we may eventually crush it, but we cannot succeed in moving it. The conclusion is quite striking, and so far we cannot but agree with Mr. Reade's opinion.

But are we entitled, therefore, to condemn the theory of the Alpine overthrusts? I think the comparison is not quite fair. First, it may be remarked, the bed may not be horizontal but inclined; in this case the component of gravity is sufficient, at an inclination of 1 : 6·5, to put the block in sliding motion, and we need not apply any external pressure at all. And what seems still more important, nobody ever will explain Alpine overthrusts in any other way than as a phenomenon of rock-plasticity. Suppose a layer of plastic material, say pitch, interposed between the block and the underlying bed; or suppose the bed to be composed of such material: then the law of viscous liquid friction will come into play, instead of the friction of solids; therefore any force, however small, will succeed in moving the block. Its velocity may be small if the plasticity is small, but in geology we have plenty of time; there is no hurry.

Some features of these phenomena have been beautifully illustrated by Professor Sollas' pitch-experiments. Pitch is not the same as rock undoubtedly, a point which Professor Bonney lays much stress upon in the August Number, 1907, of the Quart. Journ. Geol. Soc., but, on the other side, let us realize the difference between two months (required for Professor Sollas' experiments) and hundreds of thousands or millions of years which must be allowed for the analogous process in the Alps. The analogy shows mountain-building to be a very slow, gradual process, in virtue of the smallness of plasticity, but it would be in the main a continuous process, and I do not think we are forced to assume its discontinuity, as Mr. Mellard Reade seems inclined to do.

The plasticity of rocks in greater depths is to be explained partly by elevation of temperature, partly by pressure. But whatever explanation we accept, there are too many evidences to deny the fact.

In conclusion, we must say Mr. Mellard Reade's paper is very instructive; indeed, it helps us to see, by contrast with the author's ideal example, what are the most essential features of the process as displayed in Nature.

III.—A CRINOID (*TETRACRINUS* [?] *FELIX*, n.sp.) FROM THE RED CRAG.

By F. A. BATHER, M.A., D.Sc., F.G.S., etc.

(PLATE VIII.)

MR. P. G. H. BOSWELL, F.G.S., has kindly submitted to me a crinoid fragment found by him on August 20, 1908, in the Red Crag of Felixstowe cliffs, Suffolk. Although the specimen is somewhat obscure, it is of sufficient interest to warrant a brief note.

"The exact position of the place," writes Mr. Boswell, "was half-a-mile east of Felixstowe Church (Newbournian Zone of Red Crag). In the course of eight years' acquaintance with the Crag, having sifted for three years, I have not met with any other specimen of a crinoid, but Mr. F. W. Harmer, F.G.S., tells me he has met with

several worn specimens of *Pentacrinus* during his Oakley (Waltonian Zone, Red Crag) sifting. These he believes to be derivative in the Crag. I agree with him and with Dr. Bather in thinking this new specimen to be probably derivative also."

In all British Tertiary rocks crinoids are rare, some four or five species being known from the London Clay, but none from any of the later rocks. The Red Crag is one of the last formations in which one would expect to find a stalked crinoid, but it is of course probable that the fossil is derived from some older rock. The specimen is further interesting from the fact that it does not appear to agree with the remains of any species (one might almost say any genus) hitherto described, whether from rocks of corresponding Middle Pliocene age in other parts of the world, from Tertiary rocks in general, or from those Cretaceous rocks whence it may have been derived.

The fossil, which at first sight looks like a single columnal, appears on closer examination to comprise remains of the cup. Unfortunately its upper half is somewhat worn; the sides also are disfigured, both in the upper and lower half, by a few pittings, probably due to some boring organism; and the whole is covered with the glaze or patina so common in Red Crag fossils.

The shape is roughly that of a squat, swollen barrel, the upper and lower ends being approximately circular, though not quite parallel. The greatest height is 5.5 mm.; greatest equatorial diameter, 6.9 mm.; least equatorial diameter, 6.75 mm.; diameter of the articular face at the lower end, about 4.4 mm. The upper half is separated from the lower by a slight step (not a distinct ridge) approximately corresponding with the equator, but with five slight equal curves, concave towards the worn face. Apart from this feature, which may be largely the result of weathering, the curvature of the sides is equable and their surface is smooth, except for some almost imperceptible traces of pustules, more visible on the less worn half.

