path of movement in the intervals between their encounters. Owing to the removal of their crinoline, stellar atoms have only something like one-hundred thousandth the bulk of ordinary atoms, and so may be brought immensely closer to one another before the properties of a nearly perfect gas are lost. Finally, Eddington gives us reasons for imagining that in the course of its life history the star maintains its power of emitting radiation not simply by virtue of its contraction, but by converting into energy a portion of its own mass. His remarkable prediction as to the density of dwarf "white" stars has, during the past summer, been verified by Adams at Mount Wilson, who, by measuring the "relativity" displacement of lines in the spectrum of the companion of Sirius, has proved that star to have a density some two thousand times greater than that of platinum, and has directly confirmed the validity of the spectral shift as a test of Einstein's general theory of relativity.

Yet another romance is the story of helium, first inferred as an element in the sun by Lockyer in 1868 from observations of the spectrum of a solar prominence. It was not known to be a constituent of the earth until Ramsay found it in 1895 as a gas in the mineral cleveite. It takes an important place as the second member of the atomic series, the lightest of the group of inert elements which includes neon, argon, krypton, and xenon. It is found in small quantity in the atmosphere and in nearly all natural gases and spring waters. We now recognise it as a product of the disintegration of radioactive substances. Each alpha particle they shoot out is essentially an atom of helium. It is the nucleus of such an atom, which only requires to associate itself (as it can readily do) with two planetary electrons in order to become a complete electrically neutral atom of helium. The lightness and inertness of helium make it an ideal substance for the filling of airships, for it has a lifting power in the atmosphere not far short of that of hydrogen, along with the immense advantage of being completely unflammable. Helium is now assiduously collected from its natural sources for this practical purpose. From the point of view of theory it is also particularly interesting. As an agent for producing the extremest degree of cold it has been used by Onnes, who, by vaporising liquefied helium, has reached a temperature only about two degrees short of absolute zero. One may remark in passing that the absolute zero of temperature is almost the only absolute thing that is left to us in a universe given over to relativity.

Rutherford has put helium to another scientific use. He employs the alpha particle, which is the nucleus of helium, projected from a heavy radioactive substance

with a velocity of ten or twelve thousand miles per second, as a projectile with which to knock chips off the nuclei of nitrogen and certain other elements. In this way he produces hydrogen, for the chips which are knocked off are single protons, each of which forms the nucleus of a hydrogen atom. Thus in the hands of Rutherford the alpha particle is a veritable philosopher's stone by which the transmutation of elements, so long the dream of the alchemist, has become an accomplished fact. Quite lately we were told of laboratory experiments in which gold was reported to have been made by the removal of part of the nucleus of the element next above it in the list, namely mercury. The news was received with perfect calm by the scientific world, and even, I fancy, by the Governor of the Bank of England. For if you want gold it will doubtless be cheaper to find it by digging than to make it in that way.

There have been so many surprises in physics that the faculty of wonder is almost exhausted. Things have happened which a little while ago would have seemed to be miracles. We may think of Kelvin or of Tait as turning in his grave when an occupant of this chair speaks of there being no strict conservation either of matter or of energy, and accepts the possibility of transforming the one into the other. The foundations of the older physics have been rudely shaken, and the effect of such upheavals has been to alter the temper of the scientific mind. The old positiveness has gone. No longer are we positive about anything. The complacency, the facile dogmatism, which here and there showed itself in the last century, is now a rather absurd memory.

We are confronted by dilemmas and find no way out. We are obliged, one may say, to take the dilemma by the horns, boldly grasping both. The electromagnetic theory of light, established as we believed by Maxwell, is confronted with the view that there is no ether, nothing which will serve, in the words of the late Lord Salisbury, as a nominative to the verb to undulate; and, worse still, while the wave theory is amply supported by the facts of interference and diffraction, it is apparently inconsistent with the equally well-established facts of absorption and photo-electricity. How to reconcile these seeming contradictions we simply do not know. So while we may justly feel pride in all this progress and achievement, it is mingled with a consciousness of mystery, with a spirit of question. In a special sense is it true to-day that the widening of the circle of light has widened the circumference of darkness, and for the moment at least the darkness seems strangely impenetrable.

The Science and Art of Map-making.¹

By A. R. HINKS, C.B.E., F.R.S.

