the introduction of more drought-resistant varieties would enormously increase the nation's wealth.

Our forests, so uniquely Australian, offer problems which cry loudly for systematic scientific work, far too little attention having been paid to some of them in the past. The admirable pioneer labours of von Mueller and of Baker and Smith have opened up an almost limitless field in the investigation of the characters and the chemistry of our forest trees. Closely related is the practical problem of the development of forest-product industries. Those who have to do with the timber industry know how much remains to be done in the systematic study of the character of the timbers, their exact classification, and the methods of seasoning and of preservation. All this is apart from, though related to, the problem of forestry proper; that is, the development of a complete organisation, scientifically controlled, for the care and upkeep of the forests, which—though wantonly destroyed in the past—may still be one of the nation's great assets.

The thorough investigation of Australian clays, with the view of the development of a ceramic industry employing native material, is another example of what may be done by applied science in the future; and here again some noted advance has already been made by the Commonwealth Institute, though it has been compelled to restrict its field of work.

There are tasks ahead, however, of perhaps more fundamental importance than any of these in connexion with the development of our country's resources and the settlement of population—tasks, moreover, called for by our obligation to contribute in our own area to man's knowledge of the earth on which he lives. I refer to the need of much more extensive, detailed, and systematically organised topographical and geological surveys than any as yet provided for. Such work would seem to require a definite scheme of co-operation between the Federal and State Governments and the institution of permanent scientific services.

In Papua and still more in the Mandate Territory of New Guinea there is urgent need for systematic scientific work, both for utilitarian reasons and because the unknown, wherever it exists, cries loudly for intelligent investigation. There are not many parts of this earth's surface that remain to-day so unexplored as does much of the interior of New Guinea, or which hold out so much promise of reward to the topographer, the geologist, the chemist, the botanist, the zoologist, and the anthropologist. The services of all these are needed as regular adjuncts to the civil administration. The work should not be left to the casual efforts of individual enthusiasts or of occasional scientific expeditions, often privately financed and undertaken more in the spirit of adventure than of true research. It needs highly trained men and systematic organisation. Most pressing of all is the need of skilled ethnological work—the study of the natives, their beliefs, thoughts, languages, customs, and mode of life, while yet it is possible; for it can be but a little while before they become sophisticated—I had almost said degraded—by contact with white man.

Australia has voluntarily undertaken a difficult task and a great responsibility in New Guinea and the adjacent islands. Its position there is that of a public trustee. Surely its most urgent duty is to make full provision for the scientific study of the land itself, its inhabitants and all that it contains. How else can it hope to succeed? How else to discharge its obligation fully to mankind? Pioneering work has been done in the past by specialists, some of them leaders of the highest repute; but the time has surely come for systematic, co-operative, and government-supported effort.

There is, then, reason to hope that the public demand for science in Australia will grow—that it has a great future before it. In building up that future on the foundations already laid, the Australian people must look for guidance and example to the greater and older nations of the earth. In this, as in all things, we turn first to that Mother Country which we still call Home. There the Royal Society, pioneer among national academies of science, has taught and practised the true gospel of the pursuit of natural knowledge for 260 years, and many younger research associations have gained world-wide repute. There also the cause of applied science has gained steadily in recent times, and is now represented by a powerful Department of Scientific and Industrial Research and by such highly endowed institutions as the National Physical Laboratory. We look also to America, where the organisation and endowment of scientific work are now on a scale that arouses universal admiration, not unmixed with envy. There Federal and State authorities, great manufacturing firms and wealthy citizens, seem to vie with one another in promoting education and research, knowing that thus the greatness of their country will be yet increased. We look to Japan—that wonderland which, in so short a span of years, has made for itself in science, as in all ways, an honoured place among the great nations. We look to Holland, ancient centre of learning and of maritime discovery, famous in the history of the Pacific, and to its splendid colonies in our tropic seas; for both Motherland and colonies are known throughout the world for what they have done and are doing for science.

Science and the Agricultural Crisis.[1]

By Dr. CHARLES CROWTHER.

