stones were added to effect the finer reductions. This mill afterward passed into the hands of a company, and became known as the "Pester Walzmühle," and its powers of production were increased by the addition of sixty-four roller-mills, besides several pairs of stones. During the last thirty years, thirteen other large mills on the same principle had been erected in Budapest; and the result of nearly fifty years' experience was to define clearly the functions and position of the roller-mill as the agent most suited for the preliminary process of granulating, requisite in the production of high-grade flour. For the subsequent reduction of the middlings produced by the rollers, nothing had been found superior to the old-fashioned stones; a modern first-class mill in Hungary, therefore, contained each class of machine as the necessary complement of the other.

The system of milling adopted in Budapest had for its object to obtain, from a given quantity of grain, the largest amount of fine white flour, and the commercial success which had attended the costly and laborious efforts in this direction, might be taken as a proof that the end justified the means. As a broad principle, the manipulations required in high grinding remained the same under all circumstances, although local conditions and the nature of the wheat might vary the details of the operation. The process necessitated five or six times "shroten" (i. e., bruising or granulating) between fluted rollers, and the passing of the produce from each break through a system of sorting and dressing machines. Further, from twice to four times "auflösen" (i. e., separating small portions of bran adhering to the fine middlings), between rollers either quite smooth or very finely fluted, the produce being carefully sorted and dressed as before after each operation. Lastly, the passing of the purified middlings and meal between stones, and the final dressing. The whole manipulation was arranged so as to require a minimum of manual labor, and the transport of the various products in the required direction was arranged automatically.

The method of procedure in a large mill was described in detail, from the time the wheat, thoroughly cleaned, was delivered to the first roller-mill, to the sacking of the refined flour, by which time it had undergone eighteen distinct operations, performed at different stages of a continuous journey through the mill, besides being concerned in various subsidiary processes affecting the treatment of the by-products.

BOILING KEIR FOR YARN AND CLOTH.

THE keirs generally used for boiling yarn or cloth intended to be bleached are stationary, and in the modern ones the water or liquor employed is made to circulate by means of an elevator or injector. In Germany, however, a revolving keir, for circulation of the liquor, has been adopted, the idea having evidently been borrowed from the revolving boilers used by papermakers. Our illustration shows the main fea-

BOILING KEIR FOR YARN AND CLOTH.

tures of this arrangement. A is the boiler or keir, made of wrought iron, which revolves round its axis, inclined at an angle of about 40 degrees. Its upper end runs in bearings held by an upright stand, D, while the lower end, which terminates in a pipe, runs in a hollow footstep. A wheel and gearing, E, driven by a strap, give the keir its rotary motion. The pipe at the bottom is in connection with a horizontal one, going up to a centrifugal pump, H, also driven by a strap, and from which another pipe ascends and runs up to the lid of the keir. Thus, while one strap causes the keir to rotate and to turn about its contents, the other strap, by giving motion to the pump, will cause the liquor to circulate constantly from the bottom to the top of the keir. There can be no doubt about the advantage of this circulation, and when the material to be washed is in detached parts, as, for instance, well-tied hanks, the constant turning may assist the washing, but we fear that cloth may soon get entangled, and may suffer in consequence, unless there is a provision made in the keir to prevent this, of which, however, the foreign patent says nothing.—*Textile Manufacturer.*

ARTIFICIAL INDIGO.

THE preparation of indigo is still too costly, and its use in printing is attended with such inconveniences that the attempts at its production have been for the present discontinued in the two great establishments which had entered upon the undertaking. Among recent improvements have been the replacement of the oil of bitter almonds and acetic anhydride by benzyline bromide or chloride and anhydrous sodium acetate. Cinnamic acid cannot be quantitatively transformed into ortho-nitro-cinnamic acid, which alone is capable of yielding indigo. A quantity of the para-indole is formed at the same time. Indole is a new compound obtained by M. Baeyer from ortho-nitro-phenyl-propionic acid. It presents certain analogies with indigo, but is yet distinct.

IRON PYRITES: ITS FORMATION AND DECOMPOSITION.

