GEOGRAPHICAL NOTES.

THE Berlin Geographical Society are preparing for publication one of the most valuable mementoes of the Columbus celebration, in the form of a magnificent atlas, containing amongst other early maps a series of hitherto unpublished delineations of the Atlantic of very early date. These maps have been discovered in manuscript in Italian libraries, where they were copied by a young German geographer of great artistic power. They will be published with all the brilliant colouring of the original illuminated MSS.

IN the recent risings of the Arabs against European traders and officials on the Lomami in the Congo Free State, there is too much reason to fear that the veteran M. Hodister, Director of the Katanga Company in Africa, has lost his life. This is a disaster of a much more serious kind than the mere collapse of a trading company, for M. Hodister in the course of his long service in Central Africa had acquired a remarkable knowledge of the Arabs, and great tact and success in dealing with them. In his personal character he commanded the respect of all with whom he came in contact; courage he shared with many fellow-explorers, but his calmness in danger and serious earnestness in work are not too common amongst the Congo State officials or the leaders of caravans through the territory. M. Hodister was one of the first Belgian officers appointed on the establishment of the Congo Free State, and as an official, and later as the head of the Katanga syndicate in Africa, he has spent the best years of his life in opening up the Congo Basin.

THE Sixth International Geographical Congress having been fixed to meet at London in June, 1895, an organizing committee, of which Major Leonard Darwin is President, and Mr. J. Scott Keltie Secretary, has been appointed by the Council of the Royal Geographical Society. Circulars have been sent out calling attention to the fact that the meeting is to take place, and inviting suggestions. A provisional programme of the proceedings will be drawn up in the course of next year.

AN exhaustive bibliography of Socotra has just been published as a pamphlet of forty pages by M. James Jackson, the librarian of the Paris Geographical Society. Including references to maps, there are 176 entries relating to this island; many of these papers had almost passed into oblivion, and their recovery and systematic presentation is of much value.

SOME PROBLEMS IN THE OLD ASTRONOMY.[1]

IF a comparison were instituted between the position of the modern astronomer and that of his prototype on the plains of Chaldea, it would not be altogether to the disadvantage of the ancient student of the heavens. He stood at the gateway of the unexplored Uranian mysteries, unfettered by the dogmatic theories of a line of predecessors. From his own imagination he constructed hypotheses and theories, with no feeling of uncertainty about the priority of invention, and with little anxiety concerning the agreement of theory and observation. The modern questions that distract the astronomical world had no place among the thoughts that disturbed the tranquillity of his soul. He had not reached that critical epoch when he must choose between the "old" and the "new" astronomy; and he was free from the harassing perplexity that besets the luckless astronomer of this age who seeks to learn the mysteries of the moon's motion, or strives to formulate the cause and the law of the variation in the terrestrial latitude. The iniquitous behaviour of the astronomical clock and level, combined with the possible, but unknown, influences of temperature, were not then in league to vex his waking hours and fill his dreams with illusory solutions that ever floated just beyond his grasp. He was not obliged to search the ancient records in musty volumes and strain the limits of conjecture in the interpretation of careless observations and imperfect memoranda; in short, he was a happy man, free to work in any direction, and not liable to be called upon from time to time to amuse or to instruct his fellows, or even to weary them, with prosy discourse on his own work or a stale *résumé* of astronomical progress.

Unfortunately for us, we live in an age when astronomy is no longer a simple subject, stimulating the imagination by the nightly display of stellar and planetary glories, and involving in its study only the elements of geometrical analysis. Within the last fifty years the science has been separated into many divisions; and within a few years several of these branches have assumed new phases. As a result of this continued division, the range of study and investigation has spread beyond the efficient grasp of any individual, and specialists are rising up in all directions.

It has been the custom for the presiding officer of this section to present, on the first day of the annual session, an address setting forth either the progress in general astronomy or in some branch of the science, or the history or development of some department of mathematics, each confining himself to his own special branch of scientific work.

It has seemed to me that a formal statement, to this section, of the general progress of astronomy within the last year or the last decade, would be to lay before you a mass of data with which you are already familiar. This view of the case has led me to attempt the presentation of the importance of one branch of astronomical work in which for several years I have taken a deep personal interest, and which, owing to the present tendency towards specialization, is likely to suffer from serious neglect.