IT is generally recognised that the primary causes of the present difficulties of British agriculture are strictly economic in character, and not due to any gross and general failure to apply present-day scientific knowledge to the technique of farming, although the great disparity which exists between the average production of the country and that secured by the more competent farmers on soils of the most diverse natural fertility suggests that with a higher general level of technique and education the intensity of the crisis might have been sensibly reduced. Whether it be a case of the "sick devil" or not, the agricultural com-

[1] From the presidential address delivered to Section M (Agriculture) of the British Association at Liverpool on September 13.

munity is at present in a more receptive mood towards scientific advice than at any time I can recall in some twenty years' advisory experience, and I believe the moment to be opportune for a forward movement in agricultural education, which, if wisely developed, may remove the last vestiges of opposition and establish education and research firmly in their rightful places in our agricultural organisation.

Our agricultural educational system may be likened to a pyramid with research at the apex, elementary education and general advisory work at the base, with intermediate education, higher education, and higher advisory work occupying the intervening parts. Our pyramid has grown within the last thirty years from a very modest structure of low elevation into an imposing edifice, which perhaps appeals to the mind's eye more through its height than its spread, the upward growth having taken place at a proportionately greater rate than the expansion of the base. The essential need of the moment appears to be a broadening of the base with the view of greater stability and a more effective transmission of the results of the activities of the upper portions to the maximum basal area over which they can beneficially react.

For the purposes of my survey it will be convenient to follow the customary classification of our work into research, advisory work, and teaching. Of these three divisions I propose to deal but very briefly with the first, that of research, since the potentialities of research for the advancement of agriculture are too patent to require exposition, the ultimate object of all agricultural research being the acquisition of knowledge which will enable the farmer to comprehend his task more fully and to wield a more intelligent control over the varied factors which govern both crop production and animal production.

Agricultural progress must be dependent upon research, and no phase of our agricultural educational system is so full of great promise for the future as the comprehensive research organisation, covering practically every field of agricultural research, which has been brought into existence during the past twelve years, and developed upon lines which ensure an attractive career to a large number of the most capable research workers coming out of our universities. In praising the research institute scheme, I am not unmindful of the needs of the independent research worker and the spare-time research work of teaching staffs—the type of research work to which we owe so much in Great Britain—and it is with some anxiety that I have watched the distribution by the Ministry of Agriculture of the modest resources available for the support of this class of work. I trust that my fears are groundless, but I am afraid of a tendency to deflect such resources towards the work of the research institutes, a tendency which in common fairness to the independent worker should be most strenuously resisted. With a sufficiently liberal conception of the class of work which can be effectively carried through by the independent worker, there should be no difficulty in allocating these moneys to the purposes for which they are intended.

In suggesting that, in proportion to the means available, agricultural research is perhaps more adequately provided for at the moment than other branches of agricultural educational activity, nothing is further from my mind than to imply that greater resources could not be effectively absorbed in this direction. I am guided by the feeling that a due measure of proportion should be maintained between research and the organisation behind it designed to translate the findings of research into economic practice, and to secure that each advance of knowledge shall be made known quickly and effectively throughout the industry.

It is chiefly in the latter direction that agricultural science can make an immediate and effective contribution to the alleviation of the present crisis, since agricultural research in the main does not lend itself to the "speeding-up" necessary for quick action. The same applies also to formal educational work, which must necessarily exert its influence on the industry but slowly.

The one line of approach along which agricultural science can make its influence felt quickly is that of *advisory work*, which consists in the skilful application of existing knowledge to the solution of practical problems, or at most the carrying out of investigations of a simple type, with the view of securing guidance as to the solution of the problem in time for effective action to be taken.

The root difficulty of agricultural educational propaganda in the past has been to secure a sufficiently intimate and widespread contact with the farmer, and for this purpose no agency at our command is so valuable as advisory work, since it ensures a contact with the individual farmer which is both direct and sympathetic, originating, indeed, in most cases out of a direct request for help. The difficulties in the way of extending advisory work greatly I shall turn to presently, but I wish first of all to outline some of the more immediately helpful forms of advisory work which have fallen within the scope of my own personal experience.