THE progress of invention has placed in the hands of surveyors a number of beautiful new methods, and some we have not yet scientifically explored. Would you measure a base? So far from painfully seeking a dead-level plain and clearing it of every petty obstruction, you will gaily take the suspended invar

tapes across country, and by preference run them up a hill at each end to get a better view for the base extension. Would you equip a party for primary triangulation? Look thankfully at Ramsden's 36-inch theodolite reposing in the museum of the Ordnance Survey; look doubtfully at the fashionable 10-inch; and before you take it any more into the field, examine whether the instrument of the future is not a 5-inch

¹ From the presidential address delivered at Southampton on August 27 before Section E (Geography) of the British Association.

constructed on the new principles of Mr. Henry Wild, with circles etched on glass, and parallel plate micrometer that reads opposite points of the circle from the eye-end and takes the mean for you. When you lay out the triangulation, consider well the recent opinion of the U.S. Coast and Geodetic Survey, that it is better to be content with small triangles easily accessible, with automatic electric beacons tended by a party in a car, than to make enormous efforts at rays longer than Nature easily allows. Bear in mind also a remark which our lamented friend Col. Edmund Grove-Hills made to me not long before his death. I was saying how necessary it was to complete as soon as possible the late Sir David Gill's great arc of meridian in Africa; and to my horror Hills referred contemptuously to the meridian arc as an "obsolete method." He did not pursue the idea; but I think we can see what was in his mind, and that he was right. The old-fashioned arc stuck to the meridian or the parallel with a sublime disregard of the topographer's convenience. It had infrequent bases measured with pomp and ceremony. It had occasional astronomical latitudes and azimuths observed with an almost painful degree of internal precision by heavy instruments and prolonged sojourn on uncomfortable heights.

We can see now how mistaken it all was. The purpose of these astronomical observations was to compare the geodetic with the astronomical latitudes, as a contribution to the Figure of the Earth. But what use to aim at single tenths of seconds in the latter, when on the average they were divergent by several seconds owing to local deviations of the vertical? Our real need is for a latitude at every triangulation point, and those points thick upon the ground. "Obsolete" was Hills' word for the meridian arc; and I think we shall not find it too strong, when we look at a graphical plot of the contribution to our problem which Gill's arc in South Africa can make.

It seems that we shall be driven back to the old network stretching far and wide across the country like the triangulation of Great Britain; and that raises problems which can scarcely be discussed here. But let me not for one moment be taken as disparaging the practical value of Gill's great achievement. It has proved invaluable as a framework on which to hang boundary surveys. It stretches a long skeleton from Port Elizabeth to near Tanganyika—ready to be clothed with topographical maps; and still lying in stark nakedness, for there is something in self-government that is antipathetic to map-making. Our Crown Colonies are getting fairly well provided with maps, thanks in great measure to the work of that Colonial Survey Committee which was so active early in the century, and which we hope was not a casualty in the War. But our self-governing Dominions have not always much to boast of.

This is a well-worn subject, and geographers are getting tired of asking whether there is yet a single topographical sheet to be bought in Australia. I believe that the answer is still, No: though there are some thirty sheets for official use produced by the Department of Defence as an earnest of the thousands that are wanted to cover the continent. Canada has now a first-rate geodetic survey and the beginning of a good topographical map; but it is a big country that

began survey very late, and its settlement is marching faster than its maps. Thanks to the labours of Mr. Wallace, we do know at last, what Lord Southesk never did, where he went on his journey of 1859 in the Rockies, but there is still no published map good enough upon which to show the route.

It is a commonplace of books that the surveyor in the field can always find latitude or azimuth, but is in difficulty with his longitude. That is no longer true. The rapid establishment of powerful time signals has made it possible to get longitude as exactly as latitude, and this must have a profound effect on further survey, exalting the astronomical at the expense of the trigonometrical; facilitating marvellously the rapid reconnaissance survey; putting off the drastic remedy of triangulation; but heaping up trouble in the future. On the other hand, the method of wireless longitudes will tend to the solution of two great problems, one of respectable position and one a little parvenu. Is the equator a circle? No one has yet certainly challenged it, though Clarke and others have done their best with inadequate means. Are the continents floating, or rather sliding about slowly on a sima-slide? We are generally agreed that Wegener has not proved his case, because he had a naïve trust in astronomical longitudes palpably weak. Yet the question has been deemed worthy of a serious and costly enterprise, warmly advocated by General Ferrié, and gradually assuming, I think we may say, without offence to that great enthusiast, a much more acceptable shape than the rather hard and unadaptable outline that was a little criticised by British geodesists and astronomers two years ago.

