from the centre. At Taggia it was twelve feet; at Nice, fifteen feet.

In many places of the region where the earthquake displayed its greatest power, some observers claim to have heard a noise preceding the motion. To some it seemed to be similar to the rattling of a train; but it is more generally compared to the howling of a hurricane, or to the rattling of a cart rolling over a stone pavement, or to distant thunder. Even in the third zone there are numerous places in which the noise was heard before or during the shock. In the fourth zone it was noted in very few places. In several places in the province of Porto Maurizio a subterranean noise was all that was observed; it was not followed by any movement.

Great care was given to the determination of the direction of the first shock. The methods applied were to inquire into movements of lamps and other hanging objects, the stopping of pendulum clocks, the removing or falling of objects, and the destruction of buildings. This part of the investigation showed, that in the whole region of the Ligurian Apennines, which was shaken most violently, all directions were equally frequent. This fact suggests the existence of an elongated epicentre parallel to the Ligurian coast. East of the meridian of Oneglia, directions between east-north-east to west-south-west and north-east to south-west prevailed. West of this meridian the greater number of waves were in the directions from east to west and from south east to north-west. In many places the direction of the movements changed once or twice during the first shock. Thus movements resulting directly from the shock, and secondary waves, could readily be distinguished. In many cases, among the various directions, two were prevalent which were vertical on one another.

A remarkable phenomenon was observed in the valley of Padua. The direction pointing towards the centre of the disturbance existed only during the latter part of the shock. In the beginning the crystalline rocks of the West Alps, which were shaken a few moments before the neighboring recent deposits, deflected the waves towards the arc of the valley of Padua, giving them an east and west direction.

If all important directions of shocks are marked on a map of western Liguria, they will be seen to converge in the sea between Oneglia and St. Remo about fifteen or twenty-five kilometres south of the coast. Therefore this is the probable place of the epicentre. The same place results from a study of the isoseismic lines which are concentric to a point twenty kilometres south of Porto Maurizio. A secondary centre seems to have been in the sea south of Nice.

A comparison of the most trustworthy reports shows that the Ligurian coast between Nice and Laona was struck by the great shock at 6.20 A.M.: therefore the shock must have reached the epicentre a little before this time, probably at 6.19 A.M. If this movement is considered the beginning of the shock, and the time of the disturbances observed at other places is compared to it, it appears that the velocity of transmission was not equal in all directions. It was greater to the west, being 4,762 feet in the direction of Marseilles and Nice, and only 1,916 feet in that of Genoa. This difference is probably not real, as the first shock of Nice seems to have originated at a secondary epicentre south of Nice, the existence of which was known through the earthquakes of 1564 and 1752.

Only in a few places was it possible to ascertain the vertical angle of the shock with any degree of exactness; but the value of 40° seems to be well assured by observations between St. Remo and Albenga. Based on these observations, and on the fact that this angle decreased with increasing distance from the epicentre, slower than it did in the great Andalusian earthquake of Dec. 25, 1884, the seat of the centre was found to be at a depth of eighteen kilometres, while that of the secondary centre south of Nice was somewhat less. It seems probable that the shocks preceding and following the most violent one also proceeded from the main centre, but that the first originated in a greater, the later in a less depth. The centre seems to have approached the surface during the seismic phenomena.

The violent shock was felt at sea between Corsica and the western Riviera by several vessels, which were shaken in all directions, the impression being that they had struck a rock. Almost everywhere on the Riviera the sea fell a little at the moment of the first shock, and suddenly returned to its former level, without the destructive waves which have followed other earthquakes. Some observers maintain that the falling continued several days after the earthquake, while at Laona and Porto Maurizio a change of level is said to have taken place. No rise is said to have followed the first fall. At Nice, St. Remo, and Savona dead fish were collected after the earthquake. According to Bellotti, all of them were deep-sea fish: therefore it cannot be doubted that violent shocks occurred in considerable depths near the coast of Liguria. This confirms the opinion that the centre must have been under the sea.

The earthquake did not cause any important changes in the topography of the affected region, and all of them must be considered dynamical effects of the tremors upon the surface strata which were broken or slightly moved. None of the resulting changes are connected with the prime cause of the earthquake. No atmospherical phenomena proving the presence of an extraordinary amount of atmospheric electricity were observed. In this respect the Riviera earthquake differed from that of Andalusia.