I will deal first with soil advisory work, being actuated by the conviction that soil investigation is the most fundamental of all forms of agricultural research. Soil factors dominate the growth of crops from germination to maturity, and must influence the utilisation of the crops by the animal, which is their ultimate destiny. In stressing the importance of soil advisory work I am not unmindful of the fact that, despite the enormous volume of investigation relating to soils which has been carried out, the task of the soil adviser still remains a very difficult one, and except in a few directions, and over a comparatively small area of the country, the interpretation of soil analytical data is rarely clear. It is a sobering thought, indeed, to recall the abounding optimism with which soil analysis was entered upon some eighty years ago, and contrast the hopes then held with the realities of soil advisory work as we find them to-day.

The initial mistake—so common throughout a large part of our agricultural investigational work of the past—lay in a failure to visualise the complexity of the problem, even with due regard to then existing knowledge. The problem was approached as if the soil were to be regarded solely as a reservoir of plant food, the capabilities of which for crop production should therefore admit of complete diagnosis by chemical analysis. The conception is fascinating in its simplicity, and has dominated the greater part of our soil work down to the present time, repeated endeavours being made by variation in the methods and intensity of the analytical attack to improve the persistently low degree of correlation between analytical data and crop results. Parallel with this at a later date was developed the mechanical conception, which found the major part of the explanation of the differentiation of fertility in the physical properties of the soil particles, while still later soil biology has asserted its claim to provide the "simple solution." The work of recent years, however, so brilliantly led in Great Britain by Sir John Russell and his colleagues, leaves us with no excuse for such restricted conceptions of soil fertility, which must now be regarded as the index of the equilibrium established by the mutual interactions of a highly complex series of factors, the variation of any one of which may affect the interplay of the whole, with consequent effect upon the rate or character of plant growth.

The problem of fertility being so complex, one might perhaps be inclined to despair of attaining anything really effective in soil advisory work, which must necessarily be dependent upon rapid and somewhat superficial examination. Such apparently is the view held by the Ministry of Agriculture, if one may judge by the conspicuous neglect of chemical and physical science in recent extensions of advisory facilities.

My own conception, however, of the present possibilities of soil advisory work is more optimistic, and, from experience covering the most diverse parts of the country, I am confident that an extension of facilities for soil advisory work would be of immediate and progressively increasing benefit to the farmer. The real difficulty at the moment is that for large tracts of the country we lack the necessary data to enable us to determine what is the "average soil" for each particular area, and until provision is made for specific soil work in these areas, which comprise the whole of the great agricultural areas of the Midlands, our advisory work relating to this raw material of crop production must of necessity remain superficial, and only too frequently ineffective.

In no direction has the need for extended soil advisory work become more evident in recent years than in the revelation of the extent to which large areas of our soils have become depleted of lime. Cases come almost daily to our notice in which this lack of lime is clearly the chemical "limiting factor," and the annual waste due to unremunerative expenditure on fertilisers on such land must indeed be very great. In many cases, fortunately, the depletion has been detected at a stage at which it is still economically remediable, but in others, unfortunately, this is no longer the case, and unless soil-survey facilities be greatly extended, it is certain that large areas of our land must steadily fall into the latter category, with the inevitable development in the near future of a problem of such magnitude as will require national action for its solution. It is worthy of note also that this problem will probably be accentuated rather than diminished as a greater proportion of our arable land reverts to grass.

A further direction in which great scope remains for the work of the soil adviser is in the economic manuring of crops. Inadequate and improper manuring is still widely prevalent, and the annual wastage of resources thereby incurred must represent a very large sum. A considerable part of this wastage is due to the widespread use of proprietary compound manures, more often than not compounded without any special reference to the soils upon which they are to be used, or even without intelligent adaptation to the special needs of the crops for which they are supplied. It is not uncommon, indeed, to find mixtures of identical composition offered for the most diverse crops. In far too many cases also the prices charged are extravagantly disproportionate to the intrinsic value of the ingredients of the mixture, and in all these various ways costs of crop production are made higher than they need be.

