in the Swiss cantons. In Zurich a communal school is described the building for which cost sixty-six pounds per pupil, — five times the much-complained of London average. There are no fees, and ninety-seven and a half per cent of all the children of school age are said to attend schools of this type. The average attendance is returned as ninety-five, — a remarkable contrast to the seventy-two per cent which was the average in England and Wales a year ago; and no proposal for the reduction of school expenditure can find a hearing as an election cry in Switzerland. Without a mine, a canal, or a navigable river, Switzerland carries on extensive cotton and silk weaving, paper-making, and calico-printing works; and the report grows quite enthusiastic on the aniline-color works of Basle, an abundant supply of skilful chemists being thoroughly trained in such institutions as the Polytechnicum at Zurich, or the Bernoullianum at Basle. The report shows that the higher educational institutions are as various in the different countries as they are generous and complete in most. In the German empire there are twenty-four universities. The buildings for the Strasburg university are now nearly complete, and are to cost six hundred thousand pounds. The department of botany has had a sum of twenty thousand pounds devoted to it; that of physics, thirty thousand pounds; and that of chemistry, thirty-five thousand pounds. The votes for maintenance are similarly ample. The rivalry between the universities and the polytechnic schools is wholesome, if costly. New buildings are now being completed at Charlottenberg, in which the work of the old technical high school of Berlin will be carried on. There are many intermediate schools between the primary schools and the universities and polytechnic schools. The 'Fortbildungsschulen' of Germany are very beneficial institutions. "The work of the primary day schools is carried on in evening classes with a direct and practical bearing on the occupations upon which the pupils have entered. But in every country, and notably in France and Belgium, there are night classes provided for the instruction of the industrial classes in drawing and modelling, directly applied to decorative art, as well as in popular science and general knowledge. Then, again, there are schools still more specialized for instruction in weaving, in practical mining, in dyeing, and in designing for every conceivable kind of artistic manufacture. This teaching is often gratuitous; but, where fees are exacted, they are always small; and there is everywhere prevailing a system of bourses and scholarships by which meritorious pupils are enabled to carry on their studies. The state, the province, and the commune bear the charges in their allotted proportions." The use of museums and art-galleries, open on Sunday for the benefit of designers, is much dwelt on by the commissioners, who embody a recommendation of Sunday opening in their report.

Mr Samuelson and his colleagues travelled at their own expense, and have spared no exertion to place their facts before the public in a complete and useful manner.

THE AGE OF STEEL.

The creators of the age of steel (on Sir Henry Bessemer, Sir C. W. Siemens, Sir Joseph Whitworth, Sir John Brown, Mr. S. T. Thomas, and Mr. G. J. Snelus). By W. T. JEANS. New York, *Charles Scribner's sons*, 1884. 314 p. 8°.

IN this little collection of biography, the author has given a very interesting, and we may presume thoroughly authentic, account of the lives and the achievements of the great engineers who have during the past generation, 1850 to 1880, become famous as the 'creators of the age of steel.'

The list given by Mr. Jeans includes Messrs. Bessemer, Siemens, Whitworth, Brown, Thomas, and Snelus, but omits Mr. Mushet (in regard to whose claims a somewhat sharp controversy is now going on in the English periodicals), and makes no mention of two great American claimants for hardly less honor than is indisputably due to Bessemer himself, — Mr. Kelly, the contemporaneous inventor of the pneumatic process; and Mr. Holley, the great engineer, who by his wonderful ingenuity in the development of the details of the mechanical processes involved, and by his exceptional genius for designing automatic and efficient machinery, brought up the productiveness of our American establishments to double and treble that of those of European construction, and, in some cases, to several times the magnitude of output for which they were originally calculated.

The sketch of Sir Henry Bessemer is particularly full and satisfactory; and the author evidently feels unlimited admiration for the man, as well as for his work. He outlines the career of the exiled Anthony Bessemer, the father of Sir Henry, whose expulsion from France gave to Great Britain a family of whose achievements the world has learned to speak as those of its greatest benefactors. The father was no less ingenious than the son, and was famous, in his day, for his success in the arts of the gold-refiner and of type engraving and founding.