It is not many years since we first heard of the distinction between the "old" and the "new" astronomy, but in the comparatively short interval since those terms were first used the scope of physics has so expanded in all directions and so adapted itself to its new surroundings that we find it, in one department at least, casting aside its former title and masquerading under the name of astronomy. That this departure has quickened the zeal of many students, stimulated the development of numerous and valuable modes of research, and resulted in grand and important discoveries, is one of the most gratifying scientific facts of this epoch. The direction of this new movement has followed rigorously the line of least resistance. Except in rare instances, that line of work which promises the quickest returns in the proper form for publication is most attractive to the young student of physics and astronomy, and the comparatively inexpensive apparatus required for the simpler astro-physical work is apt to lead him in that direction. The new and important changes that have been wrought within a few years in the methods of teaching and in the laboratory work in physics, together with the apparent ease with which an account of a few hours' labour with the spectroscope or camera may be spread attractively over several printed pages, have doubtless had their influence in leading the candidates for honours into the new fields of astro-physical research.

The advance in the development of methods of research and the improvements in apparatus are so rapid, and the field is so broad and increasing, that constant vigilance is necessary to keep even in touch with the progress of the "new" astronomy. One of the most striking examples of the achievements in this new line of work has resulted from a skilful combination of the spectroscope and the camera in the determination of stellar motion in the line of sight with a remarkable linear exactness.

The limits of this address would scarcely suffice to simply name the problems now under discussion by the more modern methods, without essaying even a cursory review of their importance or their bearing on current scientific investigation; and yet, from the true astronomical point of view, all of these questions are at least secondary to the fundamental problems of finding the true position of the solar system in the stellar universe and determining the relative positions and motions of those stars that, within the range of telescopic vision, compose that universe.

To this latter phase of our science I ask your attention for a few minutes. These problems still lie at the foundation of the "old" astronomy and cannot be relegated to the limbo of useless rubbish or to the museum of curious relics, not even to make room for the new-born astro-physics. On this foundation must rest every astronomical superstructure that hopes to stand the tests of time and of observation, and the precision of the future science depends rigorously upon the accuracy with which this groundwork is laid.

This work was begun in the sixteenth century, but, in spite of all the improvements in apparatus and in methods of analysis and research, a really satisfactory result has not yet been reached. There is no more fascinating phase of the evolution of human thought and skill in the adaptation of means to ends than is found in the development of the mathematical and instru-

[1] Address delivered before Section A of the American Association for the Advancement of Science, by Vice-President J. R. Eastman.

mental means for the determination of the positions and motions of the bodies included in the solar system. Accuracy in astronomical methods and results did not exist, even approximately, until after the revival of practical astronomy in Europe about the beginning of the sixteenth century; and, before the end of that period, the crude instruments of the early astronomers reached their highest perfection in the hands of the skilful genius of Uraniborg.

The invention of the telescope, the application of the pendulum to clocks, the invention of the micrometer, the combination of the telescope with the divided arc of a circle, the invention of the transit circle by Roemer, with many improvements in minor apparatus, distinctly stamp the seventeenth century as a remarkable period of preparation for the achievements of the next century.

From the standpoint of the modern mechanician the instruments at the Greenwich Observatory in Bradley's time were very imperfect in design and construction, and yet on the observations obtained by his skill and perseverance depends the whole structure of modern fundamental astronomy. The use of the quadrant reached its highest excellence under Bradley's management.

The next advance, the real work with divided circles, began at Greenwich in 1811, under the direction of Pond. Since that epoch, theory and observation have held a nearly even course in the friendly race toward that elusive goal perfection; and the end is not yet. A careful, but independent, determination of the relative right ascensions of the principal stars, supplemented by a rigorous adjustment of such positions with regard to the equinoctial points, and a similar determination of the relative zenith or polar distance of the same bodies, finally referred and adjusted to the equator or the pole, seem in this brief statement to be, at least, simple problems. If, however, we examine the conditions in detail the simplicity may not appear so evident; and this characteristic may prove to be one reason why this important branch of astronomical research is now so generally neglected.

In the first place, it must be understood that such an investigation cannot be completed in a few months. At least *two* and preferably *three* years' work in observing are necessary to secure good results. Skilled observers, and not more than two with the same instrument, are absolutely necessary. Such work cannot be confided to students or beginners in the art of observing, or to observers who have acquired the habit of anticipating the transit of a star. The telescope and the circles, the objective and the micrometer, the clock and the level must be of the best quality, for imperfections in any of these essentials render the best results impossible. A thoroughly good astronomical clock is the rarest instrument in the astronomer's collection. It is not sufficient that a clock should have a uniform daily rate, the rate should be uniform for any number of minor periods during the twenty-four hours. The absolute personal error in observing transits should be determined at least twice a week, and when it is not well established it should be found every day. The level error should be found every two hours, and the greatest care should be exercised in handling this important instrument. The division marks should not be etched on the level tube unless the values of the divisions are frequently examined, for, sooner or later, such tubes become deformed on account of the broken surface, and are then worthless.

