Dikoa to Doloo. But a further advance in this direction was prevented by the disturbed state of the frontiers between Bornu and Adamawa. Buonfanti was consequently compelled to retrace his steps to Kuka, whence he turned westwards along the route recently opened by Lieut. Massari to Kano. After some trips to Yakoba and other little-known parts of Sokoto, he made his way through Gando to the Niger at Say, about midway between Timbuktu and the Binue confluence. Here he turned north, and for the first time *ascended* the Niger as far as Timbuktu. This feat, hitherto supposed to be impossible, was performed *in the dry season*, and the problem thus successfully solved possesses considerable geographical and commercial importance in connection with the attempts now being made to establish regular lines of water communication between Western and Central Sudan and the Gulf of Guinea. From Timbuktu the route lay through the States of Massina and Bambarra to the almost unknown territory of Tombo, the attempt to explore which region ended in disaster. Attacked in the Sanghi district by the natives, the expedition was plundered and almost completely dispersed, being reduced from an escort of 250 to six persons. Thus reduced to the greatest straits, the traveller was driven eastwards, and after enduring fearful sufferings reached the Bussanga country north of Dahomey. Here he fortunately came upon a Roman Catholic mission, which provided him with the means of continuing his journey southwards to the coast of Guinea. He arrived at Lagos on March 5, 1883, having lost all his scientific collections during the disastrous journey through Tembo.

WE received last year complete reports of the state of the ice around Greenland, from Nordenskjöld, and in the Siberian Seas, from Hovgaard, but no report as to the conditions around Spitzbergen. As complete reports of the state and conditions of the ice in the various Arctic seas from year to year will greatly tend to assist glacialists in their researches and future Polar travellers, we publish some particulars furnished by the well-known Arctic hunter, Capt. M. E. Arnesen, of Tromsö, of his voyages in the Spitzbergen seas last summer:—Leaving Tromsö on April 21, he encountered the ice on April 28 in lat. 68° 28′ N. and long. 41° 18′ E. On May 4 the first seal was shot in lat. 68° 50′ N. and long. 42° 10′ E. A storm clearing the ice away, he was able to sail as far as 69°. Here a large ice-field stretched west-north-west as far as lat. 69° 55′ N. and 44° 30′ E., where it curved in a north-easterly and easterly direction. During the fifteen years Capt. Arnesen has sailed in the Arctic seas he never experienced such an early and warm spring. The heat was at times quite oppressive. On the night of July 14 he rounded South Cape at Spitzbergen. The ice lay towards Whales Point, close to the western shore. The Thousand Islands were on July 16 entirely surrounded with ice, stretching about a mile out to sea on the west side. From High Rocks an ice-field runs to the south-south-west. The wind was generally northerly and light, with alternating fogs and clear weather. Deicrow's Sound was entirely free from ice, but, at Black Point, passage between Halfmoon and the other islands was impossible. Encountering the ice on July 20, west of Whales Point, he found no change in its state. On July 22 the edge of the ice was lying from High Rocks to the southern point of Hope Island. For two days a thick fog prevailed. On July 24 the southern point of Hope Island was passed, where close ice stretched south-south-west. The wind was during this week slight, but came alternately from all quarters, sometimes with rain and fog. On July 28 the current set the ice southwards, so that the Thousand Islands were in open water, and towards Hope Island only a few floes were seen. The Halfmoon Islands were in clear water. On the 29th the wind fell, "ice-blink," *i.e.* the reflection of new ice in the sky, being seen to the eastward. On the 30th compact ice was encountered south of Ryk Vs's Islands. On July 31 Whales Point was found free from ice. On August 4 the country at the mouth of Walter Thyrnen Strait was perfectly free from ice, only old glaciers being visible on the mountains. The grass was quite out. The north-eastern part of Hans Foreland forms a great low plateau with good grazings for the reindeer, where large herds are found. The reindeer were in a very good condition, a circumstance which further proves the early and mild spring of last year. On the afternoon of August 6 the temperature in the shade was 12° C., and that of the surface of the water 9° C. On the night of the 17th a little snow fell in the mountains. An old ox, castrated and marked in the ear, was shot. It was believed to be one of those which escaped from Nordenskjöld at Mossel Bay in 1872. East of Hans Foreland and Barents Land there was then no trace of ice; in fact the sea ran mountains high on that side.