About nine minutes after the first shock a second one followed, violent and long; then at 8.53 A.M. (Rome time) a third one, short, but almost as violent as the first, and very destructive in its effects. Both these shocks were felt slightly in the whole region disturbed by the first one. In the central zone about twenty-two shocks more were felt in course of the 23d and in the following night. Only one, at 2.20 P.M., was strong. After the 23d the number of shocks decreased; but they continued until March 11, when the most violent shock since the first three was felt. At Savona, between Feb. 23 and March 11, about fifty distinct shocks were felt. Only the shocks of Feb. 23 were destructive. Six hundred and forty persons were killed, and about as many wounded. The damage in the province of Porto Maurizio is estimated at $2,600,000; in the environs of Albenga and Savona, at $1,700,000. No detailed estimates are available from the French districts.

NATURE AND ORIGIN OF PHOSPHATE OF LIME.[1]

THE circumstances which have led to the preparation of the subjoined report on mineral phosphates are as follows: viz., in 1870 the present writer was employed by the superintendent of the Coast Survey, the late Benjamin Peirce, to examine the phosphate beds of South Carolina with a view to determining the limits of that field; it was also deemed desirable to ascertain, if possible, the conditions which led to the formation of the deposits.

It was at that time the intention of Professor Peirce to have the geology of the belt of country within the limits of the Coast Survey maps carefully determined, so that they might be shaped in a way that would better serve the commercial interests of the country, and also have a greater scientific value. After a time it appeared that there were legal difficulties in the way of publishing these studies in the reports of the Coast Survey, and this work was suspended. It was the hope of Professor Peirce to secure a modification of the law; but before this was accomplished, he retired from the post of superintendent, and his successor deemed it best to abandon the project. During the two years in which I was engaged in this work on the geology of the coast line, I became very much interested in the problems connected with the origin and distribution of phosphatic deposits. From 1873 to 1880, while employed as State geologist of Kentucky, I had a chance to see a good deal of the somewhat phosphatic limestones of the Cambro-Silurian sections, — a set of beds which, by their decay, have given great fertility to the soils that lie upon them. The researches of Dr. Robert Peter, the chemist of that survey, made it plain that the phosphatic contents of the soils are among the first materials to be exhausted by the careless tillage which characterizes our American agriculture, and that they are the most costly to restore to the soil.

Extending the general inquiry to the grain-producing districts which lie to the north and west of Kentucky, it became evident that all those States which are now the granary of this country, and the chief source of supply for European markets as well, are rapidly exhausting their soils, and will soon be in grave need of

[1] Portion of an introduction, by N. S. Shaler, to a forthcoming bulletin of the United States Geological Survey, prepared by R. A. F. Penrose, jun.

phosphatic manures. The importance of such manures has so far been well recognized only by the cotton-growers of this country, yet it is evident that in a short time this class of fertilizers will be equally in demand for all forms of grain-crops.

These considerations have led me to the conclusion that the geological history of phosphatic deposits should receive more deliberate attention than has yet been given to it.

When I began my work in the United States Geological Survey, I asked permission of the director to continue my studies on phosphatic deposits. There was at the time no money available for these studies: it was therefore necessary that they should be carried on without other expense to the survey than that involved in the small share of my time which could be given to the supervision of the work. It was my good fortune, however, to find in one of my students of geology, Dr. R. A. F. Penrose, jun., a person who has been willing, at his own cost, to undertake a preliminary study of the whole field as far as our knowledge extends, and thus to prepare the problems concerning American phosphate deposits for detailed inquiry. This work he has pursued with great intelligence and energy during the two years in which he has been engaged in it. In this task he has examined all the known phosphate deposits of the United States and Canada, and has made a careful inquiry into the literature of the subject, as is shown by the extended bibliography which is appended to his report.

The object of this work being to make a necessary preparation for the further study of American phosphatic deposits, Dr. Penrose's studies were not designed to be encyclopedic in their scope, but rather to afford a synopsis of what is known of the deposits in this and other countries. So little is yet generally known of the several conditions under which these deposits may occur, that it would be very blind work to search for them in this country without a careful endeavor to bring together the experience which has been gained in other countries. It will be evident to the reader of Dr. Penrose's report that the workable deposits of phosphates are found in a greater variety of circumstances than those which contain most mineral substances that have an economic value. It is not likely that we have as yet exhausted the inquiry into the modes of occurrence of this substance; but this synopsis of the experience in this and other countries, which is much more extensive than any other which has been published, will, I believe, serve as a guide to the further search for sources of supplies of phosphatic manures. It will also be evident to the reader that the conditions of occurrence of these deposits in Europe make it plain that the search for them in this country may advantageously be directed to many districts in which they have not as yet been found.