By PROF. F. SANDBERGER, Ph.D.

THERE is no state of rest in the mineral kingdom any more than in the organic creation. Both on the surface of the earth, and deep within it, old combinations of the mineral elements are breaking up, and new ones forming. It has long been known that without this continual decomposition of the mineral substances on the surface of the earth there could be no plant life, and as a necessary consequence animal life could not exist. A number of substances which are indispensable for the most important functions of the vegetable kingdom, are found in the foliage, the wood, and the fruit, such as lime, alkali, silica, phosphorus, and sulphur. They can be obtained only from the soil, and are taken up from decomposing minerals and assimilated by the vegetable organisms through very complicated processes. From the earliest times human necessity has taught us to accomplish this decomposition artificially. For this purpose the soil is broken up to a certain depth by the plow, so as to continually expose new strata to the action of the atmosphere, i. e., to permit of certain substances being converted into a soluble form, so that they can be taken up by the roots of the plants. This soil is not homogeneous, but contains, as a rule, remnants of different minerals, and must contain them if it is able to furnish plants with all the food required for their vital processes. Since every single mineral produces different products of decomposition according to its chemical relations toward water that contains air or carbonic acid, the soil and the liquids that penetrate it are the end product of a whole series, and not of a single decomposing process.

Every other mixture of minerals acts like the soil, and by its decomposition produces a whole series of new products which seem to be mixed together promiscuously. To comprehend the significance of the single factors of this mixture, it is necessary to investigate how each single original constituent of the mixture decomposes, and what new substances it contributes to the final product. Such investigations lead to one of the most interesting portions of geology, to which as yet but little attention has been directed by the public, although it certainly deserves attention.

It is not my intention here to describe the formation and decomposition of a large number of minerals, but rather to follow out one which is widely disseminated, and hence is of importance for practical life. Before entering into particulars, it may be in place to say a few words as to how we can most certainly prove from which old mineral the new one was formed. It is evident that in this respect those cases are most important in which the decomposition takes place so gradually that the new body is obtained in the crystalline form, more or less perfectly preserved, of the original mineral, or what is called in mineralogy a pseudomorph, is formed. For example, *Argentite* (sulphide of silver Ag_2S) is in the form of *Pyrrargyrite* ($3\text{Ag}_2\text{S} \cdot \text{Sb}_2\text{S}_3$) or dark red silver ore. In this case there is no doubt that the former is made from the latter, which has lost its sulphide of antimony, i. e., has given it up to a liquid in which the antimony compound was soluble, and sulphide of silver was not. But we know from chemistry that only the sulphides, such as sulphide of potassium, sodium, ammonium, barium, or calcium, are able to dissolve out the sulphide of antimony in such a dilute solution and secluded from the air, and to produce the pseudomorph in question artificially in a not very long time. If we find hydrated silicate of alumina, the white, earthy kaoline, in the same shape as a potash feldspar, or other feldspar, which is an anhydrous double compound of alkaline silicate with silicate of alumina, we have a right to infer that kaoline must have been formed from a feldspar through the loss of the alkaline silicate. In all cases where we have pseudomorphs, we have a very definite starting point for determining the original body from which they are formed, although the formation in very many cases depends upon complicated processes, such as the mutual decomposition of natural substances; not like the very simple conversion of red silver ore into argentite, and of potash feldspar into kaoline. One of the most instructive examples of mineral changes is undoubtedly that of iron pyrites.

Pyrite, or iron pyrites, when pure, are bisulphide of iron (FeS_2), with 46.06 per cent. of iron, and 53.92 per cent. of sulphur. It crystallizes in forms belonging to the regular or isometric system; the cube, octahedra, and pentagonal dodecahedra being most frequently observed. Of the same composition, but crystallizing in the rhombic system (that is, dimorphous) is the marcasite, which is much less common. Since its formation and decomposition scarcely differ from that of pyrites, any special description of it would be superfluous.