More obvious pustules surround the articular face of the lower half, and seem to form an obscurely pentagonal border, having the angles of the pentagon corresponding with the cusps between the curves of the step already mentioned. The pustules are unequal in size, and the larger ones tend to be situate at the angles, an arrangement that enhances the pentagonal appearance. Within this border the articular face is concave, rising again slightly towards the centre so as to form a faint swelling round the axial canal. This canal has so irregular an outline that one cannot say whether it was slightly pentagonal, or elliptical, or merely circular. In any case there is no trace of a fulcral ridge. The greatest diameter of the axial canal is, very roughly, about 1 mm. (Fig. 3).

The five curves of the equatorial step or rebate were intensified by iron staining, but on washing this away, there became visible traces of sutures following the curves. These were more clearly seen with the aid of glycerine and alcohol, and traces of vertical sutures could also be detected rising upwards from the cusps. These sutures are very difficult to see, but they are enough to show that the upper half of this fossil consists of five elements, and this affords the only rational explanation of the peculiar weathering. These elements must have

been closely anchylosed to one another and to the lower undivided half of the fossil (Fig. 2).

The upper face of the fossil, so far as its worn condition enables one to judge, is flat towards the margin, but slightly excavate towards the centre, not so excavate as the lower end. The actual centre is occupied by an axial canal, the borders of which appear to bear some radiating grooves; but these and the other markings of this face are so obscure that it is safer to attempt no description. If vertical lines be drawn upwards from the cusps, in the position of the traces of the vertical sutures, those lines seem in three or four cases to end in slight pustules or elevations. At the boundary of this face there are, however, three or four larger prominences, each coinciding with the middle of one of the five elements (Fig. 1).

The structures described have now to be interpreted. The five elements of the upper half cannot well be anything but basals or radials. That they are radials seems to result from the following considerations. Had they been basals, they would have shown some traces of a hexagonal outline, whereas they are pentagonal with flattened upper surfaces. Their size is more consistent with their being radials, since there is a tendency to the reduction of basals in all crinoids of Tertiary and later age.

If we accept the five upper elements as radials, we have to enquire what has happened to the basals. Are they fused into the single element forming the lower half of the fossil, or have they been overgrown by the radials and included in the interior of the cup, or have they possibly atrophied out of existence? I am inclined to adopt the first of these three explanations. The question may be put in another way: is the lower half of the fossil a proximale (i.e. a persistent top columnal), or is it a fused basal circlet? Now a proximale, while it has a modified upper face, for the reception of the elements it supports, generally has a lower face like the articular faces of the succeeding columnals. In the present instance those columnals are not known to us; but we do know enough about crinoids in general to be aware that a joint-face with a smooth regular concavity rarely has a pentagonal border of pustules. This pentagonal border is more readily explained as the last trace of the original pentamerism of the fused basal circlet.

Taking then, as a working hypothesis, the view that this fossil consists of a fused basal circlet supporting five closely united radials, we have to consider its systematic position.

Of the six families of recent crinoids recognized in the *Treatise on Zoology* (vol. iii, London, 1900), the Pentacrinidæ may at once be set aside by reason of their stem-articulation.

The Bourgueticrinidæ occasionally have columnals that recall the massive appearance and outline of this fossil; but in such forms the joint-face of the proximal columnals always has a distinct fulcral ridge, and the basals are distinct. The Upper Cretaceous *Mesocrinus* might otherwise have been thought to show some resemblance. *Rhizocrinus*, which still lives in the North Atlantic, is the only genus of the family recorded from Tertiary rocks, but bears no great likeness to this fossil.

The Holopodidæ, with their ancestors the Eugeniocrinidæ, have a similar massive structure, but had at an earlier period proceeded further in the union of the radials and inclusion of the basals within them.

The Apioocrinidæ, which are represented in modern seas by *Calamocrinus* of the Central Pacific, and in the Cretaceous of Europe by *Acrochordoocrinus*, might possibly receive this fossil; but the joint-faces of the columnals are marked by radiating striæ or by tubercles, and there is no known genus that shows any close resemblance.

