

MAPPING THE MAMMOTH CAVE.
By Dr. HORACE C. HOVEY, F.G.S.A.

THE statement has been repeatedly made, on the authority of the State geologists of Kentucky, that there are 225 known rooms and avenues in the Mammoth Cave, whose combined length would exceed one hundred and fifty miles. This random estimate has put those at a disadvantage who have wished to learn the exact facts, while it has gratified the exhibitors of this greatest of all caverns. The owners have objected to the making or publishing of accurate interior or exterior surveys, lest other modes of entrance should be found besides what is now regarded as the only mouth. They have not objected to sketches as helpful to the ordinary tourist.

In 1882, the writer had the honor to read a paper on "Subterranean Map-Making," at the Montreal meeting of the American Association for the Advancement of Science, which was published in the Proceedings of that body. It was accompanied by maps of several American caverns, one of them being the best available map of the Mammoth Cave, together with some account of its production.

Mention was made of the first rude outline, five years

published by James & Gazley, of Cincinnati, with notes. The only copy extant happens to be divided between Dr. Call and myself, he having the map and I the notes upon it in full. Lee's map contained serious errors after all, and in the writer's opinion it has had altogether too much importance given to it in its relation to better work done since it appeared and vanished.

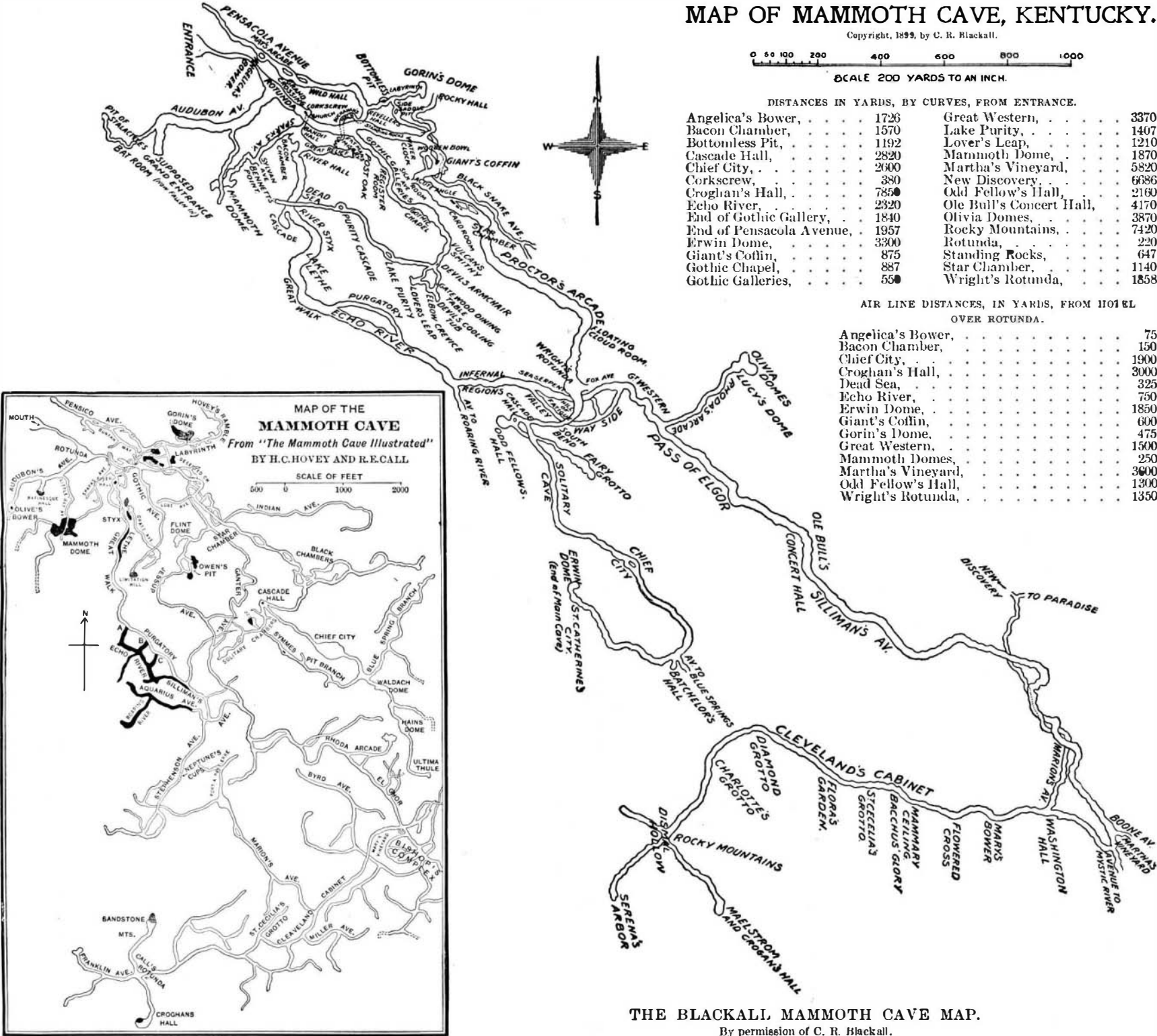
Stephen Bishop, the negro guide, discovered the region beyond the rivers, as well as other parts not previously explored. Though a slave, he had considerable learning; had some knowledge of the classics and natural sciences; and there is no reason for not giving him full credit for the elaborate map bearing his name as the author, and that was published in 1846 to accompany a volume styled "Rambles in Mammoth Cave, by a Visitor," from the press of Morton & Griswold, of Louisville, Ky. The book is out of print, and it is said, whether with truth or not we do not know, that the map was intentionally suppressed for prudential reasons. One of the few copies now extant is in the writer's library.