In the determination of zenith distances the effect of refraction plays such an important part that no work can rightly claim to be fundamental until the local refraction has been carefully investigated, and special corrections to the standard tables, if necessary, have been deduced for each observing station. The ordinary mode of observing temperature is quite inadequate to the importance of the phenomena. These observations should be made as near as possible in the mass of air through which the objective of the telescope is moved, and also in the opening in the roof and the sides of the observing room where the outside air comes in contact with that in the building. The thermometers should all be mounted, so that they may be whirled in that portion of the air where the temperature is desired, and they should be tested at least once a year to determine the change in the position of the zero of the scale. But a complete list of the things to be done, and of the errors to be avoided, are too voluminous for this occasion, and are not necessary to show the complex character of the problem; the suggestions already made must suffice.

For many years an immense number of observations of the larger or the so-called standard stars have been made at the principal observatories, for different purposes and with varying degrees of accuracy, but it is not certain that the work of the last thirty years, with all the advantages of improved apparatus, has resulted in more exact determinations of even the relative right ascension of such stars. There can be no doubt that the chronographic registration of star transits has given more accurate results for the smaller stars, but I think it is equally true that, in the case of first and second magnitude stars at least, no improvement has been made in accuracy.

With double threads it is possible to observe the zenith distances of such stars with a fair degree of precision, because the operation is one of comparative deliberation, and the centre of the mass of light can be placed midway between the threads with little difficulty. But the attempt to note, with a chronograph key, the instant when a swiftly-moving and irregular mass of light, like α Canis Majoris or α Lyræ, is bisected by a transit-thread, is an operation that rises but little above the level of ordinary guesswork. Transits of first and second magnitude stars cannot be observed with an objective of more than four inches aperture with the desired accuracy, unless the apparent magnitude is reduced, by means of screens, to that of a fourth or fifth magnitude star. It is necessary in this connection to avoid confounding the methods employed in the observations of the bodies of the solar system with those for obtaining fundamental places of the stars. The observations of the Sun, Moon, Mercury, and Venus with a transit circle are, from the unavoidable conditions, necessarily uncertain to a degree even beyond the probable error involved in the observations of the large stars. In spite of these unfavourable conditions, however, the continued observations of these bodies at the principal observatories for many years have produced the most valuable results, even when the work on the standard stars, on which their results depend, has no claim whatever to a fundamental character.

In geographic exploration the first endeavour is to secure approximate positions of salient points from a rapid reconnoissance. This is followed by more careful work, fixing the observing stations with that degree of precision which ensures good results. Finally, the highest qualities of skill and science are combined to exhaust all available means to reach the greatest attainable accuracy. In the exploration of the heavens, the first two of these steps have already been taken, and most of the stars of the larger magnitudes have been so well observed, that the accuracy of their positions is not only far higher than is required by the greatest skill of the navigator, but it is equal to all the demands of ordinary practical work. It is the next step which challenges the skill of the mechanician, the observer, and the computor; and astronomers cannot rest at ease until all known resources have been exhausted in the attempt to reach the best results. It is not a very difficult matter to fix the position of stars within a range, in the individual observations, of three or four seconds of arc; but that degree of accuracy is not sufficient for the more exact problems of astronomy, and it falls far short of what is required in the important discussions of solar and stellar motions.

Bradley's observations furnish the data for Bessel's "Fundamenta Astronomiæ," and many astronomers have since attempted by reductions to obtain improved positions for Bradley's stars. The value of these observations in the development of modern astronomy can hardly be exaggerated. Their importance in the dermination of stellar proper motions increases with the lapse of time, and yet the accuracy of the original observations was far inferior to that obtained in ordinary routine work with modern methods and improved instruments.

Fundamental catalogues of stars have notably increased since the "Fundamenta Astronomiæ," but the demand has not yet been satisfied. The catalogues of declinations or north-polar distances are more numerous than those of right ascension, evidently because, for many reasons, independent declinations are more readily determined.