The need of a strong central authority is as evident in wireless time signalling as it is in the organisation of broadcast. Happily for geographers, the astronomers have organised themselves well since the War into a Union with thirty-two Commissions. The Union spends half its whole income on the sustenance of the Bureau International de l'Heure, over which one of the Commissions exercises a general control. The prodigality of the Union, stated thus, is impressive. In cold fact, its contributions, fixed unfortunately in French francs, do not go very far to pay the cost of the service, which can be carried on only because the Director of the Paris Observatory has not hesitated to place the instrumental resources and the magnificent house-room of his Observatory at the disposal of the Bureau; while the keen interest of General Ferrié has secured the benevolent and beneficent co-operation of the French radio-telegraphic services, military and civil. Geographers owe a great debt of gratitude to the French in this matter. But we hope that the British Government will not rest content with the modest part which Great Britain has played up to the present in this great development. We have—or shall have soon—an "Imperial Wireless Chain" stretched out from the new station at Rugby to the farthest Dominions; and we shall miss a great dramatic opportunity if from the opening of this service we do not insist that time signals from Greenwich shall be sent from Rugby and retransmitted in each link of the chain, that all Britain's Dominions beyond the seas, her ships on the ocean, and her travellers wherever they may be, shall be able to take Greenwich Mean Time direct from

the source. The technique of time transmission has been so greatly improved in these last years that there is no serious difficulty about it; and of the Imperial services for which the Rugby station is built, there can be none, I think, more really, if modestly, useful than the propagation of Greenwich Mean Time throughout the Empire.

The science of cartography is based upon the sciences of precise survey, and I make no apology for having dwelt for some time on the methods of securing the foundations. But when these are well and truly laid, it is time to press forward the visible building—the maps—and a problem we share with the larger world is that of building with speed and economy, not regarding too closely the interests vested in the old methods, but prepared if it seems wise to reinforce the ancient crafts with new. Two new powers have been added to the cartographer in these last years: flight to give him range of vision, and the stereoscopic plotter to give his photographic vision a new sense. For I do not exaggerate when I use those words—a new sense—to describe the power which the stereoscopic measurement of pairs of photographs has given the surveyor of topographical detail. The brilliant idea that this could be done automatically was due to Capt. Vivian Thompson. The credit of extending and perfecting the beautiful but marvellously simple geometry belongs to an Austrian, Lieut. von Orel; and of translating the geometry into sweetly working mechanism to the German firm of Zeiss. No more beautiful piece of optical machinery has ever been made, I willingly believe, than the stereoautograph of von Orel and Zeiss. But they made a sad mistake in marketing it, granting exclusive rights over a territory to an individual, and demanding from him not only a heavy price for the outfit, but also a large and perpetual royalty on his gross receipts as a stereoautographer. So strange a method of selling a scientific instrument was never known before.

Happily there is more than one mechanical and optical solution of the problem, and at least four different machines are now in the field abroad, while a fifth is under construction in Great Britain to the order of the Air Survey Committee. We are thus fortunately saved from the reproach that nothing has been done in this our country to develop a method first devised by an Englishman. But we may feel that our instrument-makers and our surveyors have been a little unenterprising; and there is nothing I would like to see more than a real effort, with adequate means, to try out stereographic surveying on geographical scales.

We know well enough that the stereoautograph can deal marvellously with a small piece of country on a large scale; but what has never yet been shown is that it can deal with a large piece of country on a small scale. It will contour for you an inaccessible cliff at 1-metre intervals on the scale 1/5000; but can it or a rival be made to tackle 100-metre intervals on the scale 1/250,000? That is a question which has never yet been answered, and I believe that it is our duty to answer it. Along the northern frontiers of India in the ranges of the Himalaya are at least 10,000 permanently snow-clad peaks. So long as the inch-to-the-mile map is incomplete in the plains, we can scarcely expect it in the mountains. Yet a really accurate map on the scale, say, 1/250,000 cannot be deemed superfluous for de-

fence; and even the poor geographer or traveller is entitled to ask for it. How is it to be obtained? Will stereoscopic survey do anything for us?