Passing on from soil and manuring, we come to the sphere of seed and sowing problems, presenting obviously abundant scope for advisory work. The need for good and pure seed is axiomatic. Seed must not only be good, however, but it must also be of the right kind, sown under proper conditions and at the most suitable time, and the value of advisory guidance on these points has always been recognised, especially with reference to the choice between different varieties of each particular crop. The variety tests carried out on the various college farms and elsewhere have always proved helpful in this respect in so far as they serve to demonstrate the general characteristics of the different varieties. Whether they have been equally successful in measuring the cropping capacities of the different varieties is more than doubtful, owing to their restriction to single, or at most double, plots of a kind. This has been recognised in the more elaborate schemes devised for the purpose by the National Institute of Agricultural Botany, which it is to be hoped may furnish a practical scheme for more accurate quantitative field tests in the future.

Given good seed, the improvement of crop possible through seed selection is perhaps not in general so striking as that frequently obtainable by manuring, but it may nevertheless be substantial, especially with crops such as barley, where improvement of quality may have a special value. There is also a rapidly extending field for seed advisory work in connexion with the laying down of land to grass for varying periods.

During the growth of the crop, advisory work is largely restricted to the domain of diseases and insect pests, the ravages of which take incalculable toll of our crops. I believe science can make no more directly effective contribution towards the removal of at least the technical difficulties of the farmer than the elaboration of effective preventive measures against pests and diseases.

I must pass on, finally, to the utilisation of crop products as food for animals, the line of work with which my own personal interests and activities have always been most closely associated. Looking back over twenty years of advisory activity, I realise that the position of the adviser in animal nutrition is infinitely stronger to-day than when I first assumed the rôle.

With all the newer knowledge at his command, the adviser in nutrition can now approach his work with far greater confidence, and evidence of the increasing practical value of his work is rapidly accumulating. This is particularly the case with advisory work in milk production, a branch of feeding which lends itself more readily than most to carefully regulated rationing, owing to the ease with which the amount of product can be determined. Much success has also been met with in advisory work in pig-feeding, and to a less extent in the feeding of cattle, the lower degree of success in the latter case being due not so much to an inferior capability of the adviser to help as to the difficulty of dispelling the tradition that beef production represents the supreme accomplishment of the British farmer, as to which there is nothing left for him to learn. The work already accomplished represents, however, but the very beginnings of economy in the feeding of live-stock, and wasteful feeding of both home-grown and purchased feeding-stuffs for lack of the necessary advisory guidance is still far too widely prevalent.

Such are only a few of the aspects of advisory work, which, if extended more widely, might exercise a very profound effect upon the economy of the industry. Such extension implies, however, greatly increased resources in men and money and more efficient means of bringing the advisory facilities to the notice of the farmer.

I am inclined, indeed, to think that a more efficient propaganda is perhaps the first need of the situation, for one finds in all parts of the country an astonishingly large number of farmers who are totally unaware of the existence of advisory facilities of any kind. A more extensive propaganda will be useless, however, unless accompanied by increased provision for advice, since the present resources are already more than fully taxed by the relatively moderate volume of calls for assistance that now arise. Most of our counties have, at present, only one agricultural adviser—some, indeed, have none—and yet this slender organisation represents in large measure the base of contact with the industry upon which the whole pyramid of our advisory and educational work rests. It is here where I see the most immediately profitable outlet for any further moneys that may be available for agricultural education in the near future.

I have already alluded to the chemical gaps in our specialised advisory organisation, and I might also have indicated the similar and even less comprehensible inadequacy in the provision for specialist advice in economics; but these are relatively small matters compared with the paucity of the less highly specialised but scientifically trained advisers of the county organiser type, whose business it should be to secure the confidence of the individual farmer by personal contact, and to render him assistance either directly in the simpler problems or, in more complex cases, with the help of the specialist staff standing behind the county staff, whereby a more widespread and real appreciation of the practical value of agricultural education and research than now prevails might quickly be developed.