THE last volume of the *Memoirs of the Russian Geographical Society* (vol. xii. No. 4) contains the "Memoirs of the Interpreter Otano Kigoro on Corea," translated from the Japanese by M. Dmitrevsky. The author was interpreter of the Corean language on the Tsousima Island, and compiled his book in 1794 on information gathered from Corean officials, as also from Chinese and Japanese works on Corea. The Russian translator of this book has added to it most valuable information gathered especially from the great Corean Code, published in 1785 (Da-dyang-tun-byang), which contains a detailed description of Corea, as well as from several other Chinese and European works, such as the "History of the Corean Church," by Dallet. The extracts from the Corean Code are especially numerous and of great value. The work of Kigoro contains interesting descriptions of the "Customs at the Court," the provincial administration, the geography of Corea, its inhabitants, their customs, habitations, food, and agriculture, as also notes on the Corean administration, army, and literature.

THE last number of the Irkutsk *Izvestia* contains an interesting paper by Dr. Martianoff on his journeys in the north-eastern part of the Minusinsk district. In a note on antiquities in the basin of the Yenisei M. Bogolubsky mentions, among others, that on the Ouzynjoul gold-washings on a river of the same name belonging to the basin of the Abakan, implements consisting of a red copper nail, a marmor ring, and a knife and an arrow of bone, were found, together with bones of mammoth, rhinoceros, *Bos urus*, horse, antelope, wolf, and domestic animals, at a depth of from ten to thirteen feet. If implements from different levels were not confounded together, this find would surely be of great value. We notice also a note on a little-known subject, the "Scythic disease" among Aleutes and Kamchadales, by M. Grebnitzky, and another on the rapids of the Angara, with a map.

THE prospects of a trade between Europe and Siberia, through the Kara Sea, do not seem to be cheering. According to a private correspondent in Moscow, the steamer *Dallmann*, built at the Vulcan Engineering Works, Stettin, for towing on the Yenisei, lies at the trading station, Strelka, 75 versts south of Yeniseisk, where also two iron lighters of 5000 poods carrying capacity, and a wooden one capable of carrying 2000 poods, as well as two steam launches, now are. They are all to be sold, along with the buildings, depots, and factories at Strelka and the stations not far from the mouth of the Yenisei, about 800 versts north of Turukhansk. At the latter station large quantities of wheat, rye, and oats have been collected with a view to being exported to Europe. There seems at present little probability of their ever reaching their destination. During the last five or six years the steamer *Louise* has only twice succeeded in reaching the Yenisei and returning with cargo to Europe; three times the vessel failed in the attempt.

THE last issue of the *Journal of the Ceylon Branch of the Royal Asiatic Society* (Colombo, 1883) is wholly occupied by a translation of that part of Ibn Batuta's travels relating to Ceylon and the Maldive Islands, accompanied by notes. The account of the customs of the primitive inhabitants of the Maldives is especially interesting.

ON THE NOMENCLATURE, ORIGIN, AND DISTRIBUTION OF DEEP-SEA DEPOSITS[1]

III.

IT remains now to point out the area occupied by the red clay. We have seen how it passes at its margins into organic calcareous oozes, found in the lesser depths of the abysmal regions, or into the siliceous organic oozes or terrigenous deposits. In its typical form the red clay occupies a larger area than any of the other true deep-sea deposits, covering the bottom in vast regions of the North and South Pacific, Atlantic, and Indian Oceans. As above remarked, this clay may be said to be universally distributed over the floor of the oceanic basins; but it only appears as a true deposit at points where the siliceous and calcareous organisms do not conceal its proper characters.

Having now indicated its distribution, we must consider the mode of its formation, and give, in addition, a concise descrip-

[1] A Paper read before the Royal Society of Edinburgh by John Murray and A. Renard. Communicated by John Murray. Continued from p. 117.

tion of the minerals and of the organic remains which are commonly associated with it. The origin of these vast deposits of clay is a problem of the highest interest. It was at first supposed that these sediments were composed of microscopic particles arising from the disintegration of the rocks by rivers and by the waves on the coasts. It was believed that the matters held in suspension were carried far and wide by currents, and gradually fell to the bottom of the sea. But the uniformity of composition presented by these deposits was a great objection to this view. It could be shown, as we have mentioned above, that mineral particles, even of the smallest dimensions, continually set adrift upon disturbed waters must, owing to a property of sea water, eventually be precipitated at no great distance from land. It has also been supposed that these argillaceous deposits owe their origin to the inorganic residue of the calcareous shells which are dissolved away in deep water, but this view has no foundation in fact. Everything seems to show that the formation of the clay is due to the decomposition of fragmentary volcanic products, whose presence can be detected over the whole floor of the ocean.