I feel certain that the answer is Yes; but much less certain that the photographs should, at least in the first instance, be taken from the air, which seems to be contemplated by the advanced school, and taken for granted by the newspapers. Air photography made a brilliant success in the War, when the cost was not too severely scrutinised. In peace we have to approach the problem with the fear of the Treasury in our hearts, and with more respect for that sort of precision which lets one go on in an orderly way for ever, without leaving accumulations of errors "to be absorbed in the desert," as they say in the Sudan.

Now, photographs taken with axis vertical cover a surprisingly small ground, even from extreme heights. With a lens of 6 in. focal length, about the minimum, you must go to 25,000 ft. to get a result on the scale 1/50,000, and then you can photograph only about three miles square on each plate. Flying at 90 miles an hour you must take plates every few seconds to avoid getting too much stereoscopic relief. It looks as if vertical photographs combined stereoscopically will fail in mountainous country.

I turn to obliques. The photographs taken in the air are taken from unknown points, and the first thing to do is to determine the position of the camera at the instant of exposure. The geometry of the method is none too strong, anyhow, and we could not expect to find the resulting place of the aeroplane with anything like the accuracy of a ground station. This leads me to think that stereographic survey from ground stations will be found to play an indispensable part in the future survey of mountainous country.

Suppose, for example, that political difficulties did not exist, and that we were able to survey the country south of Mount Everest. I think I would rather start out with a series of camera stations along the Singalela ridge, and fix all the visible crests stereographically with horizontal axes and vertical plates. A large part of the ground would be dead ground; but quite a good deal could be put in. Would this not solve the question of providing a fixed framework for the obliques from the air, perhaps combining each with a plate from a ground station, rather than in pairs of obliques? It will at any rate be worth the trial; and therefore I am anxious that we should not fail to exploit the relatively easy and inexpensive ground stations, while we are perfecting the vastly more difficult process of the oblique air photograph.

I suppose there never was a time when it was more difficult than now to forecast the future in surveying. We have seen already that geodesy is in a state of flux; we are not even allowed to believe that the pole or the continents stand fast in their right places. The methods that were canonical in field astronomy a few years ago are being rapidly displaced by new. The prismatic astrolabe is threatening to oust the theodolite; and Mr. Reeves has retaliated by inventing a small attachment to the theodolite that does the work of the astrolabe to perfection, and makes a separate instrument unnecessary. Sound-ranging and flash-spotting may yet be turned to the arts of peace, and there is something suspiciously like the latter in the

method proposed for connecting Egypt with Crete or Alaska with Siberia. Sound-ranging in air is perhaps not so likely to be useful to geographers as sound-ranging in water. But there is a post-War invention the future of which is brilliant. Who would have dreamed in the *Challenger* that her modern counterpart, the Royal Research Ship *Discovery*, would be equipped with deep-sounding gear on the method of echoes, that takes soundings in no time, or very nearly? It has become suddenly vastly more simple to measure the depth of the sea than the height of the land. There is much more sea than land, and a disproportionate part of it is very deep. Yet now for the first time we can begin to think of ocean contours drawn less by imagination and more by soundings in the new sense of the word.

If there was twenty years ago one branch of cartography that seemed stereotyped and unlikely to develop, it was surely the subject of map projections—a subject with a large and rather unprofitable literature; a science in which pure mathematics disported itself to the little advantage of maps; a science with a misleading title, since scarcely more than one of the useful projections is really a projection at all, the rest being only constructions; a science in which guiding principles were hard to find.

But in recent years the subject has taken on a new aspect. Tissot, and Jordan, and especially A. E. Young, have developed the expressions in infinite series—a process which sounds terrifying to those whose intelligences automatically shut up when they scent mathematics, but it is really an enormous simplification, because it reveals at once how much alike all these projections are in the first few terms, and precisely by how much they begin to diverge from one another when the sheet is extended. Moreover, this way of dealing with the subject allows the conscientious cartographer to distribute the errors judiciously by a process of cooking the projection, producing a flavour much appreciated by the connoisseur, though a taste not yet acquired by the common map-maker. But these refinements must not be looked at askance, as over-elaboration tending to preciousness. They have real practical advantages in the computing office.

