DEPARTMENT OF THE INTERIOR,

CENSUS OFFICE.

FRANCIS A. WALKER, Superintendent,
Appointed April 1, 1879; resigned November 3, 1881.

CHAS. W. SEATON, Superintendent,
Appointed November 4, 1881. Office of Superintendent abolished March 3, 1885.

STATISTICS AND TECHNOLOGY

OF THE

PRECIOUS METALS.

PREPARED UNDER THE DIRECTION

OF

CLARENCE KING,

SPECIAL AGENT,

BY

S. F. EMMONS AND G. F. BECKER.

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
SECRETARY'S OFFICE,
Washington, June 1, 1885.

Hon. L. Q. C. LAMAR,
Secretary of the Interior.

SIR: I have the honor to transmit herewith the Report on the Statistics and Technology of the Precious Metals, prepared under the direction of Hon. Clarence King, formerly Director of the United States Geological Survey.

This report forms the thirteenth volume of the series constituting the final report on the Tenth Census.

Very respectfully, your obedient servant,

JAMES H. WARDLE,
Chief of Census Division.

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LETTER OF TRANSMITTAL.

NEW YORK, *February* 8, 1883.

Hon. C. W. SEATON,

Superintendent of Census.

SIR: I have the honor to transmit the accompanying report on the technology and statistics of the precious-metal industries by Mr. S. F. Emmons and myself. The investigation which forms the subject of this volume was committed to our charge early in 1880 by the Hon. Clarence King, my predecessor, as special agent in charge of the investigation of the precious-metal industries. Mr. King retained this position till May 1, 1882, a year after the completion of the field-work, when he was compelled by ill-health to resign it, and you appointed me to fulfill the very simple duties remaining to be discharged. While appreciating the honor done me, I beg leave to draw your attention to the fact that the direction of the inquiry was in Mr. King's hands until all the more important questions were settled, and that the credit of the general conduct of the work belongs entirely to him. The part taken by Mr. Emmons and myself in the investigation is sufficiently explained in the preface.

Very respectfully, your obedient servant,

GEORGE F. BECKER,

Special Agent.

INTRODUCTORY REMARKS.

By CLARENCE KING.

PECULIAR CONDITIONS AFFECTING AMERICAN MINING.—Ever since the inception of mining on a large scale and permanent basis in the United States, comparisons have been made between the methods practiced here and those in vogue in European countries, and the conclusions have naturally been at variance. The subject has been discussed by foreign engineers who have traveled in this country, and who have usually looked at the subject from the standpoint of European conditions. To them many of our methods have appeared crude, and they have been apt to condemn the apparent want of the economy and thoroughness which are so marked characteristics of the best foreign practice. American engineers who have received the earlier portion of their technical training abroad have also been prone to criticize many of our mining methods. A longer acquaintance with the conditions which prevail here has usually modified such views. It may not be out of place to note a few of the salient differences in methods prevailing in this country as compared with those abroad.

Among the best characteristics of American mining practice may be mentioned the originality and ingenuity of the methods which have been adopted. In many cases, as for example the system of hydraulic mining, a completely new departure has been made and within a short time carried to an extreme point of development. In other instances, modifications and improvements on foreign methods have been added to such an extent that their sources are scarcely recognizable. Another striking feature is the rapidity of execution and the consequent saving of time and interest. It is true that this has often been pushed too far, and in many instances better results might have been secured by more conservative methods. But it may be said, as a rule, that capital invested in precious-metal mines in this country has always secured quick returns, if any. This is necessitated by the demands of investors, who are seldom satisfied, when interested in precious-metal mining, with the plodding methods which perhaps in the long run would be more profitable, and on which they would rely in any other branch of industry. Although undue haste must be condemned from an economic point of view, the spur has not been without its advantages on the technical side.

Still another feature is the boldness of conception of engineering enterprises connected with mining, and the large scale on which operations are conducted. As examples: The ditch, flume, and pipe system of the hydraulic mines; the daring feats in railroad engineering, securing transportation to and from rugged mining districts; the extensive tunnel enterprises, and the deep shafts fitted with heavy hoisting and pumping machinery.

On the other hand, it must be acknowledged that the attempt to rely on originality of plan to the exclusion of experience gained abroad has often resulted in failure. Novel processes and machinery which have been tried and condemned by foreign miners have sometimes been reinvented and experimented upon in this country with a failure which would have been avoided had the records of foreign mining been consulted. The desire for immediate returns has been carried to an extreme and has entailed unnecessary loss. To open mines rapidly usually requires a greater outlay than where work is prosecuted at a slower rate. Mines are often worked on three shifts a day when two would be better. In districts remote from railroad communications freight is often hauled out of season at vastly increased expense, when the more economical plan would be to close down the works temporarily. Ores are treated at high cost and at a low percentage of metals saved in primitive mills and smelters, when such delay as would be caused by the erection of custom works or the approach of railroads would much more than offset the loss of interest on unreduced ores. It should be noted, however, that mines worked without capital or with insufficient capital are obliged to adopt the hand-to-mouth system in order to keep in operation at all.

Foreign engineers have frequently remarked on the apparent recklessness in regard to small savings manifested at many of our mines. Another point, which is equally patent to American miners, is the planning and construction of expensive works at mines whose development is insufficient to authorize them. Reduction works have often been erected before the character of the ore to be treated has been fully determined; thus mines not explored below the

water level, but which show free-milling ores at or near the surface, have been equipped with wet-crushing mills, necessitating extensive changes in plant after the surface ores have been exhausted, and amalgamating mills have been built where a small leaching plant would have been more suitable; and sometimes reduction works have been built for mines entirely undeveloped.