So far, the vein deposits of apatite, such as those which are so abundant north of the St. Lawrence, have not been found in workable quantities within the limits of the United States, though the general geological conditions of the Laurentian area exist in the Adirondack district and in the southern parts of the Appalachian system, as well as in several districts of the Rocky Mountains. It would be remarkable if extensive deposits of this nature, so common in Canada and in the equivalent rocks of northern and southern Europe, should not be found at many points in our American Archæan formations. It is on this account that so much space in this report is given to the description and illustration of the Canadian apatite deposits. So, too, we may hope to find in the ancient rocks of this country deposits analogous to the great Logrosan and Caceres veins in the province of Estremadura, Spain.

The cretaceous deposits of Belgium (which at the present time are, next after the phosphate beds of South Carolina, the most productive in the world) present a type of beds the like of which have not as yet been discovered in the United States, though deposits of the same age, formed under about the same conditions, abound in this country. It is not to be expected that phosphatic deposits will exactly repeat themselves in strata of the same age in widely separated regions; yet it is clear, from the summary account of the geological distribution of these phosphates in Europe and North America, that in the case of these, as well as in that of other substances of value in the arts, there are certain guiding principles which we may base on the stratigraphy of the deposits to aid our search. The known workable deposits of a phosphatic nature are limited to certain portions of the geological section. Beginning at the surface, the deposits now forming these zones are, in descending order, as follows: —

(1) Superficial deposits, including (*a*) those formed in the manner of guanos; (*b*) the deposits formed in the bottoms of fresh-water swamps, sometimes in connection with deposits of bog iron ore (hematite); and (*c*) deposits which are the result of the long-continued decay of rocks containing a small portion of lime phosphate intermingled with lime carbonate, as, for instance, the deposits of North Carolina. This superficial group of deposits has no other common feature save that they are on the surface, and are due to causes now or recently in action.

(2) Deposits of the tertiary and upper cretaceous. These deposits are generally the result of re-actions which took place on ancient land surfaces, the phosphatic matter being such as formed in swamp beds or in ablation deposits like those of the Carolinas or of eastern England. Below the level of the cretaceous no important deposits of phosphate have been found in the vast section of rocks which lies between that era and the Devonian horizons.

(3) In the horizons below the level of the upper Silurian, bedded rock phosphates and apatite deposits occur. These infra-Devonian bedded rock phosphates seem to have derived their phosphatic matter from the animals, brachiopods, and small crustaceans, which separated that substance from the sea insects or other food which the old oceans afforded them. These phosphate-bearing invertebrates appear to have been particularly abundant in the early paleozoic seas.

(4) Below the level of the Silurian the phosphatic deposits which have been worked probably belong altogether to the class of apatites or crystallized lime phosphates, and are probably all new deposits. They evidently occur through a large part of the Laurentian section, though, so far, the known deposits of economic importance are possibly limited to one portion of that vast series of rocks.

The apparent absence of phosphatic deposits of economic importance in the section between the Devonian and the cretaceous is remarkable. It is possible that it may be due to our lack of knowledge as to the chemical character of the deposits in those parts of the earth's crust. It is more likely, however, that such deposits do not there exist, owing to the fact that the invertebrate species of animals which secrete phosphatic matter in their skeletons became relatively less abundant in the middle portion of the geological section; while the vertebrate species, the birds which accumulate guanos, and the fishes which afford an abundance of bones and teeth to littoral deposits, as well as the mammalia whose skeletons occasionally form a considerable element in the later deposits, did not begin to contribute phosphatic matter to the rocks until comparatively modern times.

The absence of phosphatic deposits in the upper paleozoic and lower mesozoic strata is well shown by the fact, that, while in the carboniferous and the triassic beds there are abundant land surfaces which have been carefully explored, no phosphatic deposits of economic importance have been found in them; while on the relatively very limited areas of the tertiary and cretaceous formations, where old land areas have been explored, a large number of deposits of beds of nodular phosphate have been found.