The Bathyocrinidæ include only the deep-sea form *Bathyocrinus*, a genus which in its possession of a fused basal circlet, followed by discoidal columnals, might seem fitted to receive our fossil. In this genus, however, the radials are very easily separated from the base.

The Hyocrinidæ are also deep-sea forms, namely, *Hyocrinus*, *Gephyrocrinus*, and probably *Ptilocrinus*. No fossil representatives are yet known, but I agree with Professor Jaekel that they are probably descended from the Plicatocrinidæ of Jurassic age. It is somewhere in this series that I incline to place our fossil. In the Plicatocrinidæ and in *Gephyrocrinus* and *Ptilocrinus* the basals are fused. The last two genera have the slender habit characteristic of deep-sea crinoids, but among the Plicatocrinidæ *Tetracrinus* has the massive habit found in crinoids that occupy a more exposed position—the reef-type of Jaekel. The pustular ornament and doliform shape of our specimen are very reminiscent of *Tetracrinus*. Remains of the ornament are seen in *Gephyrocrinus Grimaldii*, Koehler & Bather (1902, figs. 1, 2), as a ring of a dozen small conical tubercles at the proximal margin of the base, projecting beyond the joint-face. Slighter traces are also found in *Ptilocrinus antarcticus*, Bather (1908). In *Gephyrocrinus* and *Tetracrinus* the joint-face of the columnals is plane, with slight radiating grooves at the periphery; where new columnals are arising, as next the base, the adjacent joint-faces would naturally be more concave.

On the whole, then, I would suggest that this Red Crag fossil represents the patina (RR and BB) of a shallow-water Crinoid, connecting the Plicatocrinidæ with the Hyocrinidæ. It does not quite agree with any of the known genera, and in the absence of further evidence it is hard to say which of them is most closely allied. Among living forms it is perhaps nearest to *Gephyrocrinus*, but it would be absurd to suppose that it had the peculiar character of the subvective grooves that distinguish that genus, since that character is clearly connected with the deep-sea habitat. On the other hand, it is probably a long way from *Tetracrinus* in the geological scale, and its superficial resemblance is largely due no doubt to similarity of habitat. Very likely it represents an undescribed genus; but I cannot bring myself to base a new generic division and name on so obscure a specimen. Let it be enough for the present to establish a new species, which may provisionally, and as a mere matter of convenience, be referred to *Tetracrinus*.

Tetracrinus (?) *felix*, n.sp.

Diagnosis.—A *Tetracrinus* (?) with doliform patina; RR closely united to each other and to the basal circlet; proximal border of base

TETRACRINUS (?) FELIX, sp. nov.

projecting beyond stem-facet and ornamented with small pustules forming a pentagon; traces of similar ornament on RR, especially a perradial prominence at the distal border of each.

Holotype.—The unique specimen collected by Mr. P. G. H. Boswell.

Horizon.—Newbournian zone of Red Crag (Middle Pliocene), probably derived.

Locality.—Felixstowe, Suffolk.

EXPLANATION OF PLATE VIII.

FIG. 1.—View of the holotype from above.

„ 2.—Side view of the holotype.

„ 3.—View of the holotype from below, showing stem-faces.

All figures are enlarged six diameters, and in each the right and left sides remain in the same position with regard to the beholder. Drawn by Mr. A. H. Searle.

POSTSCRIPT.

Mr. F. W. Harmer, F.G.S., has kindly sent me five other fragments collected by him in the Red Crag, and presumed to be of crinoid origin.

One of these is shaped like the tapering end of a belemnite, and I can detect in it no crinoid structure. The outer crust is silica in the form of beekite; the interior, exposed at the broad, broken end, is ferruginous (? limonite) with traces of calcite.

Another is a cylindrical fragment, 6.2 by 4.8 mm., much worn, with a beekite crust, and traces of radiate striæ in the interior. If echinodermal, it might be the proximal end of an echinoid radiole or part of a crinoid stem.