This branch of our venerable science is therefore very much alive. It has even produced of late two new families—the retro-azimuthal projections which are the offspring of the Survey of Egypt, and the doubly-zenithal the father of which is Sir Charles Close. The former guides the Muslim in his prostration towards Mecca; the latter serves wireless direction-finding and other devices of the twentieth century. Could a student desire a subject of wider scope in which to exercise his powers?

The thought of the very charming modification of the polyconic projection devised by M. Charles Lallemand for the International Map on the scale of one in a million, leads us naturally to consider the outcome of that ambitious programme which was launched at the London Conference of 1909. Difficult as it was to secure enthusiastic co-operation before 1914 in producing sheets the marginal lines of which were necessarily drawn on a hard geometrical convention regardless of frontiers, it is trebly difficult now.

But I think it is fair to inquire if the original scheme was sound. There is an old proverb that if you want

a thing well done you must do it yourself, and with suitable modification this seems to me to apply especially to map-making. It is difficult enough for a single office to produce at intervals sheets that will absolutely match their neighbours. To expect uniformity from twenty or thirty reproduction offices is to expect altogether too much. One might indeed overlook slight differences in layer tints if one could only get the maps; but that is just the difficulty. Some countries are keen to meet their obligations, and some are not. India has produced a fine block of sheets; the North American Continent—I will not particularise—has produced three. I think we should find if we took a census that the majority of the Powers represented at Paris in 1913 have produced none, and show few signs of doing so.

With some trepidation I suggest, therefore, that the scheme for an International Map was bound to fail, because it required that each of many different countries should do its share, after a preliminary wrangle with its neighbours as to what that share was. Successful international co-operations have never worked that way. What has been the guiding principle of the successful enterprises? Surely that the reputed cost should be contributed by the nations in rough proportion to their populations, and that the work should be done by one. The Bureau International des Poids et Mesures, the old International Geodetic Association's Institute, the modern Bureau International de l'Heure, all these work or worked on that plan, with great success. The contributing nations get a great deal for a very small payment, and the nation which has the energy to take on the responsibility, and gets the credit, naturally contributes from its own resources, directly or indirectly, a large and essential part of the total cost.

The Survey of India has set us an admirable example in its map of India and Adjacent Countries, with a liberal interpretation of what adjacent means. Is it beyond hope that even in these hard times the Geographical Section of the General Staff might be given means to produce a map of the "British Empire and Adjacent Countries"—again without too much regard to the niceties of language?

Such a map of the world is indeed an almost necessary outcome of the P.C.G.N.'s work on names for British official use, for if unity of style could be achieved by miracle in an international map, there is no hope whatever for unity of spelling, or even of nomenclature. A sheet bears inevitably in its methods of transliteration the mark of its origin. We are all agreed that names in countries using the Roman alphabet should be spelled as in that country; the difficulty comes in transliteration from the non-Roman, and in descriptive names. The International Hydrographic Bureau at Monaco seems to me to have entered on a hopeless quest when it tries to obtain international agreement for the names of international waters. The French must surely always call Pas de Calais and La Manche what we call the Straits of Dover and the English Channel. The Germans will doubtless continue to speak of the Ost See, even though the bishop's wife protested to Elizabeth in Rügen that "the Baltic exactly describes it." Much can be done, no doubt, to eliminate superfluous variants and modern corruptions; but I do believe that the names for "British Official Use" must always

have a certain British flavour, however much we try to be scrupulous or even pedantic.

It will be agreed, I trust, that the science of map-making is healthily active and growing. Let us turn now to the art, which is twofold: the art of the convention by which the outline and the relief are reduced to the compilation, and the personal art of drawing the detail, the lettering, the divided margins, the ornaments, so that the finished map shall be clear, harmonious, and beautiful.