These volcanic materials are derived from floating pumice and volcanic ashes ejected to great distances by terrestrial volcanoes, and carried far by the winds. It is also known that beds of lava and of tufa are laid down upon the bottom of the sea. This assemblage of pyrogenic rocks, rich in aluminous silicates, decomposes under the chemical action of the water, and gives rise, in the same way as do terrestrial volcanic rocks, to argillaceous matters, according to reactions which we can always observe on the surface of the globe, and which are too well known to need special mention here.

The detailed microscopic examination of hundreds of soundings has shown that we can always demonstrate in the argillaceous matter the presence of pumice, of lapilli, of silicates, and other volcanic minerals in various stages of decomposition.

As we have shown in another paper,[1] the deposit most widely distributed over the bed of modern seas is due to the decomposition of the products of the internal activity of the globe, and the final result of the chemical action of sea water is seen in the formation of this argillaceous matter, which is found everywhere in deep-sea deposits, sometimes concealed by the abundance of siliceous or calcareous organisms, sometimes appearing with its own proper characteristics associated with mineral substances, some of which allow us to appreciate the extreme slowness of its formation, or whose presence corroborates the theory advanced to explain its origin.

In the places where this red clay attains its most typical development, we may follow, step by step, the transformation of the volcanic fragments into argillaceous matter. It may be said to be the direct product of the decomposition of the basic rocks, represented by volcanic glasses, such as hyalomelan and tachylite. This decomposition, in spite of the temperature approximating to zero (32° F.), gives rise, as an ultimate product, to clearly crystallised minerals, which may be considered the most remarkable products of the chemical action of the sea upon the volcanic matters undergoing decomposition. These microscopic crystals are zeolites lying free in the deposit, and are met with in greatest abundance in the typical red clay areas of the Central Pacific. They are simple, twinned, or spheroidal groups, which scarcely exceed half a millimetre in diameter. The crystallographic and chemical study of them shows that they must be referred to Christianite. It is known how easily the zeolites crystallise in the pores of eruptive rocks in process of decomposition; and the crystals of Christianite, which we observe in considerable quantities in the clay of the centre of the Pacific, have been formed at the expense of the decomposing volcanic matters spread out upon the bed of that ocean.

In connection with this formation of zeolites, reference may be made to a chemical process whose principal seat is the red clay areas, and which gives rise to nodules of manganiferous iron. This substance is almost universally distributed in oceanic sediments, yet it is not so much of the areas of its abundance that we intend to speak as to the fact of its occurrence in the red clay, because this association tends to show a common relation of origin. It is exactly in those regions where there is an accumulation of pyroxenic lavas in decomposition, containing silicates with a base of manganese and iron, such for example as augite, hornblende, olivine, magnetite, and basic glasses, that manganese nodules occur in greatest numbers. In the regions where the sedimentary action, mechanical and organic, is, as it were, suspended, and where, as will appear in the sequel, everything shows an extreme slowness of deposition,—in these calm waters favourable to chemical reactions, ferro-manganiferous substances form concretions around organic and inorganic centres.

These concentrations of ferric and manganic oxides, mixed with argillaceous materials whose form and dimensions are extremely variable, belong generally to the earthy variety or wad, but pass sometimes, though rarely, into varieties of hydrated oxide of manganese with distinct indications of radially fibrous crystallisation. The interpretation to which we are led, in order to explain this formation of manganese nodules, is the same as that which is admitted in explanation of the formation of coatings of this material on the surface of terrestrial rocks. These salts of manganese and iron, dissolved in water by carbonic acid, then precipitated in the form of carbonate of protoxide of iron and manganese, become oxidised, and give rise in the calm and deep oceanic regions to more or less pure ferro-manganiferous concretions. At the same time it must be admitted that rivers may bring to the ocean a contribution of these same substances.