Two specimens are certainly parts of Pentacrinitid stems. One is 30.9 by about 5 mm., rather less in diameter at one end and swelling suddenly to a maximum of 6 mm. at the other end, which is rounded. The joint-face is not preserved; the side-faces are smooth; on the sutures are slight indentations, radial in position. This orientation is proved by the weathering of the thinner end of the fragment, where the interradian ligamentar areas have been eaten into owing to their less density. There is no trace of a cirriferous nodal. There can be scarcely any doubt that this is part of the stem of *Balanoocrinus subbasaltiformis*,¹ and that it has been derived from the London Clay. The other Pentacrinitid stem-fragment probably belongs to the same species; it is rounded off rather acutely at one end; at the other is an apparent hypozygal with slight traces of the markings on the joint-face. The substance of these specimens is apparently limonite, probably altered from a previous pyritized stage.

The remaining fragment is cylindrical, 11.8 mm. long, 5.3 mm. in diameter at one end, tapering to 4.6 mm. at the other end, which is more worn. The outer surface of the side-faces has been altered by partial change into beekite, so that no sutures are visible. The joint-face at the wider end is obscure, but shows some straight striæ radiating from the lumen; here are still traces of calcite. The narrower end is eaten into, and the lumen widened; this enables one to see that the fragment is composed of thin columnals, about .5 mm.

¹ *Pentacrinus subbasaltiformis*, J. de C. Sowerby, ex J. S. Miller nom. nud., in N. T. Wetherell, 1840.

high, with a radiate micro-structure, and a radiately striate joint-face producing finely crenulate sutures.

I am not acquainted with any similar stem from either the Chalk or the Lower Tertiaries; but that crinoids having such a stem must have existed during those periods is rendered highly probable by the fact that this is a usual form of stem in the Jurassic *Apiocrinidæ*, and that we still find it in their modern representative *Calamocrinus* as well as in the *Hyocrinidæ*. The discovery of this fragment, imperfect though it be, leads one to expect that the missing links will ultimately be found in their correct stratigraphical position.

It is not probable that any of these crinoid fragments, the results of Mr. Harmer's long years of collecting, are related to *Tetracrinus felix*. Their sole importance in this connection lies in their bearing on the age of the derived crinoid fragments found in the Red Crag. The only direct evidence is that of *Balanocrinus subbasaltiformis*, which is common in the London Clay, and probably had a wide range, since a variety of it (var. *Pratti*) is common at Biarritz. Specimens in the British Museum [75,838] were found at Harwich. In the London Clay the substance of this fossil, as of the other echinoderms, is generally changed into iron pyrites or marcasite; and this is consistent with the present condition of Mr. Harmer's Red Crag specimens. They, however, differ in this respect from Mr. Harmer's other specimens, which agree among themselves in having a beekite crust. The silicification no doubt took place before they were redeposited in the Crag, and, taken in conjunction with the possible belemnite nature of one, it suggests the Upper Chalk as their parent rock. However this may be, no inference can be drawn as regards *Tetracrinus felix*, which retains its original calcite composition, pure and unsilicified.

IV.—EXTINCT MARSUPIALS OF WESTERN AUSTRALIA.

By BERNARD H. WOODWARD, F.G.S., C.M.Z.S., Director of the Western Australian Museum.

BEFORE the beginning of this year the only records of the occurrence of fossil marsupials in Western Australia consisted of the account of the discovery of *Diprotodon* bones in the Kimberley district by Mr. E. T. Hardman, the Government Geologist, in 1882, and the finding of a lower jaw of this animal in 1895 in a gully near Lake Darlot in the Eastern Goldfields by Mr. Arthur, who presented it to this Institution. This jaw was so much weathered that it was valueless except for the fact of its establishing the existence of that marsupial so far inland. The Museum Committee sent an expedition to Lake Darlot in 1898, and in 1908 the Hon. Dr. Hackett sent out at his own cost Mr. Young, who was with Mr. Arthur when he found the jaw in 1895. Both these parties were unsuccessful.

In February, 1909, Mr. John Sharp, of Balladonia, Point Malcolm, on the south coast, sent to the museum a number of bones and a few teeth of *Diprotodon australis* that he had unearthed when excavating for water in a marsh on his station. These specimens