The son, now Sir Henry Bessemer, was born in England in 1813, and at a very early age exhibited his predilection for mechanics, and especially for its more artistic branches. He became a modeller, a designer, and an engraver, and invented new processes for use in the stamp-office, that were admired both for their singular ingenuity and for their efficiency. Losing the hoped-for reward for these inventions through those delays and those soulless methods characteristic of government offices, he turned his attention to other lines of invention, producing a machine for working velvets, new type-making machinery, apparatus for making bronze powders, and other equally important and profitable devices. For many years previous to the conception of his greatest invention, the young man's mind was astonishingly prolific of valuable and remarkable devices and processes.

In 1853, when forty years of age, his attention was called to the importance of effecting improvements in the then crude forms of ordnance, and the unsatisfactory character of all ordnance metal. He devised a method of firing elongated projectiles from smooth bore guns, — a plan which had been attempted, but unsuccessfully, at intervals of every few years, from the time of probably its first and tolerably successful inventor, Robert L. Stevens, in the beginning of the century. The plan was to a certain degree satisfactory; but it brought out very strongly the evident necessity of obtaining a better metal for ordnance; and to this problem the young mechanic now addressed himself. Studying the problem in the truly philosophic manner, he saw that the end to be gained was the removal of carbon, and other impurities in the crude cast-iron, by some process that should do the work thoroughly, quickly, cheaply, and yet give a product in the form of ingot-metal. He saw that this could be done by a process of oxidation, and finally hit upon the idea of performing this operation by driving air, in finely divided streams, upward from a submerged reservoir, through the mass of molten cast-iron. This was the invention of the 'Bessemer process,' the greatest invention in the history of metallurgy. It was as simple, and apparently as obvious, a method of accomplishing the work, as can be conceived: its simplicity and obviousness are such as make it seem wonderful that it had not been done a century earlier. The story of Columbus and the egg here finds a parallel.

Some minor and accessory, yet essential, inventions were required to perfect the main invention, which delayed success some months; but they were in time perfected by the unconquerable Bessemer: and the process, after those delays which are inevitable whenever it is necessary to overthrow old methods in the introduction of new ones, became commercially successful. It was only, however, after Bessemer and his partners had built steel-works, and had shown on a full scale how far his devices were capable of yielding profit, that the iron-manufacturers and the steel-makers were induced to accept it as the coming steel-making process.

But the Bessemer process would be of comparatively little value, except for the invention of the now universal method of recarburizing — after the first operation, that of removing the silicon and carbon, is completed — by the use of 'spiegeleisen' or of ferro-manganese. It is this detail that gave the inventor success, after months of delay, within sight, apparently, of his goal. The question of priority of discovery of this method of recarburizing is still in dispute between the friends of Bessemer and of R. F. Mushet, and may never be fully settled to the satisfaction of either. There would seem to be no doubt that both of these metallurgists were working in this direction at the same time, and that both hit upon it at very nearly the same date. The fact, however, that Bessemer has never paid royalties to Mushet, is perhaps the best evidence, at least, of the legal status of the case.[1] No one will, however, question that Mushet was on this track when Bessemer was working at the same point; and it is most probable that he found the solution of the problem at about the same time with the more fortunate inventor. Bessemer has himself frankly acknowledged the importance of Mushet's share in the invention claimed for him. The fact seems to be, that Mushet used spiegeleisen, or ferro-manganese, while Bessemer was still trying to use the oxide of manganese.

This, in brief, is the history of the invention of the Bessemer process of making steel, — an invention which has, in the short space of a quarter of a century, completely revolutionized some of the greatest of human industries; which has reduced enormously the cost of making the 'mild' steels which are now, consequently, displacing iron in every department of manufactures; and which bids fair in a very few years, even if it cannot be said to be an accomplished fact to-day, to convert the iron-manufactures of the world into steel-manufactures, and which has thus inaugurated the 'age of steel.'

