of the Salève. This mountain, which rises about 3000 ft. above Geneva, consists of limestones and shales (Upper Jurassic and Neocomian), with Middle Tertiary sandstones, chiefly molasse, and glacial deposits. Apart from the effects of altitude, the flora is much affected by the nature of the rock on which it grows, and besides this, a small colony of special plants generally accompanies any local physical peculiarity. Of this association the large erratics of Alpine granite and schists afford a remarkable instance. *Asplenium septentrionale* is the only phanerogamous plant found on them to which rocks, in the High Alps, it is practically restricted.

BLOOD-PARASITES AND FLEAS.

FOR the past five years Prof. E. A. Minchin and Dr. J. D. Thomson have been engaged upon the investigation of the rat trypanosome, *Trypanosoma lewisi*, with special reference to its relation to the rat flea, *Ceratophyllus fasciatus*. The results of this laborious and painstaking research are now published in the *Quarterly Journal of Microscopical Science*. They form a comprehensive monograph which occupies the whole of the last part of this journal (vol. lx., part 4) and will undoubtedly be a standard work of reference for students of these very important blood-parasites. The fact that the authors have dissected and examined more than 1600 fleas in the course of their investigations shows the thoroughness with which the work has been carried out, while the artistic treatment and accuracy of detail contributed by the illustrations, for which due acknowledgment is made to Miss Rhodes, leave nothing to be desired. *T. lewisi* is fortunately a non-pathogenic parasite, at any rate so far as the rat is concerned, and it cannot live at all in human blood. It therefore forms a much more suitable type for general study than such deadly species as those which are conveyed by the tsetse-fly in Africa, and are responsible for fly-disease amongst horses and cattle, and for sleeping sickness in human beings. The authors give a very useful account of the technique employed in their investigations, and, incidentally, throw a good deal of light upon details of the anatomy and histology of the flea.

The flea, of course, receives the parasite with the blood which it extracts from the rat, but apparently it cannot infect the rat by inoculating trypanosomes into it through the proboscis. The rat is supposed to become infected through the mouth; in the process of licking its fur it takes in trypanosomes with fæcal matter deposited by the flea; or it may become infected by eating infected fleas.

While in the flea the trypanosome is confined throughout its whole development to the digestive tract, where it undergoes extensive asexual multiplication and passes through a number of more or less distinct phases, some of which are intracellular in the epithelium of the stomach. No sexual phenomena have been detected, and the authors agree with Miss Robertson that such phenomena have not as yet been satisfactorily demonstrated in the case of any trypanosome.

CHANGES OF RELATIVE LEVELS OF LAND AND SEA.

AMONG the different kinds of evidence showing that changes in the relative levels of sea and land are going on all over the globe, the forms assumed by coast-lines are now recognised by geologists as being the most convincing and satisfactory. Sea-erosion, acting only along shore-lines, and subaerial denudation, operating over the whole land-surfaces, result in features of such clearly differentiated character that no unbiassed observer can fail to recognise their great significance and value. When we find long, narrow, deep, and winding inlets from the sea into the land ("fiords," etc.), it is obvious that such features could not result from the cutting back of the coast-line by the sea, but that they are old river-channels that have been drowned by the sinking of the land. On the other hand, sea-beaches, with caves, fan-taluses, and other signs of shore work, occurring at various heights above the present sea-level, speak, quite as unmistakably, of elevation having taken place.

The illustrious American geologist, James Dwight Dana, when accompanying the United States Exploring Expedition under Wilkes, had the opportunity of visiting many coral-reef islands, and we are indebted to him for first showing, in 1849, the value of the evidence afforded by coast-lines, where bounded by "encircling" or "barrier" reefs, of subsidence having taken place. These valuable observations of Dana seem to have been almost completely overlooked until quite recent years, and it is only fitting that to a fellow-countryman of his should fall the task of recalling and developing this pioneer work.

Where a coral-reef encircles a land-mass it is evident that the presence of "fiords" or their equivalents in the central island supplies clear evidence of submergence having taken place, though possibly this may not be the latest of the movements that have occurred. On the other hand, the existence of islands composed of upraised coral-rock, with sea-caves and shore deposits at different stages, up to more than 1000 ft. above the present sea-level, supplies equally clear evidence of movements in an opposite direction having taken place. The late Prof. Alexander Agassiz published a very valuable series of reports, abundantly illustrated, concerning these upraised Pacific reefs, and we now have the promise of equally important descriptions by Prof. W. M. Davis, also of Harvard, of the cases in which the proofs of subsidences can be no less satisfactorily made out.