Among the bodies which, in certain regions where red clay predominates, serve as centres for these manganiferous nodules, are the remains of Vertebrates. These remains are the hardest parts of the skeleton—tympanic bones of whales, beaks of Ziphius, teeth of sharks; and just as the calcareous shells are eliminated in the depths, so all the remains of the larger Vertebrates are absent, except the most resistant portions. These bones often serve as a centre for the manganese iron concretions, being frequently surrounded by layers several centimetres in thickness. In the same dredgings in the red clay areas some sharks' teeth and Cetacean ear-bones, some of which belong to extinct species, are surrounded with thick layers of the manganese, and others with merely a slight coating. We will make use of these facts to establish the conclusions which terminate this paper.

In these red clays there occur in addition the greatest number of cosmic metallic spherules, or chondres, the nature and characters of which we have pointed out elsewhere.[1] We merely indicate their presence here, as we will support our conclusions by a reference to their distribution.

Reviewing, then, the distribution of oceanic deposits, we may summarise thus:—

(1) The terrigenous deposits, the blue muds, green muds and sands, red muds, volcanic muds and sands, coral muds and sands, are met with in those regions of the ocean nearest to land. With the exception of the volcanic muds and sands, and coral muds and sands around oceanic islands, these deposits are found only lying along the borders of continents and continental islands, and in inclosed and partially inclosed seas.

(2) The organic oozes and red clay are confined to the abysmal regions of the ocean basins; a Pteropod ooze is met with in tropical and subtropical regions in depths less than 1500 fathoms, a Globigerina ooze in the same regions between the depths of 500 and 2800 fathoms, a Radiolarian ooze in the central portions of the Pacific at depths greater than 2500 fathoms, a Diatom ooze in the Southern Ocean south of the latitude of 45° south, a red clay anywhere within the latitudes of 45° north and south at depths greater than 2200 fathoms.

Conclusions.—All the facts and details enumerated in the foregoing pages point to certain conclusions which are of considerable geological interest, and which appear to be warranted by the present state of our investigations.

We have said that the debris carried away from the land accumulates at the bottom of the sea before reaching the abysmal regions of the ocean. It is only in exceptional cases that the finest terrigenous materials are transported several hundred miles from the shores. In place of layers formed of pebbles and clastic elements with grains of considerable dimensions, which play so large a part in the composition of emerged lands, the great areas of the ocean basins are covered by the microscopic remains of pelagic organisms, or by the deposits coming from the alteration of volcanic products. The distinctive elements that appear in the river and coast sediments are, properly speaking, wanting in the great depths far distant from the coasts. To such a degree is this the case that in a great number of soundings, from the centre of the Pacific for example, we have not been able to distinguish mineral particles on which the mechanical action of water had left its imprint, and quartz is so rare that it may be said to be absent. It is sufficient to indicate these facts in order to make apparent the profound differences which separate the de-

[1] "On Cosmic and Volcanic Dust," *Proc. Roy. Soc. Edin.*, 1883-84.

[1] "On Cosmic and Volcanic Dust," *Proc. Roy. Soc. Edin.*, 1883-84.

posits of the abysmal areas of the ocean basins from the series of rocks in the geological formations. As regards the vast deposits of red clay, with its manganese concretions, its zeolites, cosmic dust, and remains of Vertebrates, and the organic oozes which are spread out over the bed of the Central Pacific, Atlantic, and Indian Oceans, have they their analogues in the geological series of rocks? If it be proved that in the sedimentary strata the pelagic sediments are not represented, it follows that deep and extended oceans like those of the present day cannot formerly have occupied the areas of the present continents, and as a corollary the great lines of the ocean basins and continents must have been marked out from the earliest geological ages. We thus get a new confirmation of the opinion of the permanence of the continental areas.

But without asserting in a positive manner that the terrestrial areas and the areas covered by the waters of the great ocean basins have had their main lines marked out since the commencement of geological history, it is, nevertheless, a fact, proved by the evidence derived from a study of the pelagic sediments, that these areas have a great antiquity. The accumulation of sharks' teeth, of the ear-bones of Cetaceans, of manganese concretions, of zeolites, of volcanic material in an advanced state of decomposition, and of cosmic dust, at points far removed from the continents, tend to prove this. There is no reason for supposing that the parts of the ocean where these Vertebrate remains are found are more frequented by sharks or Cetaceans than other regions where they are never or only rarely dredged from the deposits at the bottom. When we remember also that these ear-bones, teeth of sharks, and volcanic fragments, are sometimes incrusted with two centimetres of manganese oxide, while others have a mere coating, and that some of the bones and teeth belong to extinct species, we may conclude with great certainty that the clays of these oceanic basins have accumulated with extreme slowness. It is indeed almost beyond question that the red clay regions of the Central Pacific contain accumulations belonging to geological ages different from our own. The great antiquity of these formations is likewise confirmed in a striking manner by the presence of cosmic fragments, the nature of which we have described ("On Cosmic and Volcanic Dust," *Proc. Roy. Soc. Edin.*). In order to account for the accumulation of all the substances in such relatively great abundance in the areas where they were dredged, it is necessary to suppose the oceanic basins to have remained the same for a vast period of time.