Iron pyrites have a brass yellow color, very brilliant metallic luster, a high specific gravity (5), and a hardness almost equal to that of quartz, giving sparks when struck with steel, and formerly used in starting fire. It is not magnetic, and is not attacked by hydrochloric acid, but only by hot nitric acid. Besides sulphur and iron it not infrequently contains other substances which do not change its crystalline form, such as arsenic (up to 4 per cent.), and selenium, replacing the sulphur, or gold (not over 0.02 per cent.), platinum (0.05 per cent.), silver (0.10 per cent.), copper (up to 5 per cent., Huelva), thallium (to 1 per cent.), or cobalt, nickel, and manganese replacing part of the iron.

DECOMPOSITION BY HEAT.

If heated to redness in a closed vessel, it is decomposed and sulphur is given off, which is either used for making sulphuric acid, or comes into commerce as sulphur. The residue is a lower sulphide (FeS), a black, porous, and strongly magnetic substance which resembles the natural magnetic pyrites, and, like it, dissolves readily in hydrochloric acid with the evolution of sulphydric acid. In the great chemical industries, however, as yet no process is known whereby all the sulphur expelled by heat can be obtained, but only 13 to 14 per cent., because if heated more strongly the clay retorts would be destroyed. Arsenic and selenium, if present, sublime with the sulphur, which is thereby rendered unfit for many purposes, such as fumigating casks and barrels, as the very poisonous vapors of arsenious and selenious acid are formed when it is burned. It must, therefore, be redistilled.

When strongly heated in the air, pyrites are decomposed into sulphurous acid and basic ferric sulphate. The residue can be used for making green vitriol, and then for oil of vitriol, or anhydrous sulphuric acid, and polishing rouge, *caput mortuum*. In it remain all those substances which in part replaced the iron, such as copper, silver, gold, platinum, thallium, and manganese, and can be prepared from it if present in sufficient quantity. This sulphuric acid residue is imported by the shipload into Germany from the

province of Huelva, in Spain, and worked over to obtain its copper and silver, and on a still larger scale at Newcastle-on-Tyne, England. The total amount of copper produced in Central Europe from these pyrites residues is estimated at 250,000 cwt. The amount of silver is much less, but still enough to pay. When there is considerable gold, as in the pyrites of Alais (Department of the Gard), this, too, is won. The greatest part of the sulphuric acid which plays such an important part in chemical industry is made from iron pyrites. In recent times, indeed, copper pyrites and zinc-blende are also employed for the same purpose.

FORMATION OF IRON PYRITES.

It can be said that iron pyrites are formed wherever ferrous sulphate, or any other soluble sulphates, like gypsum and Glauber's salt, and iron salts, particularly the carbonate, come in contact with decomposing organic matter. This last-named substance possesses a power not equaled by any other natural body of abstracting oxygen from other substances at ordinary temperatures, e. g., of reducing sulphates to sulphides. In this way monosulphides are first formed, as further conditions must be fulfilled to produce the bisulphides. The foul liquids from the kitchen and sinks contain, according to the state of decomposition, sulphates of potash, soda, lime, or ammonia and organic substances, or the latter are already destroyed and have converted these salts into sulphides of potassium, sodium, calcium, or ammonium. These substances at once attack the iron in the gutters or the bottom of the sewers and ditches, and deposit there an intensely black slime. This is a hydrated protosulphide of iron, like that precipitated from a solution of iron by sulphide of ammonium in chemical analysis, as shown by Chevreul (*Compt. Rend.* xliii., p. 128). Not only does this take place in the waste from inhabited places, but sulphide of iron is also being produced in every peat-bog, as well as in the slime from ponds and rivers, and on a very large scale in that of the sea, wherever iron salts and sulphates are present. The production of sulphide of iron is, therefore, going on almost uninterruptedly over the whole earth, as the necessary conditions are rarely wanting anywhere.

DECOMPOSITION OF PYRITES.