Investors in mining property seem always to have preferred taking great chances to smaller but safer investments. This trait has been so marked that a few years ago it seemed easier to place a mine on the market for a million dollars than to sell the same mine at say one-tenth of that price. Mining properties thus capitalized at high figures are apt to be equipped with over-heavy plant.

There has, perhaps, been too much willingness to experiment with novel devices, especially with untried ore-reducing machinery. This tendency has been more particularly shown in the case of mines controlled by owners at a distance and living in those portions of the country where mining is an unknown art. Mine owners who live in the mining regions are not so apt to make mistakes of this kind.

Two apparently contradictory traits have been manifested by some of our "practical" miners; on the one hand, they sometimes trust too much to rule-of thumb, and, on the other, are sometimes deceived by self-styled "scientific" men, who profess an occult knowledge of mining matters to which trained engineers would make no claim.

To the American miner the leading characteristics of foreign methods are economy as to details of expense and in minute metallurgical savings. The latter are exemplified by the complex systems of treating mixed ores as practiced in some of the German works and at Swansea, where there are no waste products, and where regenerative methods are so largely adopted. Our larger establishments are tending more and more to this system of working and are paying more attention to the treatment of residues.

In some foreign countries the mining industry possesses a stability and steadiness which results largely from government ownership and supervision; and these causes, however inapplicable in this country, have certainly had an economic effect. When such is the case, a far-sighted policy is always shown; plans are laid with a view to the remote future, and the plant and mine openings are substantial to a degree seldom seen here. The American miner, expecting to work out his mine in a few years, would hardly think of using brick-work or masonry in his galleries, etc., as is done in some of the foreign mines. Where an investment is made with the expectation of small, steady returns, extending over a long series of years, as has been the case with the greater portion of the enterprises conducted by government or by strong companies abroad, the most substantial work is in the end the most economical; but here, where the effort is too often to get out the largest amount of bullion in the shortest time possible, plans are seldom laid with a view to the remote future. The number of precious-metal mines in this country which have continued to be productive during a period of ten years is very limited, and the life of many of the most famous and successful ones has been far shorter. Indeed, a bonanza which has required two or three years to exhaust is a rarity, and when it is considered that many of the most productive mines have yielded merely a single large ore-body at or near the surface, the short average life is seen to be owing to natural causes as well as to the rapidity of operation. An engineer is hardly to be blamed, then, if he plans for the exigencies of the immediate present; on the one side he is pressed by the stockholder, clamorous for speedy profits, and on the other hand he realizes that the chances of a long period of bonanza are slight. His policy is forced upon him. He aims to secure given results by the most direct means, and when the object has been attained he cares little whether his drifts cave and the structures over his hoisting works and mills fall in, if they have served their purpose.

It is a pretty generally acknowledged saying that foreign engineers and Americans educated abroad have to divest themselves of a large part of their training before they can become successful superintendents of mines in the Far West. The attempt to graft the practices appropriate under other circumstances upon the peculiar disadvantageous conditions of mining in the precious-metal territory of the United States seldom results favorably. The high rates of wages, the difficult transportation, and the great expense (in most districts) of fuel, timber, etc., necessitate altogether different systems. It is possible that there may be such a thing as ultra conservatism; a deference to time-honored customs may be carried too far. To put the case in a concrete form, it may safely be said that had the whole management of our gold and silver mining industry been in the hands of Europeans, following the methods prescribed by their training and experience, less money might have been wasted in fruitless and impracticable enterprises, but on the other hand the gains would have been less in about the same proportion. For a typical example: Imagine a corps of German engineers in control at the time the Comstock lode was discovered. What would have been the result? Looking backward now it is easy to see how many millions of dollars might have been saved which were squandered in ill-advised, hopeless, or disconnected undertakings. But what would the foreign engineers have done? They would have worked out the surface ore-bodies of the Ophir, the Gould & Curry, etc., to the best advantage, doing in, say, ten years work which occupied by more wasteful but more expeditious methods only three or four. They would then have had to contend with the water problem. They would have driven the comparatively short adits freeing the mines of water to a depth of a few hundred feet, and finally, perhaps, would have projected the Sutro tunnel, but from that day to this operations would have been confined to ground above the Sutro tunnel. Per contra, a large amount of low-grade ore (neglected by the actual miners) would have

been taken out and worked at a small profit, and a field for labor would have been opened which would have lasted for decades. It is hardly likely that they would have projected the deep shafts, some of which, like the Forman, destined to strike the lode at about 4,000 feet, might have been considered foolhardy undertakings; and it is quite likely that the unprofitable deep explorations of late years would never have been countenanced. In the long run it is possible that the supposed system of the German engineers would have proved more economical, could it have been carried out; but it must be remembered that the mainstay of development, the money necessary to prosecute dead work, depended upon the speculative interest, which looked to brilliant and speedy discoveries of great bonanzas, and that this interest could hardly have supported the delay which would have resulted from a system more economical but less suited to the time and the locality.

One advantage which has prominently asserted itself in American mining is the intelligence and versatility of our skilled mine operatives. It may be true that for underground prospecting Mexicans may be superior, and it is certainly true that in plain work, such as drilling, blasting, and picking, Cornish and Irish miners are employed to a large extent; but the engine-drivers, the rope-men, the pump-men, the timber-men, the machinists, the millmen, are mainly native Americans. Our mining system is also in a broad sense an eclectic one, with the advantage of drawing hither the better classes of operatives from all sources.