The sharks' teeth, ear-bones, manganese nodules, altered volcanic fragments, zeolites, and cosmic dust are met with in greatest abundance in the red clays of the Central Pacific, at that point on the earth's surface farthest removed from continental land. They are less abundant in the Radiolarian ooze, are rare in the Globigerina, Diatom, and Pteropod oozes, and they have been dredged only in a few instances in the terrigenous deposits close to the shore. These substances are present in all the deposits, but owing to the abundance of other matters in the more rapidly forming deposits their presence is masked, and the chance of dredging them is reduced. We may then regard the greater or less abundance of these materials, which are so characteristic of a true red clay, as being a measure of the relative rate of accumulation of the marine sediments in which they lie. The terrigenous deposits accumulate most rapidly, then follow in order Pteropod ooze, Globigerina ooze, Diatom ooze, Radiolarian ooze, and, slowest of all, red clay.

From the data now advanced, it appears possible to deduce other conclusions important from a geological point of view. In the deposits due essentially to the action of the ocean, we are at once struck by the great variety of sediments which may accumulate in regions where the external conditions are almost identical. Again, marine faunas and floras, at least those of the surface, differ greatly, both with respect to species and to relative abundance of individuals, in different regions of the ocean; and as their remains determine the character of the deposit in many instances, it is legitimate to conclude that the occurrence of organisms of a different nature in several beds is not an argument against the synchronism of the layers which contain them.

The small extent occupied by littoral formations, especially those of an arenaceous nature, shown by our investigations, and the relatively slow rate at which such deposits are formed along a stable coast, are matters of importance.

In the present state of things there does not appear to be anything to account for the enormous thickness of the clastic sediments making up certain geological formations, unless we consider the exceptional cases of erosion which are brought into play when a coast is undergoing constant elevation or subsidence.

Great movements of the land are doubtless necessary for the formation of thick beds of transported matter like sandstones and conglomerates.

In this connection may be noted the fact that in certain regions of the deep sea no appreciable formation is now taking place. Hence the absence, in the sedimentary series, of a layer representing a definite horizon must not always be interpreted as proof either of the emergence of the bottom of the sea during the corresponding period, or of an ulterior erosion. Arenaceous formations of great thickness require seas of no great extent and coasts subject to frequent oscillations, which permit the shores to advance and retire. Along these, through all periods of the earth's history, the great marine sedimentary phenomena have taken place.

The continental geological formations, when compared with marine deposits of modern seas and oceans, present no analogues to the red clays, Radiolarian, Globigerina, Pteropod, and Diatom oozes. On the other hand, the terrigenous deposits of our lakes, shallow seas, inclosed seas, and the shores of the continents, reveal the equivalents of our chalks, greensands, sandstones, conglomerates, shales, marls, and other sedimentary formations. Such formations as certain Tertiary deposits of Italy, Radiolarian earth from Barbados, and portions of the Chalk where pelagic conditions are indicated, must be regarded as having been laid down rather along the border of a continent than in a true oceanic area. On the other hand, the argillaceous and calcareous rocks recently discovered by Dr. Guppy in the upraised coral islands in the Solomon Group are nearly identical with the Pteropod and Globigerina oozes of the Pacific.

Regions situated similarly to inclosed and shallow seas and the borders of the present continents appear to have been, throughout all geological ages, the theatre of the greatest and most remarkable changes; in short, all, or nearly all, the sedimentary rocks of the continents would seem to have been built up in areas like those now occupied by the terrigenous deposits, which we may designate "*the transitional or critical area of the earth's surface.*" This area occupies we estimate, about two-eighths of the earth's surface, while the continental and abysmal areas occupy each about three-eighths.