The general result to which these various observations appear to point is that, over the whole area of the Pacific, areas of elevation and others of subsidence can be clearly traced, though the movements were often interrupted and sometimes reversed; nevertheless, it must be admitted that in some cases the evidence seems puzzling and contradictory—islands with clear evidence of elevation lying in close proximity to others which have clearly subsided. Geologists will not, however, be unprepared for the occurrence of such seeming anomalies; they will only recognise that, eventually, actual fault-lines may be traced by such means in the oceanic areas. At the same time it may be well to bear in mind the caution suggested by Darwin in his correspondence with Semper that, however clear may be the evidence in favour of any special theory of coral-reef formation, we must be always prepared for the occurrence of special cases which can only be accounted for by the operation of exceptional causes. The full and complete account—which will no doubt be sufficiently illustrated—of Prof. W. M. Davis's important series of explorations will be looked forward to with special interest, and in the meantime the subjoined general summary of his results will be welcomed by all naturalists.

J. W. J.

Preliminary Report on a Shaler Memorial Study of Coral Reefs.

A liberal grant from the Shaler Memorial Fund of Harvard University, supplemented by a generous subsidy from the British Association for the Advance-

ment of Science, with an invitation to attend its meeting in Australia last August as a foreign guest, enabled me to spend the greater part of the year 1914 in visiting a number of islands in the Pacific Ocean with the object of testing various theories that have been invented to account for coral reefs. Thirty-five islands, namely, Oahu in Hawaii, eighteen of the Fiji group, New Caledonia, of which the entire coast-line was traced, the three Loyalty islands, five of the New Hebrides, Raratonga in the Cook group, and six of the Society islands, as well as a long stretch of the Queensland coast inside of the Great Barrier reef, of north-eastern Australia, were examined in greater or less detail. A brief statement of my results has been published in the Proceedings of the National Academy of Sciences for March, 1915. A full report upon my observations will appear later, probably in the Bulletin of the Museum of Comparative Zoology at Harvard College. The general conclusions reached are here briefly summarised.

Any one of the eight or nine theories of coral reefs will satisfactorily account for the visible features of sea-level reefs themselves, provided the postulated conditions and processes of the invisible past are accepted; hence a study of the visible features of the reefs alone cannot lead to any valid conclusions. Some independent witnesses must be interrogated, in the hope of detecting the true theory of their origin. The only witnesses, apart from sections obtained by deep and expensive borings, available for sea-level reefs are the central islands within oceanic barrier reefs, or the mainland coast within a continental barrier reef. The testimony of these witnesses has been too largely neglected, apparently because most investigators of coral reefs have been zoologists, little trained in the physiography of shore lines. Elevated reefs afford additional testimony in their structure and in the relation of their mass to its foundation; but this testimony also has been insufficiently considered, perhaps because most investigators of reefs have as zoologists been little trained in structural geology; hence it seemed desirable to give as much time as possible on the Pacific Islands to questioning the independent witnesses above designated.

The testimony of the first group of witnesses—the central islands of barrier reefs—convinced me that Darwin's theory of subsidence is the only theory competent to explain not only the development of barrier reefs from fringing reefs, but also the shore-line features of the central islands within such reefs; for the embayments of the central islands testify emphatically to subsidence, as Dana long ago pointed out; thus my results in the study of this old problem of the Pacific agree with those of several other recent students, especially Andrews, Hedley, and Taylor of Australia, and Marshall of New Zealand. Darwin's theory of subsidence also gives by far the most probable explanation of atolls; for it is unreasonable to suppose that a subsidence of the ocean bottom should occur only in regions where the central islands of barrier reefs are present to attest it, and not in neighbouring regions where reefs of identical appearance, but without a central island, are given another name.

The testimony of the second group of witnesses—massive elevated reefs such as occur on certain Fiji islands—convinced me that Darwin's theory of subsidence gives the only satisfactory explanation of the origin of such reefs also; for their limestones rest unconformably on the normally eroded surface of a pre-existent foundation. The erosion of the foundation surface shows that it stood above sea-level before the reef was deposited upon it; and the occurrence of the reef shows that the eroded foundation subsided to receive its marine cover. Only after this subsidence was the compound mass uplifted. The mere occurrence of elevated reefs above sea-level does not for a moment prove that they were formed during the emergence of their foundation.