In older countries the distances between the mining regions and the points of supply are generally small; freights are therefore cheap, communication by rail being the rule. The population is comparatively dense, and wages are therefore low, often reaching a point which would not furnish a bare subsistence for the miner of Nevada or Idaho. With good transportation facilities it is possible to operate large reduction works capable of profitably treating in mixed charges ores of different characters which it would be useless to attempt to reduce alone. Supplies, such as fuel, explosives, and steel, are relatively cheap. There are no excessive altitudes, and in the mining regions of Europe at least there is no extreme climate. And above all, perhaps, there is always a near market for products and by-products, some of the latter forming important items of profit.

In most of the mining regions of the Far West all this reversed. Often great distances have to be overcome by wagon-haulage, involving a freight charge seldom as low as one cent per pound in the more favored localities, up to six or eight in the more distant camps. The resident population is usually scanty, and dependent upon the mines rather than self-sustaining or tributary to them, and the cost of living is always higher than in agricultural regions, higher than in the eastern states, and much higher than in any civilized foreign country. This leads to higher wages; and in most districts of the Pacific slope, except in California, the rate is $4 per shift, whether of eight, ten, or twelve hours, for skilled miners, and $3 per day for surface laborers. While these men live better than their fellows of the eastern states, they are seldom able to accumulate savings, even with the increased wages, owing to the greater cost of living.

As a rule, it has been necessary to reduce the ores of each district by themselves. In the case of milling ores this would make little difference, for such ores need to be treated separately, but with smelting ores success often depends on the admixture of different kinds. Latterly, however, a few large smelting and general reduction establishments have been built at railroad centers, and these works handle ores from widely-scattered districts and of a large range in character.

Mining supplies are generally very dear, though the particular want in each district may differ. In many districts timber has to be hauled from a great distance, the supply of mine timbers used at some of the more distant camps of Nevada being derived from the Sierra, brought by rail and wagon over such long distances as to render the cost almost prohibitory. Over a large stretch of territory fuel is very scarce and the quality of that obtainable poor. Only in a small proportion of the districts is coal to be had, though as the railroads are pushed the use of coal is extending, as in parts of Colorado, Utah, and New Mexico. But few of the coals of the Far West can be made into coke—a necessity in certain branches of smelting—and coke is therefore carried from points as remote as Connellsville, Pennsylvania, and in some cases even from Wales. Charcoal of excellent quality is obtainable in many localities, but around some of the smelters the scanty growth of timber and brush has been long since stripped off, and the supply of charcoal has to be brought from a distance. For generating steam, wood is the common fuel. The increased cost of machinery, as compared with its price in the manufacturing centers, is the result of the heavy freights; and the same is true of such supplies as steel, candles, explosives, chemicals, etc.

The high altitudes, the rugged character of the country, and the severe winters are great drawbacks. Not a few camps are practically shut off from communication for several months each year. In some of the less important districts thus situated work is then suspended; in others it is carried on at great disadvantage. Besides the freight blockade caused by the heavy snows, trouble and danger often result from snow-slides. If the winters are unfavorable in the northern and higher districts, the summers are hardly less so in portions of Arizona and New Mexico.

It will thus be seen that there are peculiar natural disadvantages as compared with the conditions which prevail in the European mining districts, and indeed in most portions of the world in which mining for gold and silver is prosecuted. Almost all items of expense are more costly than in foreign countries, labor invariably so, and supplies usually, though perhaps in less degree. California, more settled, and largely an agricultural state, is to some extent an exception. The cost of mining and of reducing ores being so high, many of the smaller economies

of older countries are out of place. In one instance, in reply to the criticism of a foreign engineer who thought the percentage of metal extracted from the contents of the ores to be excessively low, it was only necessary to explain that the ore was the cheapest thing in the district. The superintendents are fully informed as to the means of close working, but however anxious they are to show fine technical results, they are ever held to the economic limit. There is always a point beyond which saving costs more than it is worth, and at this they are forced to stop.

It may be said that as time passes and the country is more and more developed our systems of financial management of mines are slowly approximating to those of Europe. In a few branches of mine engineering we also borrow, and in a wider range of metallurgical operations we are adopting European methods. On the other hand, many American practices have been copied elsewhere. The California stamp battery, the Washoe pan process, the water-jacket furnace, the hydraulic nozzle, etc., have been introduced in many new regions where appropriate. There is also a demand for engineers of American experience in opening new districts and in such countries as Mexico and the states of Central and South America, and these men carry with them their own systems. A point worthy of consideration is that there is unquestionably a greater variety of ores, not only of gold and silver, but of other metals as well, in the United States than in any other single country; so that the mines are schools of practical technology in which all specialties are developed, and in each something may be gained by comparison with the related industries.

SCOPE OF THE INVESTIGATION.—In undertaking the investigation of the statistics and technology of the precious-metal industry of the United States it was the object of those in charge of the work to make, not only a more accurate statistical estimate of the actual product of the precious metals than had hitherto been made, but also to obtain such technical data as to the various processes by which these metals are reduced from their ores as would serve to show the actual condition of the industry, the advances it has made as compared with former periods, and its relative perfection and imperfection as compared with similar industries in other countries.

These technical data it was expected would furnish to mining engineers, and to those interested in mining throughout the country, the materials to make such generalizations in any particular branch in which they might be interested as would tend to practical ameliorations, and would enable them, by comparing the practice in their own regions with that of other parts of the country, to determine where and how economy or improvements might be introduced. They would serve, moreover, as an indispensable basis of comparison with results to be obtained at future periods, when similar investigations might be undertaken.