To make the story of the Bessemer process complete, the author of this little history should have told of the advances made in the United States, where the work done by Bessemer in Great Britain was first copied, then improved upon, till to-day the capacity for production has been enormously increased, works originally built for a production of thirty thousand tons per year having carried the figure up to from

[1] Mushet patented the invention, but three years later allowed the patent to lapse by non-payment of the stamp-tax.

a hundred and twenty-five thousand to a hundred and forty thousand tons. This wonderful gain has been entirely due to American genius, and principally to the splendid engineering of the late A. L. Holley, who told his friend Thomas, the inventor of the 'basic process' (who, when visiting the steel-works at Troy, looked for an ingot-mould on which to seat himself after a fatiguing tour of the establishment), that, if he wished to find an ingot-mould cool enough to sit upon, he must go back to England for it.

A sketch of Sir William Siemens follows that of Sir Henry Bessemer, and a very good account is given of the so-called Siemens process of making steel. For a short outline of the life of this wonderfully versatile inventor and engineer, the reader may turn to the columns of *Science* for Jan. 11; but he will find a more detailed story of his life in the Creators of the age of steel.

The Siemens process of steel-making differs from the Bessemer process, of which it is in some sense a rival, but with which it is more strictly a coadjutor, in being a slow and gradual operation, conducted upon the hearth of a reverberatory furnace, — an 'open-hearth' furnace, as it is often called, — instead of being a process of rapid reduction in a closed vessel, inaccessible to the operator at any time during the period of change. This slowness of transition from the condition of cast to that of wrought iron, and the perfect accessibility permitted by the use of the open-hearth furnace, afford the workman an opportunity to watch the process of evolution of carbon, and to check it, if he desires, at any stage; to increase or diminish the proportions of any element, as he may find it necessary; and thus to obtain with certainty precisely the quality that he seeks. In the Bessemer process, the right proportions must be hit upon at the right instant, or the error permanently injures the product, and cannot be rectified. In the Siemens process, if the metal is not right when ready to tap off, the operator can readjust the proportions of carbon or of manganese until he finds, by test of samples taken from the furnace, that it is precisely as he wishes it; and he can then cast it into ingots with a positive certainty that he will obtain a marketable product. In this process, too, the refuse scrap, the rail-ends, and other waste from the Bessemer converter, can be worked up; and by it a great market for scrap wrought-iron is made.

A long and sometimes sharp controversy has arisen between the friends of the two great inventors, and especially between the friends of Siemens and of Martin, who introduced this process in France, as to the priority and the relative merits of the inventions. The true facts of this case are probably correctly given by a committee of the Styrian metallurgical association, who voted that the principle of making cast-steel on the hearth of a reverberatory furnace was known at the beginning of the century, and that it was successfully practised in France in 1860; that Sir William Siemens invented the process of making steel in the Siemens regenerative furnace; that Martin discovered the proper mixtures for the commercial grades of steel; that the processes devised by the latter have been now superseded, and are of no present use. There is and can be no rivalry between the Bessemer and the Siemens processes, or their inventors. They occupy entirely different fields of production; and each is peculiarly adapted to making a special kind of steel, and to working up materials such as the other is least fitted to handle. Each has its place in our industrial system, and each is of direct and substantial value to the other. The Bessemer process will probably make the bulk of our steel rails, and the Siemens process will probably supply us with the best of boiler-plate, for an indefinite period of time. We shall always find a field open to both, and shall always see each taking its own place, and filling it in a manner that the other cannot imitate.

The original Siemens process was one in which the carbon was removed from cast-iron, partly by dilution with wrought-iron scrap-metal, and partly by oxidation in the flame of the reverberatory furnace of Siemens, and also, perhaps, to some extent by 'dissociation.' This method of making 'mild steel' involved the use of a large quantity of scrap, and although at first a very economical process, and continuing to be economical so long as scrap-iron flooded the market, as it did at the first, became uneconomical, comparatively, as the price of wrought-iron scrap advanced. Siemens then introduced his so-called 'ore process,' in which the reduction of the carbon was effected by the use of the ores of iron. The process as now usually conducted, under the direction of the agents of the inventor, is a mixed ore and scrap process.