Next in order of time came the extensive surveys made by Dr. C. R. Blackall, of Philadelphia, during the summers of 1870 and 1871, both interiorly and exteriorly; surface measurements being by air-line, but

torial department of the American Baptist Publication Society, and is ready to explain or, if need be, to defend his map and its process of production. It is to be hoped that he may soon carry out his intention of publishing in full the methods of his subterranean explorations.

The Lippincott press, of Philadelphia, published in 1875 Forwood's manual of Mammoth Cave, an attractive volume, with a new map of the regular routes as taken in exhibiting the cave. The map must have been mainly made by guesswork, and is by no means trustworthy. Several other sketches have since been made by newspaper correspondents and others, which need not even be mentioned, except to say that they are worthless as maps.

My own mapping of Mammoth Cave has been limited to certain localities, notably the long, winding passage known as Ganter Avenue, 8,500 feet long, together with the rectification of errors in former surveys. What is naturally enough known as "Hovey's map" was prepared under my supervision and for use in my work on "Celebrated American Caverns," and the successive editions of my guide-book, all from the press of the Robert Clarke Company, Cincinnati. It also accompanied my article on Mammoth Cave in the



THE HOVEY AND CALL MAMMOTH CAVE MAP.
By permission of the American Book Company.

after the discovery of the cavern, and published in 1814 in The Medical Repository, vol. xvii., p. 391. It was either drawn by Mr. Gratz, an early owner of the property, or for him by a Mr. Bogert. Two years later Dr. Nahum Ward published in The Worcester Spy a plan of the cave in order to locate the finding of certain mummies said to have been exhumed there. Neither of these could properly be called "a map," no use of chain or compass being made.

A more careful survey of the main cave and a few of its known branches was made by a civil engineer named Edmund F. Lee, in the winter of 1834-35, who is said to have given three months to his task.* It was

* Lee's map of the Mammoth Cave has been so often referred to as the finished work of an expert civil engineer, that it becomes necessary to break that illusion. In the notes that accompany his famous map he says: "I measured the Bottomless Pit; the depth was 173 feet—perhaps a hundred feet lower." "The deepest pit is in the Little Bat Room, about 280 feet deep, or 120 feet below Green River. The Bottomless Pit is also deeper than the bed of Green River, and I believe also the Covered Pit and some others."

Ben Hains found the depth of the Bottomless Pit but 94 feet 6 inches, while the deepest spot found by my own plummet was 105 feet. In the summer of 1895 Dr. Call and myself measured the depth of the Crevice Pit in the Little Bat Room, with the utmost care, and found that from its edge to the bottom it was 88 feet; or by adding to this the remaining depth

those underground following the curves of passages. The bearings were taken by a standard compass, and the distances by line wherever practicable, and elsewhere by pacing carefully. The permission of the managers had been gained to make this survey, and it was the original intention to have the result go with a volume describing the cave and its contents, giving also accurate tables of distances, heights, and depths. Preliminary to this, however, Dr. Blackall undertook to give the first fruits of his work in the form of a familiar lecture in the hotel parlor. The apprehension of Judge Underwood, at that time the cave trustee, was excited, who so seriously objected to publication that the whole matter was dropped until now. My own share in the matter is mainly that of having finally induced the eminent author of this remarkable and valuable map to allow me to lay it before the public, as an offering to the scientific world. It should be added that Dr. Blackall is at the head of the edi-

of the floor of the Mammoth Dome, of which this pit is the upper opening, the total depth is exactly 119 feet, as against Lee's 280 feet.