During each era of the earth's history the borders of some lands have sunk beneath the sea and been covered by marine sediments, while in other parts the terrigenous deposits have been elevated into dry land, and have carried with them a record of the organisms which flourished in the sea of the time. In this transitional area there has been throughout a continuity of geological and biological phenomena.

From these considerations it will be evident that the character of a deposit is determined much more by distance from the shore of a continent than by actual depth; and the same would appear to be the case with respect to the fauna spread over the floor of the present oceans. Dredgings near the shores of continents, in depths of 1000, 2000, or 3000 fathoms, are more productive both in species and individuals than dredgings at similar depths several hundred miles seawards. Again, among the few species dredged in the abysmal areas furthest removed from land, the majority show archaic characters, or belong to groups which have a wide distribution *in time* as well as over the floor of the present oceans. Such are the Hexactinellida, Brachiopoda, Stalked Crinoids and other Echinoderms, &c.

As already mentioned, the transitional area is that which now shows the greatest variety in respect to biological and physical conditions, and in past time it has been subject to the most frequent and the greatest amount of change. The animals now living in this area may be regarded as the greatly modified descendants of those which have lived in similar regions in past geological ages, and some of whose ancestors have been preserved in the sedimentary rocks as fossils. On the other hand, many of the animals dredged in the abysmal regions are most probably also the descendants of animals which lived in the shallower waters of former geological periods, but descended into deep water to escape the severe struggle for existence which must always have obtained in those depths affected by light, heat, motion, and other conditions. Having found existence possible in the less favourable and deeper water, they may be regarded as having slowly spread themselves over the floor of the ocean, but without undergoing great modifications, owing to the extreme uniformity of the conditions and the absence of competition. Or we may suppose that, in the depressions which have taken place near coasts, some species have been gradually carried down to deep water, have accommodated themselves to the new conditions, and have gradually migrated to the regions far from land. A few species may thus have migrated to the deep sea during each geological period. In this way the origin and distribution of the deep-sea fauna in the present oceans may in some measure be explained. In like manner, the pelagic fauna and flora of the ocean is most probably derived originally from the shore and shallow water. During each period of the earth's history a few animals and plants have been carried to sea, and have ultimately adopted a pelagic mode of life.

Without insisting strongly on the correctness of some of these deductions and conclusions, we present them for the consideration of naturalists and geologists, as the result of a long, careful, but as yet incomplete, investigation.

THE FIXED STARS[1]

THERE is no science which has so long and so continuously occupied the thoughtful minds of successive generations of men as has astronomy; and of its various branches there is one which has for all ages possessed a special fascination, viz. that of sidereal astronomy.

There has ever been a desire to burst aside the constraints imposed upon our research by the distances of space, to pass from the study of the planets of our solar system to that of the suns and galaxies that surround us, to determine the position and relative importance of our own system in the scheme of the universe and the whence we have come and the whither we are drifting through the realms of space.

Questions without number crowd upon the mind. The galaxy or Milky Way—what is it? Is our sun one of its members? What is the shape of that galaxy? What are its dimensions? What is the position of our sun in it?

The star-clusters—what are they, these wondrous aggregations where hundreds and even thousands of suns may be seen in the limited field of view of a powerful telescope? Are these clusters galaxies? Have these suns real dimensions comparable with those of our sun, and is it distance alone that renders their light and dimension so insignificant to the naked eye? Or are the real dimensions of the clusters small as compared with our galaxy? Are their component suns but the fragments of some great sun that has been shattered by forces unknown to us, or have they originated from chaotic matter, which, instead of forming one great whirlpool and condensing by vortex action into one great sun, has been disturbed into numerous minor vortices, and so become rolled up into numerous small suns?

The nebulæ—what are they? Are they too condensing into clusters or stars, or will their ghost-like forms remain for ever unchanged amongst the stars? or do they play some part in the scheme of nature of which we have as yet no conception?

These and many others are the questions which press on the ardent mind that contemplates the subject; and there arises the intense desire to answer such questions, and where facts are wanting to supply facts by fancy. The history of deep and profound thought in some of these subjects goes back through 2000 years, but the history of real progress is but as of yesterday. The foundation of sidereal astronomy may be said to have begun with the art of accurate observation. Bradley's meridian observations at Greenwich about 1750, his previous discovery of the aberration of light in 1727, and Herschel's discovery of the binary nature of double stars, his surveys of the heavens, and his catalogues of double stars—these are solid facts, facts that have contributed more to the advancement of sidereal astronomy than all the speculations of preceding centuries. They point to us the lesson that "art is long and life is short," that human knowledge, in the slow developing phenomena of sidereal astronomy, must be content to progress by the accumulating labours of successive generations of men, that progress will be measured for generations yet to come more by the amount of honest, well-directed and systematically-discussed observation than by the most brilliant speculation, and that in observation concentrated systematic effort on a special thoughtfully-selected problem will be of more avail than the most brilliant but disconnected work.