Wherever this protosulphide comes into contact with the atmosphere, it rapidly oxidizes again, and it is therefore not often found in a hard, stone-like mass. Yet I have seen one interesting case, where it had kept for years in a dry place. In 1857, during ebb tide at Ostend, I discovered a new formation of that sort. The iron piles driven in there are surrounded at the base with a blackish mass 9 centimeters thick (nearly 4 inches), in which were well preserved purple shells of the edible mussel, so common there (*Mytilus edulis*). I took some pieces with me, and treated them with hydrochloric acid, which immediately evolved large quantities of sulphureted hydrogen and carbonic acid, and the mass crumbled to grains of sand. The decomposing mussels, which as usual had attached themselves in large numbers to the piles, had reduced the gypsum in the sea water to sulphide of calcium, and this had acted upon the iron and converted it into protosulphide of iron, while the calcium thus liberated had taken up the carbonic acid formed by oxidation of the organic matter, and formed carbonate of lime, which had cemented together the grains of sand from the bottom of the sea to a strong mass. It was only after several years that the piece was decomposed throughout, and fell to pieces. Undoubtedly, the same process takes place under the same conditions in every sea where the sand contains iron.

The sulphide of iron is less easily attacked when it has taken up more sulphur, and becomes a bisulphide of iron or pyrite. This takes place when it remains in contact with a solution of liver of sulphur, an alkaline sulphide, from which it is able to abstract more sulphur. This process is very clearly shown in nature by certain pseudomorphs. Such are the large, six-sided plates from the ore veins at Freiberg and Stranitz, which as a rule consist of an aggregate of small pyrite crystals, but sometimes consist in part of the original hexagonal crystals of magnetic pyrite. It is therefore probable that in nature at first a mono, or eight-ninths sulphide of iron is formed, and this is afterwards converted by the alkaline sulphides into a bisulphide. This explains the frequent occurrence of gold in iron pyrites, for sulphide of gold is soluble in the alkaline sulphides, and is added to the protosulphide of iron in such a solution.

There are some very striking but well authenticated cases, within historic times, of dead organic bodies being converted directly into pyrites. Thus, a mouse drowned in a vessel containing a solution of green vitriol, in Bakewell's laboratory, was changed to pyrites; pyrites form in hollow trunks of trees, in mineral springs, on the roots of rushes, etc. Still more instructive are the magnificent, glittering layers of pyrites upon bowlders, and rubble and rough masses like a cement of sand, such as are dug out of marshes by filled-up mineral springs that contain sulphates and iron salts, like those at Roidsdorf, near Bonn, and at Memlos, near Fulda. So, too, the pyritical lumps that I dug up in the marshy soil at the Wurzburg pile-house, at a depth of 2½ meters, and which inclosed grains of sand, pieces of bones, and fragments of oak. The examples cited, which might be multiplied still more, will suffice to justify the above assertions that iron pyrites are at present still being formed uninterruptedly, and in large quantities, on the earth's surface, and must have been formed in the same way in times past.

There are, indeed, no deposits of stone coal or brown coal that do not contain a quantity of pyrites in some of the stratifications, and in many of them they are so abundant that they are worked for the pyrites instead of for the coal, as at Kladno, in Bohemia. The bisulphide of iron is found not only in fossil coal of all ages, but in all rocks impregnated with organic substances, whether these are in the earlier or later stages of decomposition, i. e., as ulmic bodies, bitumens, pit coal, or anthracite. They are generally most abundant in certain clay-shales and marl-shales. This occurrence of pyrites is again very characteristic. Wherever there are large fossil organisms like conchyliia, ammonites, orthoceratites, or stems of plants in these strata, the pyrites are concentrated in and around them. Sometimes they are in masses as large as a fist or a man's head. There are no more striking proofs than in early geologic times bisulphide of iron was formed in great quantities by decomposing animal and vegetable substances from solutions of the sulphates, just as it is to-day everywhere being formed, and not only in the rocks already mentioned, but along with other metallic sulphides on ore veins and gangue. The tremendous beds of pyrites at Undal and other places in Norway are accompanied by a black clay shale, and in some places contain as much as 2½ per cent. of coal, which

gives it a black color. The same is true of those from Meggen, in Westphalia. In the Black Forest and the Rhenish Mountains there are scarcely any pyrites which do not rest upon rocks that are impregnated with anthracite or graphite. Here, then, the reducing substance was present in excess, and was not all consumed, as was the case in other places, where it left no residue in the pyrites to prove that it had been there.