METHODS EMPLOYED.—In considering, at the outset, the best practical method by which such an investigation could be carried on, it was found that no information could be drawn from the experience of former American studies, inasmuch as no such far-reaching and detailed examination of this industry had ever been attempted in this or any other country, at least as far as could be learned. It was well known, however, to all who took part in making the original plans, that precious-metal mining and its allied labors presented peculiar obstacles to carrying out such a work, far greater than obtain in other industrial branches, from the fact that it is carried on in regions remote and difficult of access, that its business methods are relatively unsystematic, and that it is often of such a nature as to render those engaged in it extremely unwilling to have their transactions known to the world. While, therefore, the census staff were aware that in the nature of things absolute completeness of results was impossible, they felt that with the unprecedented advantages which the present census offered for carrying on an investigation they would not be justified in attempting less than they have done, since only actual experience could tell in what particular respect they might be successful and in what they must necessarily fall short.

It was evident beforehand that the ordinary system of obtaining statistical information by sending circulars, or lists of questions to be answered, to all persons in charge of mining operations throughout the country, would be impracticable: First, because there were no certain means of obtaining their addresses; and second, because it was probable that, either through unwillingness or ignorance, a large proportion of the questions would be either imperfectly answered or entirely neglected, and it would be impossible to have any check on the completeness or accuracy of the answers obtained.

The plan finally adopted, therefore, was that of sending to every mine or reduction works in the country men of technical training and familiarity with the subject, to gather the necessary information personally, and assure themselves by local observation of the accuracy of the information obtained.

To aid these examiners a series of questions, arranged in schedules for each branch of mining and reduction process, was prepared after long and careful consideration, which should cover as far as possible all points of inquiry and also furnish checks on the accuracy of data given; intended thus to supplement any shortcoming in technical knowledge on the part of the expert and to systematize the data which he might send so as to facilitate the work of the compiler.

To carry out such a plan to theoretically perfect completion, four requisites were necessary: An amount of time and of money disproportionate to the value of the results to be hoped for, a sufficient number of men both theoretically and practically familiar with all branches of the industry to act as experts, and a uniform willingness and ability on the part of those applied to to furnish the desired information.

In point of fact, however, after the work had been some time under way, it was found that both the time and the money which could be allotted to this branch were inadequate to carry it through with the perfection aimed at; that it was impossible to find the number of men required who were in every respect fitted for it by education and experience; and that among owners and superintendents of mines and reduction works, while with a very few unimportant exceptions the greatest willingness was shown to grant us all the information they possessed, it was often found that they were themselves unable to answer the questions we asked, either through want of system in keeping records, or because they had never thought of the importance or bearing of certain facts. In spite of these drawbacks and of the further fact that by the exhaustion of the general census appropriation the work of compilation was greatly curtailed and delayed, the results obtained have proved beyond expectation valuable and instructive. The imperfections of the work none know better than its authors.

CRITICISM OF RESULTS.—It may be of value to the reader, and certainly will be to whoever may undertake a work similar to this in the future, to consider briefly the comparative value of the results obtained, the reasons of their imperfections, and the merits and faults of the methods employed.

For the geological sketches of the mining regions (Chaps. I and II) it was hoped that the collection of specimens prescribed, and the answers to the schedule questions, supplemented by the observations of individual experts, would afford sufficient data for a brief *aperçu* of the geology of each mining district. In practice it was found that, as most of the experts had at the best but a theoretical knowledge of geology, the information gathered was in most cases quite inadequate. Such of it as was deemed sufficiently important has been concisely presented in the form of tables, while the rest of the chapters are made up largely from the personal knowledge of the authors and from such facts as could be gathered from published and unpublished observations of others. They are necessarily much more complete in some regions than in others, but, in spite of acknowledged imperfections, are believed to form a most comprehensive and valuable contribution to mining geology.

In the preparation of the two succeeding chapters the greatest difficulty was found in the inequality of the schedule returns, dependent upon circumstances which will be explained below. A large proportion of the material collected was of such character that it was almost impossible to tabulate or condense it. Much of this was not found possible or advisable to publish; that which has been published has been subjected to careful sifting, and is of undoubted value to those engaged in mining, though it may not in all cases appear so to the uninitiated. The data on the Placer Mines were necessarily incomplete, since these are only worked during portions of the year, and the visits of the experts could not be so timed as to find the owners or the superintendents, from whom alone much of the desired information could be obtained. This incompleteness has been supplemented in respect to hydraulic mining from personal knowledge and observation. The process of reduction of ores by amalgamation is one which lends itself readily to statistical analysis, hence the data obtained by experts was here more complete than in most branches of the investigation. Smelting, on the other hand, by the complexity of its processes, and the necessary variation in its details, offers an almost insurmountable obstacle to presentation in the form of statistical tables. No attempt has therefore been made to present the information obtained in these schedules in this form, but it has been of great use as a check in the preparation of the succeeding chapter on Production. Lead smelting is the most important method which is used in the reduction of the Precious Metals, and its conditions present so much similarity in different localities that the description given of the process as carried on at Leadville may, with unimportant changes, apply to any other region where it is employed. For the estimation of the Precious Metal product of the country the synthetic method, as that adopted in this investigation might be termed, in distinction from those hitherto in use, was here employed for the first time, and was in so far an experiment. On the whole it has proved a most successful one, and the results obtained form, as a whole, it is thought the most accurate estimate ever made. Owing, however, to the inequalities of results to be mentioned below, the local distribution of product has in some instances been incomplete, and has given rise to adverse criticism from local interests which conceived they had thereby been injured. Had the text of the chapter been read with sufficient care for a thorough comprehension of the methods of presentation, this criticism would have been seen to be unfounded. The chapter on the Minting of Gold and Silver is the result of a careful personal investigation of the Carson and San Francisco mints, giving thus the practice prevailing in the United States, and forms a fitting close to the Precious Metal volume. In Appendix I a typical detailed description of the conditions prevailing in one of the Precious Metal political divisions—Utah—as space would not have allowed of such detail in all. In Appendix II the schedules and instructions to experts are given, as they were used during the investigation. The Mining Directory in Appendix III is a practically complete list of the Precious Metal mines of the United States in 1880, those which by the nature of the investigation were omitted being as a rule small and unimportant.