From the facts set forth in Mr. Penrose's report and the unpublished results of certain studies on swamps, we may draw certain general conclusions as to the best method of prosecuting the search for unknown deposits of American phosphates. These conclusions are essentially as follows: —

First, as regards the superficial and recently formed deposits of phosphates. We are driven to the conclusion that this class of deposits may reasonably be sought for wherever soft calcareous beds containing a certain amount of lime phosphate have been subjected to long-continued leaching by waters containing the share of carbonic-acid gas which belongs to all rain-water after it has passed through the mat of decayed vegetation. As long ago as 1870 I became convinced that it was to the leaching-out of the carbonate of lime by the carbonated water of the soil bed that we owe in the main the concentration of the nodular phosphates of South Carolina.[1] Although it is still necessary to explain many of the details of this process to adapt it to the peculiar circumstances of particu-

[1] See Proceedings of the Boston Society of Natural History, xiii., 1871, p. 222.

lar deposits, it seems to me that it is the key to the most common forms of superficial accumulations of nodular phosphates. In an admirable description of the phosphate beds in the neighborhood of Mons, in Belgium, by Mr. F. L. Cornet,[1] that distinguished author has independently propounded this simple hypothesis, and several other writers on the subject have apprehended the importance of this leaching action.

It is evidently essential to this process of concentration that the surface of the deposits which are leaching away should have been preserved from the action of mechanical erosion, which would have prevented the formation of phosphatic concentrates.

Inquiry into the conditions of the swamp deposits of this country has satisfied me that beneath the surface of many of our fresh-water marshes, and probably in a lesser degree beneath the marine deposits of the same nature, there is a more or less important concentration of lime phosphates constantly going on. The effect of this action is seen in the remarkable fitness of these fresh-water swamp soils for the production of grain-crops. For instance: in the case of the Dismal Swamp district, in Virginia and North Carolina, we find that the soils on which the swamp deposit rests are extremely barren, while in the mud that has accumulated beneath the swamp we have a rich store of phosphates, potash, and soda, which causes the soil of these swamps to be extremely well suited to grain-tillage as soon as it is drained. In a similar way, in the swamps of New England and Elsewhere, we find the bog iron ores which are frequently accumulated in their bottoms very rich in phosphatic matter. The evidence is not yet complete that this phosphatic material becomes aggregated into nodules in the swamp muds, but the number of cases in which nodules have been found in this position makes it quite likely that the nodulation of the material may go on in that position. The present condition of the inquiry goes, in a word, to show that wherever we have a region long overlaid by swampy matter we may expect a certain concentration of lime phosphates in the lower part of the marsh deposit. Wherever the swamp area lies upon somewhat phosphatic marls which have been slowly washed away by the downward leaching of the waters charged with the acids arising from decayed vegetation, or where the swamp deposits, even when not resting on such marls, are in a position to receive the waste from beds containing phosphates, we may expect to find a considerable concentration of phosphatic matter in the swamp bed. By the erosion of these swamps we may have the nodules of phosphate concentrated in beds such as occupy the estuaries of the rivers near Charleston, S.C.

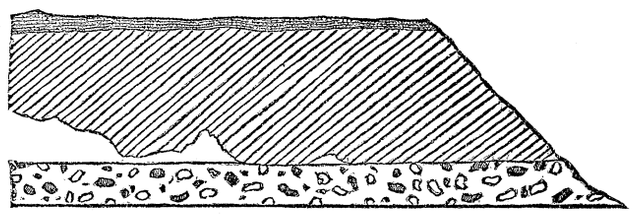
The area of swamp lands which fulfil these conditions is very large. They exist in numerous areas in more than half the so-called Southern States. At present it can only be said that they afford the conditions which, so far as the theory goes, should lead to the accumulation of phosphatic deposits of greater or less importance. It will be a simple matter to explain these deposits, though it is a task requiring a patient study of a large field. Although it is likely that the phosphatic materials will be found aggregated into nodules at many points in this area, it will not be safe to assume that they will be found in the same form as those which occur about Charleston, S.C. The nodules found in the beds about the last-named point, though in my opinion originating beneath swampy deposits, have apparently been, in part at least, swept from their original beds by the rivers which enter the sea at that point, and have thus been concentrated in estuarine deposits.