But then the mineral is formed at the present time in other ways, although in far smaller quantity. This must also be mentioned here to correct the popular but false idea that the same mineral must always be formed in the same manner in nature.

Iron pyrites are formed on volcanoes, not in the lavas, but only as a product of decomposition of the oxygen compounds of iron (magnetic oxide of iron, silicate of iron), which are abundant in volcanic rocks, by the action of sulphureted hydrogen, which is so common in many volcanic regions, especially in Iceland and Lower Italy. In 1847, Bunsen showed that by the continued action of such sulphureted hydrogen emanations the volcanic tufa of Iceland is being converted into a clay in which are crystals of pyrites and gypsum. The alumina and the silica of the rocks are not attacked by the sulphureted hydrogen, and hence form an argillaceous residue free from color. The iron gives its oxygen to the hydrogen of the sulphureted hydrogen, taking its sulphur in exchange. The lime and alkalis are next converted into sulphides, which rapidly oxidize in the air. The sulphide of calcium splits up into sulphur and sulphate of lime (gypsum), which owing to its slight solubility crystallizes out, while the alkaline sulphides form soluble sulphates, that are washed away by the rain water. Hot solutions of alkaline sulphides, such as are found in California and Nevada, have the same action as gaseous sulphureted hydrogen. They, too, deposit pyrites in the volcanic tufas which they flow through, and the like occurs on a small scale at the springs of *Chaudes Aigues* at Cantal, and at Aix-la-Chapelle.

It will be seen that the very frequent formation of pyrites all over the earth is due, with the exception of those just mentioned as of volcanic origin, to a grand reducing process on a large scale, which results in a concentration of the sulphur out of the soluble sulphates, and in a less degree to a concentration of the iron. At the same time, other elements which are present along with the sulphur, but in much smaller quantities, combine with the iron, and with this any gold, platinum, silver, thallium, copper, cobalt, and nickel present are also precipitated.

NEW COMPOUNDS.

If we consider now what new compounds are formed from its decomposition by oxygen, we will run foul of a series of very remarkable facts.

The kind of decomposition that pyrites undergo from the action of the atmospheric oxygen, varies according as there is an excess of oxygen or only a limited supply, and in some varieties, the fine granular sort, is rapid, while others fall to pieces gradually. With a limited access of air, the pyrites become slowly covered with an efflorescence of green vitriol ($\text{FeSO}_4 + 7\text{H}_2\text{O}$), in the production of which all the iron is consumed, but only one equivalent of sulphur. The second equivalent of sulphur separates as native sulphur, and remains between the crystals of vitriol in yellow flakes. On extracting this weathered and crumbling mass with water, which dissolves the ferrous sulphate, the yellow flakes can be distinctly recognized and proven to be sulphur, either directly by melting and burning, or by dissolving in alkali, which then precipitates metallic solutions. Sometimes this second equivalent of sulphur is protected from oxidation, and is found in between the second product resulting from the decomposition of the green vitriol, as very beautifully seen in the pseudomorphs of brown hematite after pyrites, at Rippoldsau, in the Black Forest, and in those from the Ural, where free gold sometimes is found with the sulphur in pseudomorphic geodes and druses.

When the pyrites are oxidized with free access of air, the second equivalent of sulphur is also converted into sulphuric acid. This gives a strongly acid reaction to the sulphate of iron solution, and when in contact with minerals that can be attacked by it, produce a very energetic reaction that results in the production of a great variety of secondary minerals to be described subsequently.

The formation of green vitriol is always attended with a large increase in volume corresponding to the oxygen and water absorbed. This causes the mass of pyrites and the rock it may be embedded in to swell up, become porous, and crumble.