A detailed acknowledgment of assistance will be found on a subsequent page.

REASONS FOR INCOMPLETENESS.—The reasons for incompleteness in the results may be thus enumerated:

1st. From want of previous experience, the agents in charge could not distribute equally the ground to be covered among the experts employed, since the number of mines to be investigated bore no necessary relation to geographical area. As a consequence, toward the end of the time devoted to the investigation some regions received less attention than their relative importance merited.

2d. The relative ability of the experts employed was necessarily unknown to the agents in charge until the investigation had proceeded so far that it was too late to make any radical change.

3d. It was a practical impossibility to secure uniformity of ability and methods among so large a corps of experts as was necessary for the work. The result was that one would give more attention to one class of facts, another to another class, and, when totals were made up from the schedule returns, it was found that these facts were more complete in one region than in another.

As regards the best method for conducting such an investigation, the experience gained in this study would seem to teach that, while that employed here would produce the most perfect results under very favorable conditions, these conditions might demand an impracticably large expenditure of time and money. They would require a larger corps of experts, who should be specialists and receive adequate salaries, and be employed for a long enough time to become thoroughly familiar with their work before the investigation was undertaken. This could be best accomplished by making the investigation a permanent one. The results to be obtained by simple untrained enumerators, or from circulars sent without means of checking the results obtained, by technical men, will necessarily prove so unreliable in mining industry as to be of little value. Should the intermittent or decennial method still prevail, a compromise between the two could be advantageously made by having untrained men go over the country rapidly and collect a few main figures for the statistical tables; and a smaller corps of thoroughly trained specialists make investigation of a few typical mines or reduction works in the various branches of the industry.

COMPARATIVE SUMMARY OF RESULTS.—One of the most instructive results of an investigation like the present should be the opportunity it would offer for a comparative study of the industry as a whole and in its individual branches, as compared with the conditions which prevail in other countries, especially the older mining regions of Europe, and as compared with those which prevailed in this country ten years before, and of the changes and improvements which have been accomplished during the preceding decade. As a natural sequence of such a study suggestions would arise as to where improvements could be introduced or greater economy practiced in the future, and the direction in which increase or decrease of production over the present might be looked for.

Unfortunately statistical data for such a comparison are wanting. The census for 1870 gave practically no data at all with regard to our mining industry, and the publications of the Commissioner of Mineral Statistics ceased after 1875.

Hence, as already stated, the best results of this work can only be looked for in later years when similar data gathered on a plan improved by our experience shall furnish a new set of comparative figures. Meanwhile it may be well to offer some suggestions on these points which, while not based on statistical figures, have a sufficient ground-work of actual observation to be of value as an indication of the tendency of the industry.

ADVANCES DURING THE DECADE.—If we assume that the value of an industry to the country can be gauged by the number of people whom it supports, mining during the decade has contributed more than its share toward the general prosperity; for while the increase of the population as a whole has been only 30 per cent., that of the miners has been 54 per cent., or 234,228 in 1880, against 152,107 in 1870.

The total value of the product seems a less certain gauge of its contribution to the actual prosperity of the country, though the value of the precious metals in furnishing the material for a currency cannot be too highly estimated. During the decade the value of the total product reached the highest point yet attained, being 96 millions in 1878, and, in spite of considerable falling off since that year, the general result has been a permanent increase of production. As regards the relative production of the two metals, gold and silver, there has been a notable increase in the value of the latter over the former, namely, from 50 millions gold and 16 millions silver in 1870 to 33 millions gold and 41 millions silver in 1880. The silver production of the country only dates back 20 years, the product of 1860 having been but $150,000. Since that time its yearly amount has increased pretty steadily and with comparatively small fluctuations, while the gold product, which has been subject to greater variations from year to year, has apparently assumed a fixed average between 30 and 40 millions, beyond which it is not likely to vary. While, therefore, our silver product may be expected to increase considerably during the coming decade, gold will probably remain at the same general average.

The cause of the change in the relative positions of gold and silver must naturally be looked for in the ores themselves. While gold-quartz and hydraulic mining have about retained their relative importance, the development of silver-bearing ores, especially those carrying lead and copper, has been most extraordinary. Perhaps the main determining cause of this unusual activity may be that prospectors as a class have now learned the value of these ores, whose outcrops had hitherto been regarded as worthless indications.

Of ores in general it may be said that the richer and purer ones, which alone were sought for in the early days of mining, have been gradually giving way to those of more complicated nature and generally of lower value in the precious metals. Consequently in the reduction processes we find smelting acquiring a relatively more important place than it formerly held, and in milling an increasing use of the dry-crushing process connected with subsequent roasting of the ore and a marked growth of the lixiviation processes.