There is probably no collection of the right ascension of the large stars that has attained, or justly deserved, a higher reputation than the Pulkowa Catalogue. The observations on which this catalogue is founded were made by Schweizer, Fuss, Lindshagen, and Wagner, at the Pulkowa observatory between 1842 and 1853. The observations were reduced by the several observers, thoroughly discussed by Wagner, and published in 1869. Only one observer was employed at any period. As these results have received high praise for their accuracy, and for their freedom from systematic errors, it may be of some interest to consider

briefly, and in a general way, the character of the data on which the results depend.

The objective of the transit instrument with which these observations were made, had a focal length of 8 feet and 6 inches and a diameter of 5·85 inches. It was so constructed that the ocular and the objective could be interchanged. It was also reversible, and a part of the observations were made with the clamp east and the remainder with the clamp west. This construction permitted the observations to be made under four different sets of conditions, and for that reason the observed right ascensions of each star were arranged, for facility of discussion, in four separate groups.

An examination of the results in each group discloses some interesting facts that are worth considering somewhat in detail. The whole number of stars in the catalogue that are reckoned as standard stars, and are south of 70° north declination, is 365. Of this number 70 per cent. have a range, in the individual results, in at least one of the four groups, of two-tenths, or more, of a second of time. This range is between 0·20 and 0·29 for 142 stars; between 0·30 and 0·39 for 92 stars; between 0·40 and 0·49 for 15 stars; and 0·50 or more for six stars. The mean range for the 255 stars is 0·297. In general, the accordance between the individual results is quite good, but the discordance just mentioned sometimes occurs more than once in the collected observations of the same star, and these doubtful data have been used in deducing the standard places given in the catalogue. It is not necessary to look for minor discrepancies, for enough of appreciable magnitude have been cited already to warrant the conclusion that better observing can and ought to be done with modern instruments, and that the needs of astronomical science to-day demand a more comprehensive, and a more accurate, standard catalogue of right ascensions.

These remarks must not be interpreted as unfavourable criticism of the Pulkowa Catalogue, by far the best work of its period, but they are made simply to call attention to the fact that the present state of stellar astronomy and the direction which the investigations of the immediate future are likely to take, plainly require the most accurate fundamental catalogue of the standard stars that modern instruments and appliances, modern methods and the most skilful observers can produce. All of these conditions are essential, and they must be carefully co-ordinated to obtain the desired results.

It must be plain to every astronomer that the needed fundamental catalogue must be deduced from new observations. The reduction and the discussion of old observations of doubtful quality is a waste of time and energy. Under existing circumstances the greatest weight must be given to the observations. Neither amount of labour nor skill in computation can derive results of the desired accuracy from careless, incomplete, or incorrect observations. An attempt on the part of the computer to apply any system of theoretical weights, either simple or complex, to such observations is almost certain to lead, at least, to self-deception; and the safe as well as reasonable rule in such case would be to use the weight zero.

One example may serve to illustrate the effect of dealing continuously with old observations. In standard star positions the four principal national ephemerides are not only not in accord with each other, but they generally do not exhibit results even from the few best modern observations. The many discrepancies of varying magnitude in these volumes present with marked emphasis the undesirable results arising from the custom of "threshing old straw."

The data on which these several ephemerides are founded are the common property of all astronomers, and no one can claim the exclusive use of any published observations; and yet national pride or national obstinacy, which is sometimes mistaken for the nobler sentiment, or some computer's pet scheme or system of combination, has led to the adoption of a variety of assumptions in the interpretation and treatment of the original data until our standard ephemerides are so complex in their structure that the exact details of their preparation are practically unknown outside their respective computing offices. The accuracy of the star positions is unchecked by any recent fundamental observations, and they lack that trustworthy character that should inhere in a system intended to serve as a basis for even good differential work.

If this character were wholly satisfactory, we should soon see the representatives of astronomy, geodesy, and geology gathering about the zenith telescope, confident of reaching some definite conclusion in regard to the variation of terrestrial latitudes by the systematic use of this simple instrument. But the accurate star positions do not exist, and under the present conditions the most feasible plan for utilizing this instrument is to so arrange the observing stations as to eliminate the effect of errors in the star places.

If it be admitted that sidereal astronomy is worthy of further and more accurate study, that the needs of astronomical research at the present time and in the immediate future demand more exact positions of the standard stars, it may be desirable to consider briefly the status of those agencies to which we must look for the successful prosecution of such an investigation.