During the last thirty years we have seen the convention profoundly modified by the rapid improvement of colour lithography. Colour has, it is true, been used on engraved maps from the very first, and in my opinion the most agreeably coloured atlas ever published was the Rome edition of Ptolemy of 1486. But this was hand colouring, and no two copies are alike. In the years that followed the colour became more elaborate, but it was largely in the ornament, and the essential outline of the map was in black, from the single engraved plate. The great extension of possibilities came with the quite modern use of colour to distinguish the outlines of different classes: blue for rivers, brown for contours, red for roads, and so on. The enormous resulting improvement was conspicuously in the re-

presentation of relief. Layer colouring in particular, first employed on a large scale by the celebrated firm of Bartholomew, has given our maps all the advantages of a relief model without the inconveniences. It is a method in which the British have always excelled; and the supreme example of skill in layer colour-printing is the "Gamme" or colour scale attached to the report of the Paris Conference of the 1/1,000,000 Map in 1913: a scale which we may be proud to think was printed in England, at the War Office. There are infinite possibilities in the combination of layer colouring with contours, hachure, vertical and oblique hill shading; many of them have already been realised by the Ordnance Survey, particularly in their special maps of holiday districts, and in a map of South Devon which I regretfully remember in proof only, because it was found too expensive for issue. For we must note that a modern map passes through the press eight or ten or twelve times, and the cost of the machine work, apart from all the plates, is multiplied in the same ratio. The wonder is not that maps are expensive, but that in the circumstances they are so cheap. We should wish to believe, however, that the progress of invention may some day give us back that richness of tone that distinguishes the old engraved maps.

Obituary.

MR. J. Y. BUCHANAN, F.R.S.

THE last member of the original scientific staff of H.M.S. *Challenger* on her famous voyage of discovery in the great oceans has passed away by the death, on October 16, at eighty-one years of age, of Mr. John Young Buchanan. He holds an assured place as one of the founders of modern oceanography, and if his personal share in the fundamental researches is not more conspicuous in the text-books, it is largely because of his loyalty to the spirit of the expedition which gave the glory to the *Challenger* group rather than to individuals. He was in the most literal sense an original worker, always preferring to settle a point by observation or experiment rather than by books, and when reference to recorded work was necessary, always going direct to the fountain-head, never to a compilation. He paid no regard to authority or scientific orthodoxy, and did not get on comfortably with those who did. Censorship of research, even the reference to experts of papers submitted to a learned society, was obnoxious to him, and he spoke very plainly on this subject in communications to *NATURE* and elsewhere. So far as he allowed his singularly restrained and reserved nature to express itself in warm terms, he showed a passion for the freedom of research. He said: "To standardise research is to limit its freedom and to impede discovery. Originality and independence are the characteristics of genuine research, and it is stultified by the acceptance of standards and by the recognition of authority" (Preface to his "Comptes Rendus," 1917).

Buchanan was born in Glasgow in 1844, the second son of Mr. John Buchanan of Dowanhill, and was educated at the High School and University of his native city, where he graduated as M.A. Having decided to follow chemistry as a profession, he proceeded to study on the Continent, where he spent some time at the Uni-

versities of Marburg, Bonn, and Leipzig, and under Wurtz in Paris. On returning to Scotland he acted for a short time as assistant to Prof. Crum Brown in the University of Edinburgh. His leaning was always towards practical work rather than theoretical study, and he had little liking for teaching or lecturing. He excelled in manipulation, and especially in glass-blowing, a fact which weighed in his appointment as chemist and physicist on the *Challenger* expedition, where it was desirable that a scientific man should be able to make his own apparatus in case of need. The voyage of the *Challenger* lasted from December 1872 to May 1876, and most of Buchanan's time was occupied by routine work in measuring density of sea-water, collecting gas contents, and making qualitative analysis of all manner of natural deposits. He found time for several pieces of research which he afterwards developed in the private laboratory which his ample means allowed him to maintain, first in Edinburgh and latterly in London. The most important of these involved the thermal relations of sea-water and of salt-solutions generally, especially with regard to the formation of ice and steam.

A picturesque incident in the *Challenger* was his determination of the true nature of *Bathylbius Hæckeli*, which Huxley believed from microscopic examination of preserved deposits to be a primitive organism covering the bottom of the sea. Buchanan proved it to be a gelatinous precipitate of calcium sulphate thrown down by alcohol, a fact which was very reluctantly accepted by the biologists on board, who were unwilling to think that Huxley, the highest authority, could possibly have made a mistake. Huxley himself at once accepted the correction in the frankest manner. A less dramatic but more constructive piece of work was the analysis of deep-sea deposits, especially of the red clay and the nodules of manganese peroxide embedded in it, on