Lee's theory that the accumulated waters of Mammoth Cave occupy a bed lower than Green River, and that they ultimately run by subterranean channels to the Ohio River, or possibly the Ocean, is proved to be utterly erroneous by barometric observations, which he, as an expert civil engineer, should have made before risking such a wild assertion. "Honor to whom honor is due;" but when a map-maker trips into such errors as the foregoing, he forfeits his standing as an authority to whom those that come after him must defer.—H. C. H.

Encyclopedia Britannica, vol. xv., p. 449; is found in Dana's new Text-book of Geology (fourth edition, 1883), p. 103, and elsewhere.

In my paper on "Subterranean Map-Making," read before the A. A. A. S., after ample mention of what had been done by Lee, Bishop, and Blackall, it is stated that "all the portion open to the public, as far in as the Echo River, is drawn after the recent survey made by Col. Francis Klett, manager of the cave;" while concerning the portion beyond the rivers it is stated that "the details are filled in from older surveys." A similar statement is made in a foot note to my article in the Encyclopedia Britannica, mentioning particularly Bishop and Klett. The writer, indeed, claimed for himself less than he was entitled to in his anxiety to do justice to others. It may be added that Col. Klett was made manager by Capt. George M. Wheeler, U.S.A., when the latter was trustee of the estate, and he had for nine years before that been working with him for the United States Geographical Survey. When Capt. Wheeler's trusteeship ended, Klett's services were dispensed with, and he never accomplished all that he promised to do by way of a survey of the entire cavern; but he should get credit for what he did, especially seeing that he is now departed from this life. As I was with him during his partial survey, and made use of his material, I only affirm what I know to be true in saying that Klett re-

surveyed the entire "Short Route," proving its courses to vary materially from the maps of Lee and Bishop.

In preparing the illustrated manual of Mammoth Cave that was brought out early in 1897 by the press of J. P. Morton & Company, of Louisville, as the joint work of H. C. Hovey and R. E. Call, it was felt that an improved map was required. Numerous discoveries had been made by various explorers since the publication of the older maps, and many errors needed to be corrected. In the division of labor, this task of redrafting the map was claimed by Dr. Call, but it was by no means intended by the present writer to renounce his share in it altogether. Much less can he allow to pass without a protest, even at this late hour, the remark by Dr. Call before the Indiana Academy of Science, and repeated in *Spelunca*, the official organ of the Société de Spéléologie (Paris), that Hovey's map "is chiefly that of Bishop, and follows closely the original work of Lee, though no mention is made of these sources." Such a slip of my comrade's usually careful pen does not tally with the facts. For, as previously stated, all the "short route" had been resurveyed under my supervision, and full credit for the rest was given to those to whom it was due. It is only fair to Dr. Call to presume that he would have conferred with me about this matter, had I not been abroad, cave-hunting in France, with MM. Martel and Viré, at the time of publication. Aside from this, however, no cartography of Mammoth Cave can be regarded as complete that fails to mention the great work done by Dr. Blackall, or the less important, yet genuine, work accomplished by Col. Klett. In thus claiming what is due to others, it is farthest from the writer's thought to disparage the indefatigable and eminently successful achievements of Dr. Call, or any other explorer of Kentucky's famous labyrinth.