A great extension of advisory work, such as I suggest, must necessarily involve heavy expenditure, and further, an exceptional measure of care in the selection of men, since in the direct approach to the farmer personal qualities may in the first instance count for more than technical proficiency. Furthermore, if the full measure of success is to be achieved, it is essential that a more closely organised and intimate contact should be established between the various units of the advisory organisation, from the research station through the scientific adviser, to the practical adviser. Our present organisation is too indefinite and too widely permissive in this respect and calls urgently for consideration by all concerned, both county authorities and advisory and research workers, with the view of more effective co-ordination and co-operative effort.

I have laid great stress upon the potentialities of advisory work as a contribution to the alleviation of the present crisis, but I cannot close without some reference to the far greater contribution to the future prosperity of British agriculture which we can make through our educational system, if wisely pursued, in the training of the farmers of the future.

The existing facilities for organised agricultural education—at least so far as universities and colleges are concerned—are adequate to deal with the numbers of students presenting themselves. There is indeed at the moment a considerable excess output of the class of student who is either unwilling or unable to take up practical farming and must needs have a salaried post.

Of more immediate concern is our comparative failure to secure for our educational courses more than a small fraction of the sons of farmers, upon whom the future of the industry will largely rest. I have testified to the greatly awakened interest in agricultural education which has been displayed among farmers in recent years, but it is yet far from having developed into a conviction that such education is to be regarded as a vitally essential part of the farmer's training. One must perhaps be content with gradual advance towards this goal by internal development, although the possibilities of more rapid advance by external pressure should not be overlooked. The enlightened landowner might exert an influence more potent perhaps than any other in filling our colleges with farmers' sons, if in letting his farms—at any rate so far as young applicants are concerned—he showed his faith in agricultural education by giving preference where possible to men who have received adequate instruction in the principles of agriculture in addition to practical experience. So long as the private ownership of land continues, the landowner will have it in his power to render in this respect the most powerful aid to the progress of agricultural education, and by action along these lines might exert more good in one year than is attainable by many weary years of propaganda.

Whatever the character of our land-tenure system of the future, it is certain that sooner or later some guarantee of efficiency for the productive occupation of land will be demanded from the would-be farmer. We cannot continue indefinitely, on one hand, to proclaim that the land is our greatest national asset, to be maintained with the help of, and in the interests of the State in a highly efficient state of productivity, while, on the other hand, the use of the land is left open to all, regardless of fitness for its effective use. This vision of farming reduced to the status of medicine and law as a close profession regulated by an entrance examination, may perhaps be stigmatised as a horrible nightmare; but some movement in that direction I believe to be inevitable, and, with nationalisation of the land, it might well come more speedily than one would venture to contemplate. None will question, at any rate, that, should such a day arrive, education in the principles underlying the calling will loom as largely as practical training in determining the standards of admission to the use of the land.

The Structure of the Great Rift Valley.

By Prof. J. W. GREGORY, F.R.S.

THE explanation that the lake chains of East Africa lie in a system of tectonic valleys which are a continuation of the basin of the Red Sea was due to Suess (1891) in his contribution to the geological results of Teleki's expedition. Suess regarded the Great Rift Valley as made by a sudden rupture of the crust of the earth owing to contraction, as preceded by no upheaval, its age as Pliocene and Pleistocene, and the height of the land beside it as due to an uplift[1] in consequence of the rupture; and he considered that as the East African Rift Valley is bounded by block mountains and not by parallel horsts, it is different in structure from that of the Rhine. The present writer, after a visit in 1892–3 to the highest part of the Rift Valley, supported Suess's view of its formation by earth-movements due to lateral tension, but he considered that the valley had a much longer and more complex history than Suess recognised; for the Rift Valley was made by faulting repeated at intervals from at least the Oligocene to the Pleistocene, it was initiated by an uplift of a broad arch in the Upper Cretaceous, and the infall of the top of that arch was probably a consequence of the foundering of the floor of the Indian Ocean.