Although local concentrations of phosphatic nodules other than those now known may well be sought for in the Southern States, I do not think that the precise conditions or character of the deposits as found at Charleston should be expected to repeat themselves elsewhere. It is characteristic of the process of concentration of phosphatic as well as of other matter into nodules, that the material takes on a great variety of aspects, each proper to a particular site, and this although the surrounding circumstances of the several localities may apparently be identical.

Next lower on the geologic section we have, in the tertiary region of the Mauvaises Terres, extensive deposits of vertebrate remains which may possibly yield some commercially important supplies of bone phosphates. Although none of the existing sources of supply of these materials come from deposits of the nature of those found in Nebraska, the conditions of that remarkable region are so peculiar that it will not be well to pass it by without inquiry.

While the American cretaceous deposits are, as a whole, decidedly different from those of the Old World, the greensand beds of the section in the two countries present considerable likeness in their characters. It is probable that in this country, as in Europe, considerable parts of the cretaceous section are somewhat phosphatic, and that these beds containing disseminated phosphatic matter have been in many places exposed to the process of leaching in former geologic periods: therefore we may reasonably search in the cretaceous beds of this country for the same class of phosphatic deposits which have proved so important in the northern parts of Europe.

Although some peculiar deposits of phosphate have been found in the Devonian rocks of Nassau, it may safely be assumed that below the line of the cretaceous we have no facts to guide us in our search for phosphates until we come to the horizon of the upper Silurian limestones, at about the level of the uppermost beds of the upper Silurian, as far as that level can be determined by the perplexing assemblage of fossils. There occurs in Bath County, Ky., a thick bed of much decayed, very phosphatic siderite. This deposit covers but a small area, and consists of a patch of limestone of about fifteen feet thick, which has been converted into siderite by the inleaching of iron-bearing waters from the ferruginous Ohio (Devonian) shales which formerly overlaid the bed. Since the escarpment of the Ohio shales retreated beyond this bed, it has been subjected to oxidation, and is now in the main converted into a much-decayed limonite. Beneath this limonite there is a greenish argillaceous sand, which contains frequent nodules of lime phosphate. These nodules are smooth-surfaced, and not unlike some of the nodules from the Carolina district. They contain as much as 92 per cent of lime phosphate. It seems likely that these nodules were formed by the leaching-out of the lime phosphate from the overlying ferruginous layers, which has completely removed the lime carbonate, but has not removed the whole of the less soluble lime phosphate.



SECTION AT OLYMPIA, BATH COUNTY, KY. (PRESTON ORE BED).

Although this deposit of nodules is not of sufficient abundance to have any economic value, it is clear that we have in it an indication of a method where, by a slight variation of the conditions, important beds of nodular phosphates might be found.

In the horizons of the Cambro-Silurian section, or, as it is generally called, the lower Silurian, there is much greater reason to expect the occurrence of workable phosphates than in the beds immediately above. It is likely that the most important of the Spanish deposits belong in strata of this period, and the Welsh deposits of this general age are of noteworthy extent. We know, moreover, that the commoner marine animals of this part of the geological section were particularly adapted for the secretion of lime phosphate.

The search of this portion of the section for phosphates should be directed to two ends: first, to finding beds of very phosphatic limestone; and, second, to discovering veins formed by a segregation of lime phosphates either in the form of the Spanish deposits referred to by Dr. Penrose or in the condition of nodular accumulations. The area of rocks of these lower Silurian and Cambrian periods in this country is very extensive, and so far there has been no search of them for phosphatic materials. The little work done in Kentucky during the above-mentioned geological survey served only to show that the proportion of lime phosphate in the rocks is extremely variable, and that in certain beds it is so considerable that the ma-

[1] See Quarterly Journal of the Geological Society, London, xlii., 1886, p. 325.

terial might advantageously be used in a local way for fertilizing purposes.[1]

The search for phosphatic materials in the stratified rocks demands a method of inquiry that has not yet been applied to the study of our rocks. It seems to me that the method, or rather methods, should be as follows: —

First, there should be a careful inquiry to determine the share in which the several important groups of rock-making organic forms contribute phosphatic matter to strata. This can be accomplished by carefully comparing the chemical character of particular strata with the fossils the beds contain. When this determination is made, we shall have one means of guiding our inquiries, which will surely be of great value in the search for bedded phosphates.