The two maps most prominently mentioned in this article are laid before the reader for comparison. It must be remembered that each was made independently of the other; a fact making their points of agreement, or of difference, all the more interesting. They agree in general outline. They suggest the theory that the congeries of caverns known as the Mammoth Cave may be regarded as underlying a long ridge, from which branches reach out sidewise to surface openings. That such openings exist is demonstrated by the perfect atmospheric ventilation, as well as by the currents in the subterranean rivers, and the debris of forest leaves, nuts, twigs and other objects recently brought in from outside. They agree in differing from Bishop's old map on numerous minor points. For instance, Pensacola Avenue was located by Klett and myself north of and parallel to the beginning of the Main Cave; whereas Bishop made it run far south of it into proximity to River Hall. Blackall coincides with us instead of with Bishop. But, on the other hand, his plotting of the river region agrees with Bishop, instead of with Hovey and Call. Both maps depart widely from Bishop's in the location of Cleveland's Cabinet. I discovered long ago that Bishop had erred in swinging the end of the cave too far to the north, and wished to correct the error on my map, but was not allowed to do so by Manager Klett, lest the lines should run beyond the limits of the estate. In the recent standard map the end is pushed much further southward; and in Blackall's further yet—which is undoubtedly correct. Other divergencies and coincidences will be noted by any one familiar with the cavern topography. The names in use thirty years ago were intentionally retained by Dr. Blackall, whereas in our latest map the names at present in use are given.

Blackall's map is drawn to the scale of 200 yards to the inch, which he assures me is meant to be exactly correct. Many important exterior and interior measurements are indicated. The former have never previously been given; and the latter are just about one-half what is stated by the guides. The lines within the cave are run from the entrance following the curves of passages; those without are by "air line" from the hotel that stands directly over the Rotunda. The total length of what is termed the Main Cave is 3,300 yards, or less than two miles; said by the guides to be four. The air-line distance is 1,850 yards, or a little more than a mile from the hotel. The distance interiorly from the entrance to the end of the long route, at Croghan's Hall, is 7,850 yards, or about four and a half miles. This agrees with my measurement as made in 1882; and also with subsequent measurements made by Prof. Newton, of Yale University, and Dr. Foote, of Philadelphia, and others. The guides had previously called it ten miles.

The Standard Map, so called because adopted by the authorities, is in a sense composite, being the work of no one man, but embodying what has been successively done by Lee, Bishop, Klett, Hovey and Call, and finally redrawn on a reduced scale for the revised edition of Dana's Text-Book of Geology (1897), the original plate being kindly furnished for this article by the American Book Company, to whom due acknowledgment is hereby made for the favor. The same map substantially is found in the illustrated guide manual of Mammoth Cave, with the different routes indicated by shading, and all the noted localities numerically designated according to a key prepared by Dr. Call. For the most part it is drawn to a scale of about 2,000 feet to the inch. This does not apply throughout, however, as can be seen by applying it to Ganter Avenue, which is known to be 8,500 feet long, whereas on this map it seems only half that distance. There are five different galleries in the cavern, from one to another of which the pathway wanders, often by bridging or tunneling other courses, thus making it very difficult for the map-maker to mark these changes on a flat surface of paper. Some of the deepest parts are marked in black, especially where the excavation cuts down to the drainage level.

In conclusion we are ready to agree with critics who may say that after all no adequate and satisfactory map of the Mammoth Cave has yet been published. The only claim for these two maps is that they are the best extant. We wish that men of science, and all who are on any account interested in underground America, would unite in an appeal to the owners of this marvelous cavern to dismiss their apprehensions of harm from rival interests, and after taking due legal measures to protect their rights, to encourage and aid in every way the most complete and accurate interior and exterior survey that can be made by expert cartographers.

The Mammoth Cave estate belongs to the immediate heirs of the late Dr. John Croghan, his nephews and nieces, of whom only three survive, all being over eighty years of age. By his will, a copy of which is in our possession, the estate must be sold at auction to the highest bidder after the death of the last survivor, and the avails divided equally among the heirs of the original legatees. Wishing length of days to the present owners, we would suggest and urge that, whenever the day of sale shall arrive, the State of Kentucky should become the purchaser, and should include the group of neighboring caverns and grottoes, of which there are ten or more, in a public domain, to be styled "The Mammoth Cave Park," whose mazes and mysteries should be fully and scientifically explored and made known to the world.

[Continued from SUPPLEMENT, No. 1228, page 19685.]

PROGRESS IN THE IRON AND STEEL INDUSTRIES.*

ATTENTION must now be directed to the great process for the production of steel which involved the use of the "open hearth."