The Great Rift Valley in its course from Syria to Mozambique varies greatly in structure. In some places it consists of a single trench, and at others of several branches. Its structure is geographically most complex in Tanganyika Territory, where it was studied with especial care when that area was part of German East Africa. A valuable discussion of the combined topographic, geological, and geodetic researches in that region has now been prepared by Prof. Krenkel, of the University of Leipzig.[2] He shows that between the Congo and the eastern coast of Africa three great tectonic belts are now well established. That nearest the coast forms the eastern front of the main African plateau. As it is the oldest, and in the most exposed position, its structures have been obscured by denudation. Hence the determination that this mountain rampart was formed by faulting required close examination of its geology. The evidence available shows that the central part of Tanganyika Territory is traversed by a zone of fractures, which extends from Lake Nyasa to the plateau front west of Mombasa. This eastern zone consists in places of a series of step faults, but includes, as in Uluguru, some rift valleys.

The second belt is the continuation of the main trunk of the Great Rift Valley southward from Kenya Colony. It includes Lake Magadi, and forks at Lake Natron; one branch goes south-westward, and includes Lake Eyasi, and disappears near the town of Tabora. The main trunk continues southward; it is repeatedly deflected south-westward by faults parallel to those of the eastern fracture belt; it becomes indefinite after passing Kilimatinde on the railway from Dar-es-Salam to Tanganyika. There is some evidence of the extension of this fracture belt through the Ruaha valley to Lake Nyasa. The only gap still uncertain in the course of the Great Rift Valley is from the lower part of the Ruaha to near Kilimatinde.

The westernmost tectonic belt follows the western branch of the Rift Valley, and includes the Albert Nyanza and Lake Tanganyika. It forks near its southern end: one branch breaks into splinters on the southern coast of Tanganyika; the longer branch goes south-eastward past Lake Rukwa, joins the main trunk at the Ruaha valley, and continues through Lake Nyasa to south of the Zambezi, where it has been traced by Teale and Wilson. The evidence of the tectonic origin of the valley is especially clear around Lake Tanganyika, the coasts of which show complex series of faults, fault blocks, and secondary rift valleys. Many of the faults are quite modern, as some of them have dislocated recent conglomerates and have tilted some of the lake beaches. The walls of this valley, from the features noted in the original graphical description of it by Burton, are young, and, as Prof. Krenkel holds, the westernmost of the three tectonic belts is probably the youngest.

Between Suess's simple theory that the Rift Valley was formed from a single series of fractures in the uppermost Kainozoic and my more complex classification with its three different series of fractures separated by four volcanic periods, Prof. Krenkel adopts an intermediate position. He accepts two periods of faulting and three of volcanic activity for the Nyasa basin; so that his sequence of events is nearly as long as mine; but he regards all the volcanic rocks as Miocene or later. The evidence on which I referred the lava of the plains near Nairobi to the Upper Cretaceous was admittedly scanty; but that age fitted in best with the general history of that part of the world. Later a promising clue to the age of the earlier volcanic eruptions was offered by Dr. Oswald's work on the Victoria Nyanza; but the volcanic pebbles he collected in the pre-Miocene conglomerates cannot be certainly identified. It is to be hoped that some visitor to that area will make a further collection of the volcanic pebbles from these conglomerates, so that their position in the East African volcanic sequence may be determined.

The view that the Kapitian lava plains are Pliocene has been held persistently; but that view has now been conclusively disproved by fossils collected by Mr. Sikes from beds deposited in depressions in the surface of these lavas. The fossils have been identified by Mr. R. B. Newton as Pliocene, so that the lavas themselves must be Miocene or older. Their Cretaceous age

[1] [In 1891 he referred to the uprise as an *Aufwölbung*; later as an *Aufwulstung*.]

[2] Die Bruchzonen Ostafrikas: Tektonik, Vulkanismus, Erdbeben und Schwereanomalien. Von Prof. E. Krenkel. Pp. viii+184. (Berlin: Gebrüder Borntraeger, 1922.) 7s. 4d.