The peculiarity of the product of the Siemens process is the wonderful uniformity, toughness, and purity of the metal. The most stringent demands of the engineer are readily met by the open-hearth steel-maker; and the most delicate shades of quality are obtained with an ease and accuracy that are approached by no other known methods of making mild steels in large quantities. This is the only kind of steel in general use for boiler-plate, for bridge-work, or for general construction. The largest and finest steamships in the world are now made of this material, and their machinery is gradually absorbing a larger and larger proportion of the same kind of metal; and the time is probably not far distant when it will have completely displaced iron for all ordinary purposes of engineering construction, — as completely as has Bessemer steel displaced its rival in the manufacture of rails.

The great bridge over the Firth of Forth, with its two spans of seventeen hundred feet each, is to take forty-two thousand tons of Siemens steel. The one firm of Elder & Co. of Glasgow, the pioneers in the introduction of the marine compound engine and of steel ships, uses some twenty thousand tons of this steel per annum. In the ship-building trade, over two hundred and sixty thousand tons are now used each year.

There are now over a hundred and fifty open-hearth furnaces in operation in Great Britain alone, exclusively for the manufacture of the Siemens steel. It has been found possible to obtain temperatures sufficiently high to remove phosphorus, that bane of the steel-maker; and now moderately phosphuretted ores are worked for steel. The scrap-iron used is to a considerable extent obtained from the Bessemer works, which supply rail-ends and other waste.

Space does not permit more than a mention of the other minor, but nevertheless great, 'creators of the age of steel.' Sir Joseph Whitworth has, by a system of compression of the molten and solidifying ingot, given us a steel so perfectly sound and free from 'blow-holes' that it may be used for a thousand purposes for which ordinary steel is entirely unfitted. This steel is made by the ordinary processes, and, when poured into the ingot, is immediately placed under the plunger of a very powerful hydraulic press, and there subjected to a pressure of a thousand or two thousand tons; under which enormous load every pore is closed up, and the steel solidifies in a compact mass of such fineness of structure, that no microscope, and no physical or mechanical test, can detect the slightest defect in homogeneousness. Its strength and its ductility are such that the inventor tests the ordnance which he makes of this metal by securing the shot in the gun so that it cannot be driven out; and then, firing the charge behind it, the whole mass of gas resulting from the combustion blows out at the 'vent' without injury to the gun. No such test was ever dreamed of by any ordnance officer, or attempted with any other kind of ordnance metal.

Sir John Brown, the proprietor of the great iron and steel works at Sheffield, famous for the magnitude of the armor-plates often made there, was the first manufacturer in Great Britain to countenance Bessemer in his endeavor to make a new steel, and was the first to put up a Bessemer converter, after the early experiments of the inventor had indicated a probable success. The armor-plating of ships — an invention of our countryman, Robert L. Stevens of Hoboken — was adopted in England during the Crimean war, at about the time that the Emperor Napoleon made the first attempt to make armored vessels of service in attacking the forts at Sevastopol. Sir John Brown was one of the first of the British iron manufacturers to fit up works for the purpose of making heavy plate. He soon added Bessemer works to his establishment, and produced steel for the general market. His armor-plate is now made as a 'compound' plate, consisting of an iron backing, with a facing of steel,— a combination of which more is expected than from the simple construction. The magnitude of the works may be imagined from the fact that there are in use a hundred and sixty steam-boilers, supplying steam to the amount of eleven thousand or twelve thousand horse-power.

Other great promoters of the revolution now in progress are Messrs. Gilchrist and Thomas and Snelus: they have done much toward the reduction of the cost of making steel by the modern processes, by making it possible to use the cheap phosphuretted ores which had previously been unavailable. The new method of operation of the Bessemer process, which has effected this change, and which, as Mr. Carnegie says, has "done more for England's greatness than all her kings and queens and aristocracy together," consists simply in the lining of the converter with materials having a basic reaction, and in the introduction of similar material with the charge. Lime is the base found best adapted to the purpose; and its use has, after long experiment and the expenditure of much time and money, been made practicable by Messrs. Thomas and Gilchrist, and Mr. Snelus. At extremely high temperatures, and in the presence of lime, phosphorus will pass from the molten iron in the converter into the lime with which it meets in the lining of the vessel, and which is added before the blow; and the steel is thus freed from its most persistent and dangerous impurity. Mr. Snelus seems to have been the first to work out this problem, and it was then perfected by the other inventors mentioned. The success of the process is to a considerable extent dependent upon the mechanical details of the plant and of its operation, — details perfected, in part, by the late Mr. A. L. Holley, one of whose latest inventions was a form of rapidly removable converter especially adapted to this modification of the older process. This new method has not been introduced as rapidly outside of Great Britain as in that country, where the scarcity of pure ores renders it of very great importance. In the United States the abundance of ores comparatively free from phosphorus renders the steel-maker to a great extent independent of the 'basic process.' All of the larger makers now have their own mines of good 'Bessemer ores,' and do not feel much interest in this latest of the great inventions of the opening age of steel.

