due to his necessarily defective information of the past changes in the atoll. The features, in fact, that escaped his notice, throw considerable light on the mode of origin of these lagoon islands, and give no support to the theory of subsidence.

In the first place, I have ascertained that Keeling Atoll consists essentially of a ring of horse-shoe or crescentic islands inclosing a lagoon and presenting their convexities seaward. The crescentic form is possessed in varying degrees by different islands: some of the smaller ones are perfect horse-shoe atollons, and inclose a shallow lagoonlet; others, again, exhibit only a semi-crescentic form; whilst the larger islands have been produced by the union of several islands of this shape. The whole land-surface, however, is subject to continual change. The extremities of islands are often being gradually swept away or extended. Some islands are breached during heavy gales, others are joined, so that by the repetition of these changes the island in the course of time loses its original form. Hence it is that, although the crescent is the primitive shape of each island this structure is partly disguised in the case of some of the larger islands by the union of several of smaller size. The Admiralty chart gives but an imperfect idea of the true shape of the islands; but, notwithstanding, its inspection will prove very instructive.

In truth, Keeling Atoll exhibits in an incomplete manner the features of the large compound atoll of the Maldive Group. If it was considerably larger and possessed a less protected lagoon, so that open-sea conditions prevailed in its interior, it would have all the features of a compound Maldive atoll—that is, an atoll consisting of a circle of small atolls or atollons. In its original condition, however, it was an atoll consisting of a circle of crescentic islands. Such it is essentially now, but extensive changes have often partly disguised this feature.

Before proceeding to explain the origin of the incompleted compound atoll of the Keeling Islands, it will be necessary to dwell on the exaggerated prevailing notion of an atoll. This kind of coral-reef is usually described as a circular reef inclosing a deep basin or lagoon; but this description only applies to very small atolls less than a mile across. By drawing a section on a true scale of an atoll of average size, like Keeling Atoll, it will at once become apparent that such a description