All the still-stand theories of barrier reefs—that is, all the theories which involve a fixed relation of the reef foundation to the sea-level during the formation of the reef mass—are excluded by evidence of submergence found in the embayed shore lines of the central islands within barrier reefs. It may seem over-bold thus at a stroke to set aside several well-known theories, accepted by experienced observers; and so indeed it would be if these observers had discussed the features of the embayed central islands, and had explicitly shown that their embayments are not due to submergence but to some other cause. It is, however, a regrettable fact that the observers who adopted one or another of the still-stand theories took, like Darwin himself, practically no account of the embayed central islands, essential as the testimony of these islands is in the solution of the coral-reef problem. Such neglect is all the more remarkable in view of the clear statement, long ago published by Dana, regarding the pertinence and the value of the testimony afforded by the central islands of barrier reefs.

The glacial-control theory of coral reefs, recently elaborated by Daly with special reference to the lagoons of atolls, will not hold for barrier reefs. This theory assumes that no subsidence of the reef-foundations took place, and explains the lagoon floors of atolls as platforms abraded across pre-glacial sea-level reef-masses by the lowered and chilled sea of the glacial period after the corals were killed; the pre-glacial reef-masses having been formed by upward or outward growth on still-standing foundations. It then explains the encircling reefs which now surround the lagoons as having been built up while the sea was rising and warming in post-glacial time. But if the broad lagoons of large atolls twenty or thirty miles in diameter were thus formed, the central islands within narrow-lagoon barrier reefs should be cliffed all around their shore line, and they are not. Furthermore, this theory explains the embayments of central islands within barrier reefs as occupying new-cut valleys that were eroded during the glacial period of lowered sea-level; but if this were the case, the new-cut valleys should be prolonged upstream from the embayment heads as incisions in the floors of pre-glacial valleys, thus producing a "valley-in-valley" landscape; and this is not true in any one of the hundreds of embayments seen during the past year. Furthermore, many of the embayments are so wide that, if they were opened by slow subaerial processes, the spur-ends ought to have been well cliffed by the sea; yet, as above stated, they are not cliffed. Finally, many of the embayments are too wide to have been eroded during the last glacial epoch, or even during all the glacial epochs of the entire glacial period, if the valleys of the formerly glaciated volcanoes in central France are taken as standards of the amount of erosion that could be accomplished on such masses during such intervals of time. The glacial control theory thus proves incompetent to explain barrier reefs, and it is therefore held to be generally incompetent to explain atolls also; it may have more importance on the borders of the coral zone, where the corals would most likely have been killed during the glacial period: the Marquesas islands promise interesting results in this connection. The glacial-control theory has its greatest importance in conjunction with Darwin's theory of subsidence; for sub-

mergence during subsidence may have been almost neutralised by the lowering of the sea-level during the oncoming of a glacial epoch, and under such conditions coral reefs would broaden and lagoons would become shallow; but with the passing of a glacial epoch the return of ice-sheet water to the ocean would accelerate the submergence due to subsidence, and at such a time, coral reefs might be more or less completely drowned; thus the discontinuity of certain reefs on so-called "platforms" may be explained.

All the phenomena which testify to the formation of coral reefs on subsiding foundations can be equally well explained by the assumption of a rise of the ocean surface around or over fixed foundations; but a rise of the ocean surface in any coral-reef region demands a rise of the whole ocean surface; and if the coral-reef foundations are to stand still, a rise of the whole ocean surface can be explained only as the diminished result of a greater rise of the ocean floor in some non-coral-reef region. The conditions involved in this alternative for the simple theory of local subsidence are so extravagantly improbable that, as soon as they are explicitly defined, they must be rejected.

No absolute demonstration of the origin of coral reefs, or, for that matter, of any other geological structure, is possible; the most that can be hoped for is a highly probable conclusion. The conclusions announced above in favour of Darwin's theory are believed to have about the same order of probability as that usually accepted as "proof" in geological discussions.

A number of local conclusions may be briefly announced as follows:—

The elevated reef along the south coast of Oahu, Hawaii, was formed during or after a sub-recent period of subsidence, for its limestones enter well-defined valleys that must have been eroded when the island stood higher than now, and before the reef-limestones were deposited in them.