The production of green vitriol is going on in a large way in the pyrites deposits, which are from 100 to 300 feet thick, at Rammelsberg, near Goslar, in the Hartz Mountains, and at Rio Tinto, in Spain. Besides the green vitriol, and the lemon yellow basic sulphate of iron formed from it by oxidation, there are at the so-called "Old Man" in Rammelsberg, sulphate of copper, sulphate of zinc, and other sulphates formed by the oxidation of other metallic sulphides that accompany the pyrites. These are separated as far as possible from each other, and then worked up. At Rio Tinto acid water flows from the abandoned Roman mines at Teil, in such quantities that it blacks everything, and the precipitated hydrated oxide of iron cements the pebbles into a conglomerate. The copper in it is precipitated by old iron, and obtained in the form of cement copper. It is estimated that 75,000 tons of copper have been washed out of this old mine since the fifth century, and carried into the sea. Since the iron pyrites do not contain over 5 per cent. of copper, of course the quantity of iron is still greater, and it would be remarkable if iron sandstone were not formed in large quantities continually at the mouth of the river.

The formation of vitriols in mines has other consequences, too. In proportion as oxygen is taken from the air to oxidize the sulphides, the percentage of nitrogen in the air increases, and if the ventilation of the mine is bad, it may increase to such an extent that the workmen not infrequently die of suffocation. Such cases also occur in all coal veins which are rich in pyrites and the necessary precautions are neglected.

Not less fraught with danger to the mine are the physical effects of this oxidation, particularly the considerable increase of temperature that accompanies it. In stone coal and brown coal mines, if the slack and small pieces of gangue, which are full of finely divided pyrites, are not carefully removed but left in porous heaps in the galleries where the air has free access to it, oxidation begins; slower, indeed, than with the monosulphide of iron, but gradually increasing until it glows, and if the draughts of air are strong enough, it sets fire to the heap of slacks. This would gradually spread, if the access of air cannot be cut off, until the whole mine is on fire. The fire in the Fanny Mine, in Upper Silesia, at Planitz, near Zwickau, and the burning

mountain at Duttweiler, near Saarbrück, are the best known mine fires in Germany. But in France and other countries many mines have suffered from fire at different times. At Teplitz and Carlsbad there are evidences of such fires.

Everywhere, the shale that incloses the vein, at the spot nearest the fire, is converted into a pearly-gray substance resembling porcelain, and called porcelain jasper. Sometimes it is melted to a glass or slag. At considerable distance it is burnt red, and hard. In the cooler spot the crevices are filled with sulphur, which has distilled directly from the pyrites and alum, the formation of which we shall describe presently, and salamoniac formed at the expense of the nitrogen in the coal. To utilize the heat greenhouses were put up at several places, as at Zwickau; and tropical plants, especially pine apples, cultivated on a large scale.

If the deposit of pyrites is in quartzose rock that cannot be acted upon by free sulphuric acid, mine water, having a strongly acid reaction, will flow out, destroying any vegetation that attempts to grow along its banks. Such waters contain 1 part, 2-2 parts, and even 5½ parts of free sulphuric acid in 10,000 parts of water. Such waters are found at Ronnelly, in Sweden, Civillina, near Venice, and in Rockbridge Co., Virginia. No higher percentage is found, except in waters of the Solfataras, which are formed in lower Italy, Mexico, South America, and Java, by the condensation of sulphurous acid and vapor of water.

In most cases, the sulphuric acid formed by the weathering of pyrites has an opportunity to unite with bases at once, and to form various new minerals according to the kind of rock the pyrites were in. The most common ones are sulphate of alumina and gypsum. Since potash is seldom wanting in the shales where iron pyrites are found, alum is formed, and is seen as a white, mealy, or capillary efflorescence. As long as no cheaper materials were known from which to make this substance, which is so indispensable in many technical operations, alum was obtained in very many places from just such rocks. Up to the present time they retain the name of alum slates, and occur in all geological formations, for example in the transition rocks of Sweden, Saxony, and Thuringia; in the clay formation over the carboniferous in Thuringia and Wurtemberg; in the brown-coal clays of the lower Rhine and Lausitz, etc. At present they are not worked, except under exceptionally favorable circumstances, for alum can be made far cheaper and purer from alum-stone, and from the residues left in making soda from cryolite, without the necessity of removing the troublesome iron salts which are formed in the alum slates with the sulphate of alumina. Where such rocks have been decomposed on a large scale, they break up in little splinters, which are continually breaking off. Streams that wash away the slime from these rocks contain neither fishes nor plants, not even shell-fish, because the dissolved salts are inimical to vegetable and animal life. Before such alum shales can be worked they must first be roasted, to oxidize the fresh or only partially decomposed pyrites which they contain. This is finally completed by letting them lie exposed to the air for a year. Then they are leached out, and clarified, so as to separate the iron as basic salts. An equivalent quantity of carbonate of potash is now added, and pure alum is obtained.