It is not an easy task to determine the exact number of active observatories in the world. Some published lists contain the names of all observatories, from the most expensive and fully equipped Government establishments to the temporary shelter that protects a small equatorial telescope, and perhaps a chronometer, which is kept by the owner for the amusement and possibly for the instruction of himself and his friends. A fair enumeration, however, would probably give a list of about 250 observatories sufficiently equipped to do some kinds of astronomical work. Of this number more than 20 per cent. are found in North America. In the equipment of these 250 observatories are to be found about sixty transit circles with objectives ranging from nine to about three inches. The quality of about one-fourth of these instruments is such that good results may be expected from their proper employment. To the latter class of instruments we are limited when we seek for the highest class of work now under consideration. If we take account of the modern subsidiary apparatus, and of the electric methods of recording transit observations and illuminating the different parts of the instrument, it does not seem extravagant to conclude that, if one third of the best transit circles were devoted for the next four years to observations for the formation of a fundamental star catalogue of right ascensions and north-polar distances, the aggregate result would be not only the best positions ever published, but it would be of the greatest value in the discussion of current, as well as future, astronomical problems. Unfortunately, however, we do not find any such number of instruments employed in fundamental work. At the present time there is no general fundamental work in progress in any portion of the world, and within the last thirty years there have been no results of that character to take the place of the Pulkowa determinations. This statement does not refer to observations of one ordinate only, or to those cases where several observers, both trained and untrained, are accustomed to observe in turn with the same instrument and their several results are indiscriminately mingled in such a way that critical discussion is out of the question. Several observers may work together in the determination of declinations with a fair degree of success, because, to a large extent, each observer's work in a period of twelve or twenty-four hours is independent of that of his fellow's; but even this work is better when done by one skilled observer alone. Fundamental right ascensions, however, cannot be determined with the requisite accuracy, and the necessary freedom from systematic errors, if more than one or, at most, two observers work with the same instrument. If only accidental errors of observation, or such as are due to atmospheric disturbances, uncomfortable positions, or the unsteady nerves of the observer, were introduced by increasing the number of observers, then increasing the number of observations would tend to diminish the error of the result. But the personal errors of observers, and their various habits of manipulation, are of the same nature as systematic errors, and cannot be eliminated by increasing the list of observers or the number of observations.

Of the many valuable star catalogues in existence, I know of none in which the right ascensions depend upon the observations of more than one astronomer, where it is possible to know, or to eliminate, either the constant or the variable errors due to the personal equation of the observers.

In the current astronomical work of this country in which we, as members of this section, are especially interested, observations and discussions, planned solely, and properly carried out, for the determination of absolute star places, are quite unknown. The necessary instrumental outfit, with the exception in some cases of a clock of the requisite quality, exists in several observatories, and I have no doubt that trained observers of the highest character can be found to meet all demands.

With the exception of a few Government establishments, and of those built to promote a higher grade of instruction, the ob-

servatories throughout the world have been founded generally for some special purpose. Their existence depended upon some endowment or bequest originating in the real or fancied interest which the wealthy benefactor took in some popular branch of the science, and this founder, with a real enthusiasm for the stimulation of research, and a noble generosity that deserved recognition in a broader field, often unwittingly limited the scope of his foundation and restrained the usefulness of his gift. Utility or novelty, separately or in combination, were frequently the groundwork on which were based the successful claims for pecuniary assistance in founding and maintaining astronomical observatories. The working observatories founded fifty years or more ago, with scarcely an exception, were supported entirely in the belief that the results of the observations would be, directly or indirectly, beneficial to navigation and to commerce. At that time this belief rested upon a reasonable basis. This plea for the construction and support of observatories is sometimes heard even at this period in the evolution of science, in spite of the fact that, if every fixed observatory in the world were destroyed to-day, no interest of navigation or commerce would suffer for the next fifty years. The function of astronomy in promoting the development of navigation and in fostering the extension of commerce has been completed.

In the periodical struggle with wealthy patrons to secure the yearly stipend, and with corporations and legislative bodies to obtain the annual appropriations for the support of observatories, may be found perhaps an apparent, if not a sufficient, motive for selecting the class of work that is pursued in most of the American observatories at this time. The apparent conclusion of those who have sought financial support for astronomical observatories seems to have been that such aid could not be secured except for some special work or research, and that the particular branch of investigation selected must be one that promised either immediate and novel results, or such as would enable capital to win, either in material benefits or in popular reputation, some returns for the risks incurred in speculative advances. Persistence in these theories and in the consequent lines of action, has doubtless resulted in the evolution of a certain type of astronomer, and also of a corresponding type of astronomical patron, whether the latter be an individual, a corporation, or the legislative agents of millions of intelligent people. Such a result would be the obvious outcome of the forces in action.