The Fiji group has suffered various movements of subsidence and elevation by which its many islands were affected in unlike ways. Elevation has taken place at different times in different islands, for some of the elevated reefs are elaborately dissected, others are very little dissected, and still others remain at sea-level. The embayments due to the latest submergence of the larger islands, Viti Levu and Vanua Levu, are now largely filled with delta plains. All the reefs, those now elevated as well as those at sea-level, appear to have been formed during periods of subsidence; the evidence afforded by the elevated reefs of Vanua Mbalavu, Mango, and Thithia is specially significant on this point. The medium-sized island of Taviuni has few visible reefs, because its flanks and shores are flooded by sheets of recent lava. The small island of Wakaya seems to be a tilted block of lava beds, not a dissected volcano.

The extensive barrier reef of New Caledonia has grown up during a recent subsidence by which that long and maturely dissected island has been much reduced in size and elaborately embayed; but unlike most encircled islands, this one was strongly cliffed around its south-eastern end, and along much of its north-eastern side before the recent subsidence took place.

The two south-eastern members of the Loyalty group, Maré and Lifu, are former atolls, evenly uplifted about 300 ft.; Maré shows a small hill of volcanic rock in the centre of its limestone plateau or elevated lagoon floor. Uvea, the north-western of the three Loyalty islands, is a slightly tilted atoll; its eastern side shows an uplifted reef in rudely crescentic form, which reaches a height of 100 or 200 ft. at the middle of its crescent, and slowly descends to sea-level at its horns; a bight in its convex front may be the result of a landslide; the tilted lagoon floor slowly deepens westward and is enclosed by disconnected, upbuilt reef-islands.

The New Hebrides show signs of uplift in their elevated reefs, and of depression in their embayments. There is some evidence that certain uplifted fringing reefs on the island of Efaté, near the centre of the group, were formed during pauses in a subsidence that preceded their uplift, and not during pauses in their uplift as inferred by Mawson. The narrowness of the lagoons enclosed by the barrier reefs that encircle certain strongly embayed islands in this group may be explained by supposing alternations of slow and rapid subsidence; thus the earlier-formed reefs, which began to grow when the subsidence was slowly initiated, were drowned when it was later accelerated; and new reefs, thereupon begun on the shore line of that time, now, after a second period of slow subsidence, stand near the present shore line, though the shore line is strongly embayed, because the total subsidence has been large. The absence of reefs around the island of Ambrym is due to its abundant eruptions in recent time, the latest one being in December, 1913; scattered corals were seen growing on one of its sea-cliffed lava-streams, thus illustrating the initial stage of a fringing reef.

The Great Barrier reef of Australia, the greatest reef in the world, with a length of some 1200 miles and a lagoon from 15 to 70 or more miles wide, has grown upward during the recent subsidence by which the Queensland coast has, after a long period of still-stand, been elaborately embayed, as was pointed out by Andrews in 1902. A very recent uplift of some 10 ft. has occurred, as was long ago noted by Jukes. There is much reason for believing that a broadened reef-plain, with extensive land-fed deltas along the continental margin, had been formed before the recent subsidence took place; and it is this broadened reef, now submerged, that is thought to form the "platform" on which the Great Barrier reef has grown up. Guppy's suggestion that the platform or "submarine ledge" is due to marine abrasion, before coral reefs were established here, and that no subsidence has taken place, cannot be accepted. It is highly probable that the well-attested recent subsidence was due to a gentle flexure, by which the offshore sea-bottom was bent down; and, if so, the coastal submergence will give too small a measure of the thickness of the distant barrier reef. In this respect the Great Barrier reef along the shore of a continent differs significantly from smaller barrier reefs around oceanic islands, in which the subsidence of the island and its reefs are essentially uniform.

A few hours on shore at Raratonga, the southernmost member of the Cook group, sufficed to show that extensive embayments formerly entering its elaborately carved mass are now occupied by delta plains and perhaps in part by slightly elevated reef- and lagoon-limestone.

Five islands of the Society group exhibit signs of recent subsidence in their intricately embayed shore lines, as has lately been announced by Marshall. A sixth, the cliff-rimmed island of Tahiti, the largest and youngest of the group, suffered moderate subsidence after its cliffs were cut, but the resulting bays are now nearly all filled with delta plains, which often advance into the narrow lagoon; hence a pause or still-stand has followed its latest subsidence. All the barrier reefs of this group appear to have been formed during the recent subsidence that embayed their central islands.

W. M. DAVIS.