If the rocks that contain the pyrites are chiefly carbonate of lime, like limestone, quite another phenomenon takes place. The liberated sulphuric acid first attacks the carbonate of lime, and converts it into hydrated sulphate of lime (gypsum), liberating an equivalent quantity of carbonic acid, while the sulphate of iron decomposes the carbonate of lime, forming sulphate of lime and carbonate of iron ($\text{CaCO}_3 + \text{FeSO}_4 = \text{CaSO}_4 + \text{FeCO}_3$). Protocarbonate of iron, known in mineralogy as siderite, is readily oxidized still higher, and with access of air and water the carbonic acid escapes, and the hydrated sesquioxide, called brown hematite, is formed, $2(\text{FeCO}_3) + \text{O} = \text{Fe}_2\text{O}_3 + \text{H}_2\text{O} + 2\text{CO}_2$. Thus the pyrites is at last changed to brown hematite. Yet not infrequently the crystals preserve their form perfectly, but of course the interior is greatly changed, having become porous and crumbly. This metamorphosis may attack a whole bed or deposit of pyrites, and extend to a great depth. At Huelva, it reaches down over 300 feet. The miners rightly call these deposits of porous hematite, that consist of pyrites down below, iron hats, and prize them highly. The old miner's saying, that "No vein is so good as an iron hat," is founded on this, for in the hematite are found concentrated all those metals like gold, silver, and platinum, which were mixed with the pyrites in small quantity, but which cannot oxidize any farther, and when separated from their sulphur compounds, appear native or free. The richness of these "iron hats," or pacos, the Spanish-Americans call them, is frequently extraordinary, and increases rapidly with the depth. All the beds and veins of gold and hematite in Australia, California, and South America have proven without exception that the amount of gold decreases rapidly as we descend, when this oxidized zone is passed and we come to the pyrites below. It is true that this also contains gold, but only in very small amount, and scattered through a very large quantity of iron and sulphur. No less definite are the statements regarding the decrease in the yield of silver, in all cases where the shaft extends from one of these iron hats down to the original pyrites.

It will be seen that many wonderful geological phenomena are connected with the formation and destruction of iron pyrites, as well as many products of industrial importance.

Humboldt, May, 1882.

THE AMOUNT OF OIL REMAINING IN PENNSYLVANIA AND NEW YORK.*

By HENRY E. WRIGLEY, C.E., Phila

THE BOUNDARIES OF THE OIL REGION.

The boundaries in the oil region of Pennsylvania and New York, as determined by the drill, embrace a much larger extent of territory than is generally supposed, being nearly 200 miles in length from north to south, with an average width of 25 miles, covering an area, within somewhat irregular lines, of about 4,250 miles.

After twenty years of development we find these lines practically the same as those laid down by McClure in his geological map of the United States, published in 1817, and denominated and colored by him as the "line of salt," which was found in quantity long before petroleum.

The eastern line of the entire oil region lies in a northeast and southwest direction, parallel to and some distance west of the Allegheny Mountains; the south line is substantially one drawn between the southwest corner of Butler County and the town of Kittanning in Armstrong County; the west

line passes up through Butler County, cutting off a small corner of Mercer, west of the towns of Franklin, Titusville, and Warren, into New York State, where it rounds off the end of this long strip in the counties of Allegheny and Cattaraugus, and joins the eastern line, near Olean, New York, just north of the city of Bradford. (See map.)