Second, we should have a carefully executed chemical survey of our stratified rocks. Enough can be gathered from the scattered records of chemical analysis to make it plain that certain features of the chemical character of particular beds or divisions of strata often extend laterally for great distances. This is shown in a general way by the character of the soils formed of the waste of particular horizons; for instance, the deposits of the horizon on which lies the Cincinnati group of this country and the equivalent deposits of Europe are nearly always well suited to grasses and grains, and have a great endurance to tillage. It is now desirable to take these beds which promise to afford mineral manures, and subject each stratum to analyses which shall determine the quantity of phosphoric matter, soda, and potash which they contain, so that their fitness for use as mineral manures may be ascertained.

Below the level of the Silurian and Cambrian strata, and partly in those sections where they have been much metamorphosed, lies the field of the vein phosphates. It is more than likely that in this vast thickness of rocks, with their development in this country, there are many extensive sources of this class of phosphates which await discovery. As yet no careful search has been made for such veins in any part of the United States. The regions most likely to contain such deposits are found in the central parts of the Appalachian system of mountains, especially in the section from Virginia southward; in the Archæan district of Missouri and Arkansas, and in the vast region of highly metamorphic rocks of the Cordilleran district, extending from the Rocky Mountains to the Pacific Ocean. It is true that at present the economic value of phosphatic deposits in the western part of the continent would probably be small, on account of the great cost of transportation to the seaboard districts. But the growing use of phosphatic manures in the Mississippi valley, and the rapid exhaustion of the soils of that district, will soon give commercial importance to any sources of supply of phosphates that may be found in any parts of the Cordilleras which are convenient to transportation.

A proper study of the mineral manures of this country can best be carried on by means of a well-considered co-operation between geological explorers and the experiment stations of the several States. At present the methods of using mineral phosphates are extremely costly. Not only is the material brought into the soluble condition by saturation in sulphuric acid, but it is then mingled with ammoniacal and other matter to increase its effect as a fertilizer. The result is, that although a ton of Carolina phosphate now costs but six dollars, the average price of the manufactured product to the consumer at the phosphate factories is about thirty dollars per ton. It is probable that the essential value of the phosphatic ingredients to the plants of most soils is not enhanced by this costly treatment, though an incidental but dearly purchased gain, in the case of some crops, is obtained from the ammoniacal matter. The only effect of the superphosphatizing on the phosphatic matter is to make it more immediately absorbable by the plants. If placed on the soil without any other preparation than grinding, lime phosphate will slowly pass into a condition in which it may be absorbed by plants, while, if treated with sulphuric acid, it is, for a time at least, in a soluble state. That this treatment is not essential is well shown by the fact that the phosphatic matter derived from the rocks is brought into a condition for absorption by the ordinary process of decay in soils. Our present costly method of applying phosphates has come about through the commercial history of artificial manures, which is as follows: —

Before guanos were brought into use, the English farmers had learned that they could profitably use the phosphatic marls of their tertiary and cretaceous deposits without any artificial preparation. If guanos had not existed, it seems likely that mineral phosphates would have always been used in this way. When the Peruvian guanos came into use, they afforded a much more stimulating material than any other purchasable manures, and in a short time they established the type of commercial fertilizers. When the sources of supply of these guanos became in part exhausted, artificial compounds, formed on a basis of rock phosphates or apatites, were devised to take their place. These were made to imitate the effect of the guanos as closely as possible. Like them, they gave a quick though temporary stimulus to the soil, enabling the farmer to obtain the greater part of the return for his investment in the season following the application of the high-priced manure. Very generally the fertilizer, guano or compounded material, was applied with the seed or dibbled in the soil alongside the young plant; so that it would be immediately available in the first stages of its growth, and, what is a more important consideration, that it might take less of the substance to give the effect than if it were sown broadcast over the surface or mingled with the soil of the whole field.

In this way a habit has been established in the art of using phosphates, as well as in the composition of the material, which, like all commercial habits, is hard to overcome. The question to be determined is as to the utility of phosphates with other modes of treatment than those which are applied in the imitation guanos. At present this treatment requires the commingling of the lime phosphate with a number of costly substances. The manufacture can only be advantageously carried on at points remote from the districts where the materials are produced, and remote from the fields where they are used, so that the costs of transportation are great. The problems to be solved by the agricultural stations are as follows: —

(1) As to the effect, immediate as well as permanent, arising from the application of ground phosphatic rock commingled with other materials on soils used for the production of different crops.