The motives that actuate the early settlers in new countries, that guide them in the struggle with the untamed forces of nature, arise mainly from the material interests of the pioneer. As the subjugation of the land progresses and the comforts and luxuries of life are substituted for the bare necessities of existence, the higher, intellectual side of humanity asserts itself and demands, not only a hearing in the councils, but also its share in the advantages won in the campaign for material prosperity.

The progress in the development of the various stages of civilization has its parallel in the evolution of the science of modern astronomy. For many centuries the timid navigator skirted the familiar shores of his native land, or, occasionally lured by the hope of unusual gains, he rashly tempted fate by adventurous cruises along distant shores that bore no name in the traditions of his forefathers. But, however lofty his ambition, he never allowed the known or unknown peaks and headlands to sink below his horizon. To him the open ocean was a symbol of infinite space that he dared not explore until astronomy furnished the key to its uttermost recesses, and the art of navigation rose to the dignity of a science.

Greenwich Observatory was founded in 1675 to promote the interests of navigation. The royal warrant appointing the first astronomer royal also declares that his duty is "forthwith to apply himself with the most exact care and diligence to the rectifying the tables of the motions of the heavens and the places of the fixed stars, so as to find out the so much desired longitude of places for the perfecting the art of navigation." Right faithfully have the successive astronomers royal carried out the spirit of the royal mandate. For many years the success was far from uniform, nor was the progress always satisfactory, but, through adversity as well as prosperity, the original design of the foundation was always kept in view, and the results have been commensurate with the effort. If the work of all the other observatories of the world were neglected or destroyed, the data in the annual volumes of the Greenwich Observatory would be sufficient, not only to build anew the science of navigation, but to reconstruct the entire planetary and lunar theories. Surely there can be no more flattering commentary on the value of a well-planned system of observatory work closely followed, through two centuries, with true Anglo-Saxon pertinacity.

The history of Greenwich Observatory is in many respects that of nearly all the observatories, of that early epoch, that have survived to the present time, but most of the urgent needs that led to their foundation have ceased to exist, and new problems have arisen to take their place. The immediate material and commercial advantages, sought for in obedience to the demands of the original foundations, have been fully gained, and the scientific results obtained from the same researches remain a permanent benefaction to the whole world.

To this extent the science of astronomy is deprived of some, perhaps the most efficient, of the influences that commended it to public approval and support during the last two centuries; and the science has now reached a period in its development where we may with propriety consider two pertinent questions. First, what has astronomy gained for itself in the effort to present, in its results, commercial advantages or popular reputation to its patrons, in return for financial support?

Second, what shall be its future attitude when seeking aid in the foundation and endowment of new observatories or in the maintenance of those already in existence?

It may be assumed without fear of contradiction that after the revival of astronomical studies in Europe the rapid development of practical and applied astronomy and the consequent establishment of a large number of observatories was due to the stimulus derived from newly-awakened interests of navigation and commerce. Around these centres of scientific activity the astronomers of the world gathered to discuss not only the problems of practical astronomy, but the more abstruse, theoretical questions which lay at the foundation of the higher branches of the science. The work of each observatory not only furnished the means for determining the accuracy of the numerous theories then extant, but it produced original data on which new theories were constructed, to be in their turn subjected to the rigid test of observation. In the extreme interest evolved in such discussions by those who eagerly sought the key to Nature's methods in the simple form of general laws, the minor problems of practical astronomy were soon solved or passed over to clear the way for the more profound questions that involved the motions in the solar system and the structure of the stellar universe. So, indirectly at first, with a zeal superior to all obstacles, and an ambition that looked beyond the simple and practical idea underlying the original foundation, astronomers have steadily but persistently sought for Nature's general laws in the labyrinth of complex phenomena, have devoted years of intense labour to the most refined tests of methods and theories, and finally, have won for their exacting but fascinating study the foremost place among the sciences. Success in all these labours has justified the wisdom of those royal and wealthy patrons who generously gave their support when a favourable issue was by no means certain.