The two most important factors in the development of the precious-metal industry during the decade have been the extension of railway systems and the introduction of coal as a fuel throughout a portion of the mining regions of the West. In 1869 the first transcontinental railway was opened, and now not only are there practically

four great railway systems crossing the mountains from east to west, but a great number of short lines, generally narrow gauge, penetrate them in every direction, reaching mining towns which not many years since were only accessible by pack trains or saddle animals.

Although the existence of coal in the Cretaceous and Tertiary beds of the West was known before 1870, its development, like that of the railroad system, has practically been the work of this decade. The production of the region west of the one hundredth meridian, as well as can be ascertained from confessedly incomplete data, has increased from about a quarter of a million to nearly two million tons, and it is probable that in the coming decade the rate of increase will be far greater. California, Washington, Colorado, Wyoming, and Utah are now the principal producers, and New Mexico, Montana, and Dakota are yet to be added to the list.

To the development of these two great elements which form the basis of the industrial prosperity of every country may be ascribed the reduction in the cost of labor, supplies, and power, which, in their turn, have produced the most important and healthful changes in the mining industry of the West.

In view of these changed conditions the decrease in the supply of high-grade ores, and the consequent development of low-grade and complex ores, requiring more elaborate processes for their reduction, and yielding a smaller margin of profit to the producer, may be regarded as a benefit, both to the mine owner and to the laborer whom he employs, in spite of the decrease in the actual money return either may receive for his investment of capital or labor. Stability is the most essential condition for the permanent prosperity of any business, and unless this is reasonably well assured the reluctance of capital to embark in it is too well known to require remark. On the other hand it may be more difficult to persuade the laborer that permanent employment at a low rate of wages is more beneficial to him in the long run than the precarious and expensive conditions attendant upon the high rates which prevailed during the fitful extravagance of earlier mining excitements.

The fictitious prosperity of mining consequent upon some new discovery of exceptionally rich and extensive ore deposits is comparable with that occasioned by the inflation of the currency and fever of speculation which prevailed at the close of our civil war, and the reaction which is sure to follow is even more injurious in its effects, since in it more than in any other business is the element of chance a necessarily important factor.

In the direction of stability its advance during the decade has been the most important that has occurred during its history, and especially during the latter five years has there been a notable decrease in the fever of mining speculation. It may be said that, in spite of the falling off in the production of the Comstock and other important mines, the actual earnings as a whole are probably greater than ever before.

Among the general improvements may be noticed the more frequent employment of scientific methods both in mining and in reduction, a desire for more accurate geological information as a basis of development of mines, and a gradual dying out of the former unreasoning prejudice in favor of the so-called practical miner over the educated engineer.

The principle of combination is also beginning to enter more largely into both branches. In mining it is seen in the combination shafts and pumping machinery, of which the most notable instances may be seen on the Comstock lode, where all work in the lower levels is carried on from a few large shafts owned by two, three, or even five mining companies, and most winzes, together with many exploring drifts, have a joint ownership. In reduction works it is seen in milling in jointly-owned amalgamating mills and large custom works, in which, by reason of their greater size, a marked economy in running expense is effected. In connection with smelting it is seen in the ever-increasing number of sampling works which afford to the small miner on the one hand a certain and immediate market for his ore, and on the other assure the smelter a more regular supply of ore of known and comparatively regular composition.

More attention has been given than hitherto to the concentration of low-grade ore prior to shipping, but in this direction there is still much room for improvement, and until properly-constructed concentration works are established, enormous bodies of sulphuret and other low-grade ores now actually developed in many mining camps must remain as valueless as they are at present.

If we examine into the technical details of exploitation of mines, milling, or of smelting, we find no very important advances over the best class of work that prevailed ten years ago, the conditions of which are admirably set forth in the volume on Mining Industry of the Fortieth Parallel publications, by Mr. J. D. Hague. The changes which seem most worthy of note are briefly as follows:

In mining.—a. The general introduction of high explosives, such as Giant, Hercules, Vulcan, and other nitro-glycerine powders, in underground work, where they can be used in wet ground and require smaller drill-holes. These were just being introduced at the commencement of the decade. A series of low-power explosives, such as Judson, have also in part supplanted black powder in bank blasting.

b. The use of and improvement in power drills. Many large mines now use percussion drills, driven by compressed air, for running drifts and tunnels, though their use is not so economical as a rule for vertical openings, such as shafts and winzes. Wherever mining is done on so large a scale that power must be used to a considerable extent, the use of drills is bound to increase, and gang-drills such as are employed in driving the great tunnels of the Alps will also in time come into use.

c. The capacity of machines for compressing air, used not only for drills but for underground machinery in general, and as a consequent aid to ventilation and for cooling the air, has sensibly increased, air being readily carried several thousand feet and delivered at a pressure of 60 to 75 pounds. Larger and better blowers, used for ventilation and for blast purposes, are also made.

d. The diamond drill has been more largely used, though experience has shown its value as a prospecting tool to be perhaps less than as a safeguard in a mine against sudden inrushes of large bodies of water.

e. The more general use of compound engines, and consequent economy of power in mining machinery generally.

f. For hoisting, steel cables have almost entirely superseded those of iron wire. Hemp is still used in small shafts and for shallow depths. The use of the flat as distinguished from the round cable does not, however, seem to have become as general as it should. The number of accidents to cages and consequent loss of life to miners is still large, and an improvement in safety devices is much to be desired.

g. The use of the telegraph and telephone in signaling at mines has been considerably experimented upon, but their employment underground has not proved altogether satisfactory. On the surface the telephone for connecting shafts, mills, and offices is productive of economy of time and labor.