(2) As to the degree of comminution of the material which is most advantageous. It seems possible that fine pulverizing may take the place, in a measure, of superphosphatizing.

(3) As to the effect of mingling the powdered rock with ordinary barnyard manure, peat, and other similar substances.

(4) As to the effect of lime phosphate used alone on soils containing different mineral constituents; as, for instance, those having considerable proportions of lime carbonate, and those having but little of that substance.

(5) As to the proportion of the lime phosphate which it is necessary to apply in order to produce different degrees of effect upon the fertility of soils.

It is desirable that these and other experiments should be tried at a number of stations in different parts of the country, in order that the needs of various crops may be considered, and the effect of the fertilizers on different classes of soils ascertained.

The effect of a small amount of lime phosphate on the fertility of the soil is clearly great; but, so far, we do not know with accuracy the amount necessary to produce a given effect. The range in phosphoric-acid contents in the soils of Kentucky, as determined from many hundred analyses, varies from 0.540 to 0.061.[1] In most cases the fitness of the soil for grain-tillage is measurably proportionate to the phosphatic contents. It seems almost certain, though not yet demonstrated, that the greater part of the phosphatic matter in the soil is in the state known as insoluble and that it only becomes in small part, year by year, soluble, or, in other words, fitted for assimilation by plants. Whenever the soil

[1] Among the analyses recently made by the chemists of ahe Kentucky geological survey is one which indicates the presence of phosphoric acid in considerable quantities in the limestones of coniferous age exposed at Stewart's mill, on Lulbegrud Creek, in Clark County. This partial analysis, for which I am indebted to Mr. John R. Proctor, the present director of the Kentucky survey, is as follows: viz., —

Lime carbonate	21.380
Magnesia	3.055
Phosphoric acid	9.710
Potash	.830
Soda	.228
Silicious nodules insoluble in acids	27.580

[1] See report of Dr. Robert Peter in Reports of Geological Survey of Kentucky, new series, vol. v. 1878.

contains the quantity of lime which characterizes the better class of Kentucky soils, it is supposed, that, even if soluble phosphatic manures are applied, the superphosphate becomes again insoluble by taking up a molecule of lime. It is therefore an interesting question as to the means by which the lime phosphate enters the plants. It may be that the solution is effected through the action of the various humic acids of the soil, or it may arise from some specific change which takes place at the contact of the soil with the roots. It is evident that this point requires precise determination, for on it will depend further experiments as to the methods of applying phosphatic manures.

There is yet another point on which we need experiments. Many of our rock phosphates, especially those which are distinctly bedded, contain low percentages of phosphatic matter. Many of our lime phosphates contain crystals of apatite and calcite so intermingled that it is not possible to separate them; yet from these deposits it will be easy to produce a mixture of lime carbonate and lime phosphate containing from 10 to 20 per cent of phosphoric acid. The value of such material for manure has never been determined. If it can be used in a way which will give to the fields the full value for both the lime and the phosphorus, it will open a way for an extensive production of cheap fertilizers.

The foregoing considerations give the general results of the preliminary inquiry into phosphatic manures, of which Dr. Penrose's work forms a part. Before we go further into these studies, I much desire to have the criticism and advice of others who have considered this subject. It is with this view that I have ventured to give in the foregoing pages an account of the aim of the inquiries I have in hand. The questions are at once chemical and geological, and demand much co-operation for their solution. Much of the work of searching for the unknown phosphatic deposits of this country will necessarily have to be undertaken by local students of geology or by commercial explorers in search of such deposits. Unfortunately, the unfamiliar aspect of the various forms of phosphatic deposits will make this task under any circumstances difficult. There is no substance of equally wide diffusion among those of considerable commercial importance, which, in the present state of popular knowledge, so readily escapes detection as lime phosphate.

BOOK-REVIEWS.

Social Progress. By DANIEL GREENLEAF THOMPSON. London and New York, Longmans, Green, & Co. 8°. $2.