I hope that no one present thinks from what I have said that I undervalue the imaginative fervid mind that longs for the truth, and whose fancy delights to speculate on these great subjects. On the contrary, I think and I believe that without that fervid mind, without that longing for the truth, no man is fitted for the work required of him in such a field—for it is such a mind and such desires that alone can sweeten the long watches of the night, and transform such work from drudgery into a noble labour of love.

It is for like reasons that I ask you to leave with me the captivating realms of fancy this evening, and to enter the more substantial realms of fact. And if at any time I should become too technical or dry I beg that you too will remember the noble problems for the solution of which such dry work is undertaken.

We suppose ourselves then face to face with all the problems of sidereal astronomy to which I have hastily referred—the human mind is lost in speculation, and we are anxious to establish a solid groundwork of fact.

Now what in such circumstances would be the instinct of the scientific mind?

The answer is unquestionable—viz. to measure—and no sooner were astronomical instruments made of reasonable exactness than astronomers did begin to measure, and to ask, are the distances of the fixed stars measurable?

I should like to have given a short history of the early attempts of astronomers to measure the distance of a fixed star. I had indeed prepared such an account, but I remembered that there is in this theatre a relentless clock that has curbed the exuberant verbosity of many a lecturer before me, and I found that if the real subject-matter of this evening's lecture were to be reached and dealt with before 10 o'clock, I must pass over this earlier history, instructive and interesting though it is, and come at once to the time when the long baffled labours of astronomers began to be crowned with success.

Perhaps I cannot summarise it better than in the words of Sir John Herschel. In one of his presidential addresses he says:—"The distance of every individual body in the universe from us is necessarily admitted to be finite. But though the distance of each particular star be not in strictness infinite, it is yet a real and immense accession to our knowledge to have *measured* it in any one case. To accomplish this has been the object of every astronomer's highest aspirations ever since sidereal astronomy acquired any degree of precision. But hitherto it has been an object which, like the fleeting fires that dazzle and mislead the benighted wanderer, has seemed to suffer the semblance of an approach only to elude his seizure when apparently just within his grasp, continually hovering just beyond the limits of his distinct apprehension, and so leading him on in hopeless, endless, and exhausting pursuit."

Those who have read the history of exact astronomy from the days of Flamsteed—*i.e.* from 1689—down to 1832, will understand how exactly these words of Sir John Herschel describe the position of the problem.

But these laborious pursuits, like all honest researches in quest of truth, were not without reward, even though the immediate object in view was not attained. Bradley was rewarded by his great discovery of aberration, and Sir William Herschel by the greatest of his great discoveries, the binary nature of double stars, when engaged in vain attempts to measure the distance of a fixed star. Time forbids that I should tell more of this instructive story—for the story of failure is often fully as instructive as that of success—and I must begin the history of our problem between 1832 and 1842, when success was first attained.

But before I begin it will save both time and circumlocution if I define a word that we must frequently use—viz. the word parallax.

Here on the table is a large ball representing the sun, and here, travelling on a circular railway round the larger ball, is a smaller ball which we shall suppose to represent the earth. The larger ball is suspended from the ceiling by a white string, the small ball is suspended from the same point by a red string. At the far end of the white string you can suppose a star whose true direction is represented by this white string, and whose apparent direction as looked at from the earth is represented by the red string. Now if the star is within a measurable distance, the red string which indicates the star's apparent direction as seen from the earth will always be displaced inwards towards the sun. This displacement is called "parallax." It may be defined as the change in the apparent place of a star produced by viewing it from a point other than that of reference. Our point of reference for stars is the sun, and as we view the stars now from one side of the sun, and six months afterwards from a point on the

[1] Lecture on Friday evening, May 23, at the Royal Institution, "On Recent Researches on the Distances of the Fixed Stars, and on some Future Problems in Sidereal Astronomy," by David Gill, LL.D., F.R.S., Her Majesty's Astronomer at the Cape of Good Hope.