Sir William Siemens' life was one long and ultimately brilliantly successful effort to apply the kinetic theory of gases and the dynamical theory of heat to industrial practice. He was eminently a practical worker; but the depth and accuracy of his scientific knowledge gives him a place near that of all the great atomists from the time of Lucretius to that of our own countrymen, Graham, Joule, Clerk Maxwell, and Kelvin. In many of Siemens' papers, theory and practice are closely blended. In viewing the results of his labors, it will be seen in future ages that confidence in the trustworthy character of steel was finally established by experiments on metal produced in the regenerative furnace of Siemens. Looking back, it is astonishing with what difficulties the use of steel for structural purposes was beset. In 1859 Sir John Hawkshaw was not permitted by the regulations of the Board of Trade to employ steel in the construction of the Charing Cross bridge. Time will not permit me to indicate the efforts which were made to induce the Board of Trade to remove the serious hindrances to the use of steel which had "rendered the construction of the projected bridge over the Firth of Forth practically impossible." These efforts were not successful until 1877, when a committee, consisting of Sir John Hawkshaw, Col. Yolland, and Mr. W. H. Barlow, were able to recommend that the employment of steel in engineering structures should be authorized by the Board of Trade. The steel employed was to be "cast steel, or steel made by some process of fusion, subsequently rolled or hammered;" one condition of such recommendation being that "the greatest load which can be brought upon the bridge or structure, added to the weight of the superstructure, should not produce a greater strain in any part than $6\frac{1}{2}$ tons per square inch."

As regards the use of steel for shipbuilding purposes, in the year 1875 Sir Nathaniel Barnaby asked, "What are our prospects of obtaining a material which we can use without such delicate manipulation and so much fear and trembling?" He partly answered his own question four years later, when he quoted experimental evidence as to "the recent successes" of open-hearth steel. In 1890 he completed the case by pointing out that naval architects now "have a perfectly regular material, stronger and more ductile" than iron, and he speaks of "our lasting debt of gratitude for the birth and training of that true prince, William Siemens." It is hardly necessary to point out that the country owes the excellent materials used in naval architecture mainly to the productions of the regenerative furnace.

In connection with the production of mild steel, the addition of ferro-manganese to the decarburized bath proved to be most effective. We can hardly overestimate our indebtedness to those whose perseverance insured the adoption of mild steel for maritime and other purposes. "Looked at from the standpoint of to-day, when thousands of tons of such steel are made weekly without serious anxiety or trouble, it is scarcely possible to realize the anxieties and difficulties of the days when the manufacture of open-hearth steel was being perfected." To no one is our debt greater than to our vice-president, Mr. James Riley, who bore a large share of the anxieties of the early days, and whose words are those I have just quoted.

With regard to the great modifications which have been effected in the Bessemer and open hearth processes, reference must be made to that ample source of information, our journal. It must also be consulted for the history of the appliances for heating the blast, with which the names of Cowper and of Whitwell will always be specially connected.

In speaking of Bessemer and Siemens, I have been obliged to depart somewhat from strict chronological order. I must now resume it.

In the year 1866 Graham's first paper on the occlusion of gases by metals was published in the Philosophical Transactions. Its results have been far reaching, and will always be ranged with the metallurgical triumphs of the century.

In the year 1869 our institute was founded. In view of certain aspects of the treatment which inventors had previously received from their industrial brethren and from the country, it will be evident that the time for its formation had fully come. Taking instances almost at random, I may remind you that Dud Dudley was, as he says, "with lawsuits and riots wearied and disabled" in the seventeenth century, and that Henry Cort was neglected and oppressed in the eighteenth. The great invention of iron bottoms in the puddling furnace made by Rogers was received with ridicule, and he died in poverty. Popular tradition of Sheffield indicates that possession was obtained of Huntsman's secret "by the heartless trick of a rival." Neilson, though he warmly acknowledges the support he received from certain iron masters, was treated with singular meanness by others. Heath fought single handed for fifteen years "against a common purse, the accumulation of the wealth which he had created." Even Bessemer's early statements were received with incre-

* Abstract of the presidential address to the Iron and Steel Institute, by Prof. Sir W. Roberts-Austen, K.C.B., D.C.L., F.R.S., delivered before the members of the Institute on May 4.—From *Nature*.

dulity and contempt. With the formation of our institute all this is changed; men place the results of their work and experience freely at the disposal of their brethren, and each fresh advance meets with appreciative consideration. "Vigorous moderateness," wrote the late Walter Bagehot, "is the rule of a polity which works by discussion. . . . It was government by discussion that broke the bond of ages and set free the originality of mankind."

It was then pointed out that the history of the iron and steel industry since the formation of this institute was epitomized by the labors of those who had occupied the presidential chair. The president, therefore, gave a brief sketch of the work done either by the successive presidents of the institute, or during their respective terms of office.]