THIS work is an inquiry into the foundations of social life and the means and methods of progress. The first part deals with the conditions of social progress; the second, with the means of promoting it. The work contains nothing that is specially new or striking, but is rather a restatement of the general principles of free government and social improvement as viewed from the standpoint of an evolutionist. The author's style is clear and flowing, so that the book is easy and agreeable to read; and there is much in it that thinkers of all schools will agree with. Mr. Thompson begins with a discussion of liberty and law, which he declares to be inseparable. All men, he maintains, must have equal rights and equal protection under the law; but as men and classes differ in power, the maintenance of equal rights has always been difficult. In former times the difficulty arose chiefly from military ambition and priestcraft, while in our time the danger that threatens us is that of a plutocracy. The main defect in this portion of Mr. Thompson's work is its inadequate recognition of the moral element in society. He does indeed recognize it, but he gives an altogether insufficient account of it. He bases society on self-interest alone, and reduces even benevolence itself to selfish prudence. He inquires why it is that we take pleasure in promoting the good of others, and answers the question thus: "Upon investigation we cannot fail to be led to the conclusion that the foundation for this is the selfish consideration of how delightful it would be if everybody else besides ourselves were animated by the desire and purpose of helping instead of hurting his neighbor" (pp. 63, 64): in other words, we do good to others in order that they may do good to us. The second part of Mr. Thompson's treatise treats of radicalism and conservatism, of the need of frequent change in order that society may progress, and of the best way of effecting such changes. It offers many interesting remarks on the need of care in the formation of opinion, on the folly of attempting political changes before the public is ready for them, and on other matters incidental to the subject. On the whole, this part of the work, though dealing with less fundamental questions than the first part, is more satisfactory.

Scientific Religion. By LAURENCE OLIPHANT. Buffalo, Charles A. Wenborne. 8°. $2.50.

WHY the doctrine taught in this book should be called scientific we do not know, for its characteristics are all of the opposite kind. Mr. Oliphant sees, as most other men do, that the old religious views will no longer suffice, and he undertakes in these pages to furnish a substitute. He believes in communication with departed spirits, who will teach us many important truths and render us invaluable aid if we will but listen to them. He holds that "the unseen world teems with intelligences, whose action upon this one is very direct, and is governed by laws." "This," he declares, "is a fact of my own personal experience." Spirit, he maintains, is only a higher form of matter, and the spirits in the unseen world communicate with us by the "interlocking of atoms." It is sad to learn, however, that the unseen spirits are not all good, and that the bad ones exert a baneful influence upon us, some of our worst impulses being due to their "infestation." Insanity, also, is due to them; and "when, therefore, we read in the Gospels of the cures by Christ of men possessed by devils, the expression is literally accurate." It depends on us, however, whether we will be influenced by the good spirits or the bad ones; and, in order to obtain the highest favors from the spirit world, we must become "bisexual." Adam, we learn, before the fall, was bisexual, and though his feminine part was separable from the masculine, the two were still one, this being possible in the case of Adam and Eve because their atomic structure was "four-dimensional." Christ, also, was bisexual, and, in fact, came into the world to restore the bisexual principle. Such is the stuff that Mr. Oliphant offers us as a new religion, and he expects men to abandon the Christianity of the churches for this! A large part of his book is devoted to a mystical interpretation of the Bible, and the rest is mainly occupied with the doctrine of spirits. We regard the appearance of this work and others of a similar character as one of the strangest signs of the times, and as indicative of a mental aberration that is truly amazing.

German Commercial Correspondence. By JOSEPH T. DANN. London and New York, Longmans, Green, & Co. 16°. 80 cents.

THIS book is of the *multum in parvo* kind, containing a great deal in a small compass. Its author was at one time assistant master in University College School in London, and it is intended not only for the use of schools and classes, but also for self-tuition. Specimens of letters are given for translation from German into English and from English into German. Copious notes, sufficient to enable the student to understand and render every idiom, are supplied, being placed at the end of the book, so that students may learn them by heart before translation is attempted. At the end of each section, subjects for writing letters similar to those contained therein are given, by way of exercises, so as to enable students to turn the study of the section itself to account. Copious vocabularies, German-English and English-German, are appended, embodying all the words which the student cannot be expected to have acquired in an elementary training. The idioms and peculiarities of the language have received special attention, so that the student may know not only what to do, but what to avoid.

French Commercial Correspondence. By ELPHEGE JANAU. London and New York, Longmans, Green, & Co. 16°. 80 cents.

THIS and its companion, the "German Commercial Correspondence," mentioned above, are constructed on such a plan that they may be used separately or together. The substance of the letters, in French or German, forming the first part of each section, is the same, and the English letters forming the second part are identical in the two volumes. In the third part are subjects for letters,