The eastern line, starting from Kittanning, passes through the northeast corner of Clarion County, the southeast corner of Warren, cutting Forest County through the center, and reaching the before-mentioned extreme northeastern developments near Olean. These lines have been taken broadly to include all territory that could ever possibly come into the question as oil producing.

These lines having been proved by the drill may be considered final. But there are also structural reasons for their existence. The south line is final because the oil-gathering sponge-rock on the line is found at such a depth, owing to the dip of the strata from the northwest, that the known temperature of the earth at that depth precludes the existence of hydrocarbons in any other than a gaseous form. The string of gas wells from Leechburg to South Butler County are brilliant and permanent witnesses to this fact.

The whole of this section of the States was at one time a level plain, the Allegheny Mountains being only waves of upheaval; these waves dying out as they went more and more faintly toward the Ohio line. The vertical fissures left in the strata by these waves of upheaval allowed the gas to come up from the buried shale 20,000 feet below, and condense in the pebble rocks under a solid cap or cover of unbroken rock 1,500 feet thick, where the drill tapped it in the form of oil. But where the rolls of the strata were so great that the fissures extended all the way to the surface, the gas came to the surface, too, and went off in the air as fast as it was made.

The eastern limit is the line where all the fissures of the anticlinals and synclinals have come to the surface, and a very little research will satisfy one as to the certainty and finality of this line.

The reason for the west line is just the opposite; the waves all died out and there were no fissures at all, so the gas could not come up. This same reason holds good on the north line all the way round to Olean, with this exception, that on the north line the fissures do exist at a greater and greater depth as we go northward; and we can reach them by drill and torpedo if we go deep enough, provided we never exceed the safe depth for temperature of 2,200 to 2,250 feet. We may safely assume that at a red-hot depth under the whole country lies the vast bed of the Huron coal shales, and the question is only one of distillation and outlet; of a conduit to some

natural condenser with a strong cover near enough to the surface of the earth to be above the line of temperature, so that we can tap it with the drill. No account is taken of the occurrences of oil from the upper light shales in the shallow wells at Mecca, Ottin, and elsewhere west of this western line, as they are totally unimportant factors in the general problem.

GEOLOGY OF THE OIL REGION.

Assuming the general surface of the country in Western Pennsylvania to be level, a board with its edges due north and south, east and west, tilted up slightly at the upper left-hand corner (representing the city of Erie), will give the general idea of the dip of the strata throughout this section. It will show two dips, one to the east, the other to the south; and, as the surface is level, these strata come successively to the surface as we go northward and westward. The oil sands of Butler County, for instance, if projected into the air on the line of their dip, would be 1,000 feet above the level of Lake Erie; so, too, the same third oil sand that we find at Tideoute, at a depth of 100 feet on the river bank, we find at 1,800 feet in Butler County. The oil sands practically end and crop out all across the oil section on the line shown above Tideoute.

Now there are four conditions necessary to the production of oil in quantity:

1st. The oil shale, which exists under the entire region, and far outside of it at a red-hot depth in the earth.

2d. Such vertical fissures, caused by upheavals in this secondary strata, as will allow the gas generated by the heat of the earth from these carbonaceous shales to escape upward to a point within, say, 2,000 feet of the surface.

3d. Between this point, and within, say, 100 feet of the surface, a cooler reservoir, either of coarse pebble rock or an aggregation of small fissures to receive the gas and condense it, either with or without pressure, into oil.

4th. Over this reservoir there must be a solid cap or cover of rock to confine the products of distillation.

In the entire region south of Tideoute the third or oil sand is traced readily by the record of the wells, and the known dip of the rock of about 20 feet to the mile, the level of the wells, if on a hill, being first taken from some known point.

In the entire region north of Tideoute the reservoirs are simply crevices and have no reference to sands, but the operator, carrying his experience of oil sand with him from below, drills his well down to a certain close gray sandrock as a guide. It is simply because he finds that the general horizon of the termination of the vertical fissures at the

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