In its practical results astronomy has returned to mankind a thousand-fold the cost of founding and maintaining its observatories, and at the same time it has developed a science whose field of action includes not only the figure, motions, and positions of our own insignificant planet, but it reaches the uttermost limits of the universe.

If the second question be regarded as involving only a simple problem in ethics it could be readily answered by following the homely, but sometimes pertinent, injunction to "speak the truth." But in view of the complexity of interests now existing this question has a wider signification and deserves some consideration. As already stated, utility or commercial advantage can no longer be given as a reason for carrying on astronomical investigations. Novelty, combined with a desire for architectural display and an absurd ambition to secure the largest telescope and the greatest variety of astronomical instruments, has, even at the present time, a place, and sometimes a prominent one, among the reasons assigned for establishing new observatories. In view of these facts, it is surely the duty of astronomers to see to it that, for their own reputation and for the present and the ultimate welfare of their science, the true purpose of astronomical study and research, and the grounds for the existence and the support of observatories should be frankly given and courageously maintained. It is possible that pecuniary

profit may sometimes indirectly arise from some branches of astronomical work or investigation; but the only sound and honest reason that can be given for such work is, that it stimulates the highest form of intellectual activity, widens the already broad field of investigation, and increases the sum of human knowledge. Whoever pleads the cause of astronomy on a lower plane discounts the intelligence of himself or of his audience. Why should the astronomer stoop to select a less noble theme, or consider it from a lower point of view? He who leads an intelligent and thoughtful life must feel himself in daily touch with those phenomena that are involved in the most important astronomical problems of the present and the immediate future. The figure and motions of the earth which he treads; the constitution and translation of the sun that invigorates his life and lights his days; the movements and structure of the moon and planets that beautify his nights; the proper motions and distances of the countless stars that nightly set before his eyes the highest types of rigorous law and of boundless space that the mind can grasp; all of these, and more, tend to convince him that the constantly growing demand for broader and more exact knowledge is ample warrant for the time and expense involved in the most profound astronomical investigation. In this direction lies the justification of astronomical research; on this basis the astronomer is sure of the stimulating support of every cultivated mind as long as the questions "why" and "how" are constantly reiterated and still are unanswered. On this ground, and on this alone, rest the valid reasons for the expenditure of corporate, municipal, or national funds for the establishment of expensive observatories and the prosecution of astronomical investigations; and in the closing years of this century the conscientious astronomer can in no way more thoroughly vindicate the highest claims of his science than by holding the standard of work well above the popular fancies of the hour, and by devoting his time and energy to that class of fundamental work that shall not only satisfy the rigorous demands of the present time, but shall make the last decade of the nineteenth century an important epoch in the real progress of astronomy.

GEOLOGY AT THE BRITISH ASSOCIATION.

NEARLY fifty papers were contributed to Section C during the meeting of the British Association, and although no new facts or theories of startling interest were brought forward, the record of the year's geological work was decidedly above the average. Owing to Professor Lapworth's regrettable illness his address could not be delivered until Monday, and the chair at the meetings had usually to be taken by one of the vice-presidents.

Glacial and local papers occupied the first two days, the most remarkable being the pair by Messrs. Peach and Horne on the Radiolarian Chert of Arenig age, once probably a deep-sea ooze, which covers 3000 square miles in the southern uplands, and passes like the Moffat shales into sediment when traced towards the north. When the chert is traced to within half a mile of the Loch Doon granite the quartz has become quite granulitic, the radiolaria being still recognizable in the matrix although there is a faint development of mica; close to the granite the rock is completely recrystallized, and consists entirely of large quartz particles full of liquid cavities and rounded inclusions of biotite. Dr. Hicks claimed as pre-Cambrian some tender gneisses, schists, quartzites, and limestones, of the central Highlands, of which he gave microscopic descriptions, and Prof. Blake argued that the discovery of *Olenellus* of the type of *O. Thompsoni*, in beds above the Torridon sandstone, did not necessarily parallel these beds with those containing *Olenellus* beneath the Paradonides zone of America. Amongst the other papers dealing with Palæozoic rocks may be noted Prof. Blake's discovery of a felsite like that of Llyn Padarn, apparently intrusive into the Llanberis slates, seen in a new section in the Penrhyn quarries; Prof. Sollas's discovery of bodies like radiolaria in the slates of Howth, and the limestone of Culdaff; and Prof. Bonney's comparison of the pebbles of the English Bunter with those in the old red conglomerates in Scotland.