In *amalgamating* there have been no essential changes of practice during the decade. The reduction in the cost of steel has brought about its partial introduction for shoes, dies, and tappets, but the results have not been such as to cause its general adoption; it is mainly used in dry-crushing mills. Large mills of over 100 stamps have been built and proved a success.

Owing to the increase of complex ores and consequent necessity of preliminary preparation of ores before amalgamating, roasting and chloridizing furnaces with mechanical appliances have come into more frequent use.

There has also been an increase in the practical application of leaching systems for the treatment of auriferous pyrites and of base silver ores.

In *smelting*, the use of water-jackets in shaft furnaces and of the siphon-tap in lead smelting has become very general during the decade. Besides this, some minor improvements in the smelting plant, such as the safety-tuyére, have been introduced.

PREFACE.

At the beginning of 1880 the Hon. Francis A. Walker, Superintendent of Census, committed the census investigation of the precious-metal mining industries to the charge of the Hon. Clarence King, then director of the geological survey. The director called upon us to draw up plans for the examination of the technology and statistics of these industries, reserving to himself the organization of an inquiry into mining laws and mining civilization. We accordingly drew up a series of schedules to furnish a basis for the inquiry, which are reprinted in an appendix to this volume. These were submitted to the director, and by him to the Superintendent, and were duly approved. Thereafter the conduct of the inquiry was left entirely in our hands.

It was not expected that answers to all the questions proposed could be obtained at any one mine or reduction works, nor was it the intention to limit the inquiries to these questions. The purpose was rather to suggest subjects of inquiry and assist the visiting experts to frame the best possible report on the mines and reduction works in the short time necessarily allowed to each mine. The questions were also so framed that the more important data are involved in the answers to several of them, a measure intended to guard against errors of recording and mistakes in statement, as well as intentional misrepresentation. This system was of great use to the experts in detecting erroneous statements, as it has afforded the office an excellent check on the accuracy and care of the experts, and has led to the rejection of some inferior work.

As will be seen from the instructions, the examination was limited to mines which showed at least 300 feet of shafts and galleries, or which had produced 100 tons or more of ore. This was plainly an inevitable measure, for had the attempt been made to examine every mine, however small, the task would have been absolutely endless. Many times the number of experts who could be paid out of the allotted fund would have been needful to visit even the prospects opened in the census year alone. At the same time, of course, all thought of obtaining exhaustive statistics was abandoned. In other words, the investigation was planned, and inevitably so, with a view to obtaining as large a number of representative facts as possible from which to draw general deductions, and it was distinctly recognized that even a very close approximation to any actual totals could be obtained from direct returns only at an inordinate expense and at the sacrifice of the comprehensiveness of the investigation. It was believed, however, that sufficient information could be secured to supplement and check certain totals derivable from other sources, and in many cases enough to form the basis for estimates of totals sufficiently close for any purpose to which statistics are actually applied. On a great number of subjects absolutely accurate totals, if they could be obtained, would be mere curiosities, and of no more use than approximations, with a probable error of 5 per cent. In the examination of technological questions totals are usually of very little consequence, and what is needed is statements as to construction or practice, founded on a sufficient number of instances to secure their representative character. It was plain that the results which could be obtained would depend largely upon the competency of the experts engaged in the direct collection of the required information. Only men of considerable experience, as well as thorough training and much energy and ability, could really answer the requirements, as any professional mining man who glances at the schedules will readily appreciate. Men of this stamp are never readily to be procured, and the small salaries which could be paid caused an additional difficulty. The gentlemen secured were all honest, faithful, well educated, and able, and a part of them had ample experience. Their names and the districts to which they were assigned, together with the organization by divisions, were as follows:

PERSONNEL OF THE PACIFIC DIVISION.

The headquarters of this division was placed in San Francisco, and the direction of the work confided to Mr. George F. Becker, United States geological survey, geologist in charge of the Pacific division. This division includes the states of California, Oregon, and Nevada, and the territories of Idaho, Utah, Arizona, and Washington.

Mr. J. M. Cunningham, for the eastern portions of Washington and Oregon and the northeastern part of California.

Mr. J. S. Curtis, Nevada south of the line of the Central Pacific railway.

Mr. J. H. Hammond, central and eastern counties of California.

Mr. D. B. Huntley, Utah, southwestern Nevada, and portions of California.

Mr. H. W. Leavens, the tract lying west of the Cascade and Coast ranges in Washington, Oregon, and northern California.

Mr. Walter Nordhoff, southeastern and middle Arizona.

Mr. H. W. Sander, western Arizona.

Mr. Luther Wagoner, southern California.

Mr. Albert Williams, jr., Idaho, Nevada north of the Central Pacific railway, and the Comstock lode.

PERSONNEL OF THE DIVISION OF THE ROCKY MOUNTAINS.

The division of the Rocky mountains adjoins the division of the Pacific on the east, and extends eastward as far as the one hundredth meridian, including the state of Colorado and the territories of Dakota, Montana, New Mexico, and Wyoming. At the head of this division was placed Mr. S. F. Emmons, United States geological survey, geologist in charge, with headquarters at Denver.

Mr. W. B. Fisher, portions of Lake, Chaffee, Clear Creek, and Gilpin counties, in Colorado, and Beaverhead county, in Montana.

Mr. William Foster, Montana and Wyoming.

Mr. J. E. Hardman, the smelting works in Lake county, Park and Summit counties, and portions of Clear Creek and Gilpin counties, in Colorado.

Mr. Charles Potter, New Mexico.