The address then continues as follows: This concludes the list of those who have hitherto presided over the institute, and it will have been evident that from time to time other interests than those connected with iron and steel have been represented by your presidents. We were reminded of this fact when the institute first met, now twenty-four years ago, at Manchester, where we are promised a delightful meeting again next autumn. The bishop of that great city then welcomed us by a quotation from Virgil, which connects the age of iron with the age of gold. The passage runs thus:

"Quo ferrea primum
Desinet ac toto surget gens aurea mundo."

A president of this institute who has had the privilege to serve in the mint, in a sense connects the iron and the golden age. I find that during the course of a long official career I have been responsible for the standard fineness of over one hundred and twenty-one millions of gold coin. This sum is so vast, and the anxiety connected with it has been at times so great, that I am not careful to conceal the pride revealed by this reference to it, as it is an exponent of the financial greatness of the nation which created the age of steel. But I value as highly the means of conducting research and the hope of being useful, which was also given me by the government when I was appointed Professor of Metallurgy at the Royal School of Mines. I have in the discharge of my duties persistently striven to show that what is called applied science is nothing but the application of pure science to particular classes of problems.

I regret that space will not permit me to consider the progress of the century as measured by the work of our Bessemer medalists. I hope, however, as regards the labors of the foreign recipients of the honor, to deal with them next spring. The metallurgy of America is so closely interwoven with our own, that I must permit myself a brief reference to four men who stand out from the industrial ranks of our kinsmen. These are Alexander Lyman Holley, the Hon. Abram S. Hewitt, John Fritz, and Prof. Henry Marion Howe. All of them are Bessemer medalists.

It may help us to estimate the value of the labors of the four men whose names I have given if we remember that at the present time the United States export about a million tons of iron and steel a year, while twenty years ago they were not exporting any. We may also fairly consider their influence on the rapid development of the United States navy. It would seem that we, in this country, in the belief in our insular security, had somewhat neglected the art of naval warfare, until Admiral Mahan reminded us of what we had done in the past, and of our possible course in the future, in a series of writings which have done much to convince the two nations, England and America, "that they are in many ways one."

It is time to offer a collective statement of the achievements which have either been actually effected or are in immediate prospect.

There are blast furnaces which will produce 748 tons of pig iron in twenty-four hours, with a consumption of little over 15.4 cwt. of coke per ton of iron. The gases from blast furnaces are used, not only as sources of heat, but directly in gas engines.

There are Bessemer converters which can hold 50 tons of metal, and open hearth furnaces which will also take 50 tons, while 100-ton furnaces are projected. The open hearth furnaces are fed with one ton of material in a minute, by the aid of a large spoon worked by an electro motor. There are gigantic "mixers," capable of holding 200 tons of pig iron, in which, moreover, a certain amount of preliminary purification is effected.

Steel plates are rolled of over 300 feet in area and 2 inches thick. There are girders which justify the belief of Sir Benjamin Baker that a bridge connecting England and France could be built over the channel in half-mile spans. There are ship plates which buckle up during a collision, but remain water tight.

There are steel armor-piercing shot which will penetrate a thickness of steel equivalent to over 37 inches of wrought iron. The points of the shot remain intact, although the striking velocities are nearly 2,800 feet a second. There are wires which will sustain a load of 170 tons per square inch without fracture. Hadfield, whose labors will, I trust, be continued far into the twentieth century, has given us manganese steel that will not soften by annealing; while Guillaume has studied the properties of certain nickel steels that will not expand by heat, and others that contract when heated and expand when cool. Nickel, chromium, titanium, and tungsten are freely used alloyed with iron, and the use of vanadium, uranium, molybdenum, and even glucinum, is suggested. There are steel rails which will remain in use seventeen years, and only lose 5 pounds per yard, though fifty and a half million tons of traffic have passed over them.

Huge ingots are placed in soaking pits and forged direct by 120-ton hammers, or pressed into shape by 14,000-ton presses. With such machinery the name of our late Member of Council, Benjamin Walker, will always be connected.

There are steel castings, for parts of ships, that weigh over 35 tons. We electrically rivet and electrically anneal hardened ship plates that could not otherwise be drilled. Photomicrography, originated by Sorby in 1864, now enables us to study the pathology of steel, and to suggest remedial measures for its treatment. Stead's work in this field is already recognized as classical. Ewing and Rosenhain have, in a beautiful research, recognized quite recently by its aid that the