Several important glacial papers were read. Dr. Crosskey reported on the recording of new erratics chiefly in the north of England. Mr. Lomas traced Boulders of the Ailsa Craig, Riebeckite Rock, on Moel Tryfaen, in Anglesey and the Vale of Clwyd, at Liverpool and Birkenhead. Mr. Bell considered that the evidence from the shell-beds of Clava and Chapelhall was less consistent with the theory of submergence than with that of transportation by land ice. Messrs. Peach and Horne adduced evidence to show that in Sutherland and Ross-shire, at the time of greatest glaciation, the ice-shed was to the east of the present watershed, and the lofty mountains of Assynt and Loch Maree were glaciated by ice travelling westward. Mr. Clement Reid gave a list of twenty-eight species of Arctic plants from a series of silted-up tarns at Corstorphine and Hailes, near Edinburgh. Prof. Axel Blyth exhibited and described a beautiful set of plant remains preserved in calcareous tufas from Gudbrandsdal, in central Norway. The investigation of the Elbolton cave will probably be completed this year, and it has so far failed to reveal any trace of occupation by Palæolithic man. Messrs. Peach and Horne have studied one out of a group of caves in the Assynt limestone of Sutherlandshire, and found charcoal with split and calcined bones of reindeer, fox, and grouse in the upper layers, and a finely preserved canine tooth of brown bear at a depth of about five feet from the surface. Mr. Coates gave a description of the cuttings, chiefly in boulder-clay, in the Crieff and Comrie railway. And Mr. Kendall attributed the glacical period to variability in the heat of the sun.

Foremost amongst the palæontological papers stands that of Mr. E. T. Newton, in which was given an account of several remarkable skulls obtained from the Elgin sandstone and probably belonging to two or three species related to the African dicynodonts; together with these occurred the skull of a reptile allied to Pareiasaurus of the Karoo beds, but with no less than thirty horns varying from a quarter of an inch to three inches in length. Mr. M. Laurie described two new species of *Eurypterus*, two of *Stylonurus*, and one of a new genus, *Drepanopterus*, of Eurypterids from the Silurian rocks of the Pentland Hills. The work of the type committee still continues, and lists have been received from several museums and private collectors. Reports were also presented on Cretaceous Polyzoa and Palæozoic Phyllopoda, and a paper by Mr. Bullen Newton recorded the discovery of *Chonetes Pratti* in the carboniferous rocks of Western Australia.

The petrological papers included a note on the Malvern crystalline rocks, by Mr. Irving, one on the felsites, andesites, and diabases of Builth, by Mr. Woods; and a short note on the Limerick Traps, by Mr. Watts. Mr. Ussher endeavoured to prove that there must have been a rigid mass occupying the position of the Devon and Cornwall granites at the time when the stratified rocks were folded, in order to account for the deviations in their strike. Mr. Goodchild argued that the junction of the granite of the Ross of Mull was best explained by the absorption of sedimentary rocks in the granite. Mr. Harker explained the presence of porphyritic quartz in basic igneous rocks by supposing that it had formed in the upper layers of a magma basin, and sunk to its present position by gravity. Mr. Teall gave a sketch of the succession of rocks in an area of gneisses, which accorded with the succession from basic to acid types in plutonic masses; and Mr. Somervail endeavoured to explain the chief rocks in the Lizard area by segregation from a single magma.

Finally must be mentioned Professor Hull's paper on the Physical Geology of Arabia Petræa; a very interesting paper by Miss Ogilvie, on the landslips in the South Tyrol, in which she showed how much the mapping of that region was complicated by the constant repetition of portions of the strata by landslips; a new classification of the New Red Sandstone of Northern England, by Mr. Goodchild; and papers on the Green sand and Fuller's Earth of Bedfordshire, by Mr. Cameron.

Dr. Johnstone Lavis's report on Vesuvius chronicled the phases of eruption in the past year, and was illustrated by a beautiful series of photographs, chiefly of fumarolles and spiracles in the streams of lava. Mr. De Rance's report on underground water was continued. Mr. Davison's earthquake report dealt chiefly with new forms of seismic apparatus, and the photographic committee recorded that the collection of geological photographs now numbered 700, amongst which half the English counties and Scotland were, however, poorly represented. An excellent exhibition of the photographs was held in a room provided for the purpose, where also the Geological Survey of Scotland showed a fine series of views illustrating the scenery and structures of the ancient gneisses and schists of the Highlands.