The 'creators of the age of steel' have rendered inestimable service to mankind, and all mankind will be interested in reading the story told by Mr. Jeans. R. H. Thurston.

THE GUATEMALTEC LANGUAGES.

Zur ethnographie der republik Guatemala. Von Otto Stoll. Zürich, *Orell Füssli & Co.*, 1884. 9+180 p., map. 8°.

A grammar of the Cakchiquel language of Guatemala. Translated by D. G. Brinton. Philadelphia, *McCalla and Stavely*, 1884. 72 p., map. 8°.

To suppose that dialects of the Maya family are the only languages spoken by the Indians of this extensive Central-American republic would be at variance with existing facts, although they cover, indeed, the largest part of its area. The present tribes speaking allophylic languages (that is, languages belonging to other families) are the Pipil Indians, speaking an Aztec tongue, and now found in two districts only (near Escuintla, Salamá, etc.) ; the Pupuluca Indians, on the border of San Salvador, belonging to the Mije stock ; and the Caribs, at the mouth of Rio Dulce and in the adjacent territory of Honduras, who still speak the language of the Lesser Antilles. Otto Stoll, who, during a five-years' stay in the mountainous parts of Guatemala, has made extensive linguistic and ethnographic studies of the aborigines, has established the above classification, and also mentions the former (if not present) existence of two other dialects which may possibly form linguistic families for themselves, — the Sinca on the southern coast, and the Alaguilac on Middle Motagua River, both from the historian Juarros.[1] The first three of the above languages are illustrated by vocabularies and linguistic comparisons with cognate dialects.

Of sixteen Maya dialects, the learned investigator offers a useful and complete vocabulary extending over three hundred terms. Subjoined to these are short texts, conversations in Indian, historic and ethnographic notices from the conquest down to our times, and an elaborate bibliography. To judge from their lexical and grammatic character, the dialects have evolved, according to Stoll (pp. 173–175), in the following historic order from the parent language : —

1. *Huastec* forms the most archaic group, now separated from all the others by its northern location.

2. *Maya*, with its subdialects of Peten and Lacandon.

The following groups (3–6) have detached themselves from the Maya of Yucatan, and their forms are of a much less archaic type : —

3. *Tzental* group, embracing Chontal of Tabasco, Tzental proper, Tzotzil, Chañabal, Chol, — all in southern Mexico ; Mopan in northern Guatemala.

4. *Poconchi* group, embracing Qu'ekchi, Poconchi, Pocomam, Chorti, in central and eastern Guatemala.

5. *Qu'iché* group, comprehending Qu'iché, Uspantec (dialect discovered by Stoll), Cakchiquel (the dialect studied more especially by the author), Tz'utujil, — all in south-western Guatemala.

6. *Mam* group, comprehending Ixil, Mam, Aguacatec, in the western sections of the republic.

The third group constitutes a much younger branch of the Maya of Yucatan than the fourth, fifth, and sixth groups.

The Cakchiquel language is a Maya dialect, spoken on the Upper and Middle Motagua River, and around Guatemala, the capital of the republic of the same name. It was therefore called also 'lengua metropolitana' and 'lengua guatemalteca.' By request of the American philosophical society of Philadelphia, Dr. Brinton has just translated and published in its proceedings, and also in a handy, separate edition quoted above, a Spanish grammar of that language, dated 1692, and composed by an unknown author. To render the exposition of the language, which is extremely harsh of pro-

[1] Sinca is declared to be a Mixtec language by Alphonse L. Pinart.