Mr. E. H. Schaeffle, Dakota and portions of Colorado.

Mr. W. G. Sharp, San Juan, Hinsdale, Gunnison, La Plata, Huerfano, Ouray, and Rio Grande counties, in Colorado, and portions of New Mexico.

In addition to the census experts the following-named gentlemen acted as temporary assistants: Messrs. Herman Garlichs, J. C. Hine, H. B. Price, H. L. Simmons, and W. H. Whittlesey, in Colorado, and W. F. Wheeler, in Montana.

PERSONNEL OF THE EASTERN DIVISION.

The eastern division comprises the whole territory lying east of the one hundredth meridian. Professor Raphael Pumpelly, United States geological survey, was placed in charge, with headquarters at Newport, Rhode Island.

Mr. George H. Eldridge, southern states and reduction works east of the one hundredth meridian.

Professor N. S. Shaler, with the assistance of Messrs. Jos. M. Wilson and J. E. Wolff, New England states.

We were able personally to take but a small share in the collection of the data, for, beside duties unconnected with this investigation, much time and labor were involved in advice to the experts as to routes, in the decision of doubts referred to us, the approval of expenditures, and the multifarious matters of administration implied in keeping twenty men (all of them unfamiliar with the conditions and restrictions of government work) moving without delay and performing their duties to the advantage of the service.

Excepting one or two who were engaged at an advanced stage of the examination, all the experts were in the field before the expiration of the first month of the census year; but it was found that the time involved in the collection had been underrated, chiefly on account of the difficulties of traveling after winter had set in. Additional time unfortunately meant additional expense, and we were reluctantly obliged to stop field-work before we were quite ready to do so.

The compilation followed, and for lack of census funds we were obliged to call upon the geological survey for a large part of the expenses incurred.(*a*) Our thanks are due to Hon. J. W. Powell, director, for the substantial aid which he has furnished us. Mr. Albert Williams, jr., who had distinguished himself by the judgment and energy which he had displayed as special expert in his examination of Idaho and northern Nevada, was appointed to take direct charge of the compilation under our supervision and co-operation. This task he has accomplished to our entire satisfaction. There is no doubt that statistics lose some of their value by not appearing promptly; but though we have realized this fact throughout the investigation, it has been entirely impracticable to proceed more rapidly. Only a very subordinate portion of the work was of such a character as to permit of tabulation by clerks devoid of a professional knowledge of the mining industries. Each of us was personally engaged in geological investigations of important subjects, as the publications of the survey will show, and could give but a portion of our time to technology and statistics, while a greater expenditure for expert assistance was out of the question.

The work has been pushed with all possible energy, and when for a period of several months no public funds could be procured Mr. Clarence King advanced the necessary money without interest, so that not a single working day has been allowed to pass unutilized.

In preparing the data for publication it became a question as to how far estimates should be introduced. After careful consideration, it was decided to introduce no estimates except such as might be specifically mentioned.

a Our own services to the Census Bureau have, of course, been entirely gratuitous throughout.

This throws certain parts of the work open to criticism as to completeness. These it would in most cases have been easy to cover by estimation, but in doing so the integrity of the figures given would have been destroyed. Readers will probably find few imperfections not familiar to us and for which sufficient grounds could not be given, which in most cases were a lack of funds to carry the field-work to an end as planned. In one set of tables there seems to be internal evidence of manipulation, but this is only apparent. When the tables of production were first transmitted, the quantities of bullion were entered both in dollars and in ounces. The practice in respect to the unit used for bullion varies in different parts of the country, some mines reporting dollars and others ounces, so that in some cases we had to convert ounces to dollars and in others dollars to ounces. Our figures were reviewed at the central office to test their correctness, but in the revision it was assumed that the ounces were the original data in all instances. In recalculating the dollars from the ounces the conversion in some cases resulted in inevitable, though unimportant, discrepancies, and the numbers were altered accordingly. The change was not known to us until the matter was in type, and it then seemed scarcely worth the while to make the insignificant corrections in value at a great expenditure in labor. The reader will readily understand that where a district is reported as producing $9,999 the actual return was $10,000.

In the table upon which technological deductions are made the number of mines or other establishments reporting is stated. It is, of course, to be understood that this is the number of mines or works from which we have reports on this particular subject, not the total embraced in the investigation. The extent to which generalizations are permissible from the data of any table will be evident from this figure to those familiar with the industry.

The discussion of hydraulic mines and ditches is almost wholly the work of Mr. Williams; the chapter on milling is founded largely on a report made by Mr. J. S. Curtis; the chapter on smelting in Leadville is founded on a report by Mr. A. Guyard; the discussion of the mints of Carson and San Francisco is due to Mr. Williams; the report on the mining industry of Utah is by Mr. D. B. Huntley. All of these are founded on the schedules, and all of them have undergone criticism and revision at our hands, while some have received extensive additions or modifications. Each of us has sketched the geology of his own division.

Orders having been issued by the Superintendent to condense the census memoirs to the smallest possible compass, a large amount of valuable material is omitted, some of which it is to be hoped will be made available in future publications of the survey. Had there been room many details would have been published by mines or works which are now given only for districts; but this could have been done only at the expense of an unallowable increase in the size of the memoir. We have reports on other regions corresponding to that of Mr. Huntley, though this is not the case for all the states and territories, and the records contain a very large number of descriptions of apparatus and practice which would be well worth publication. Mr. Huntley's paper was given a place in the appendix, because Utah is in many respects a representative mining region, and because the report seemed to us of unusual merit. The schedules are allowed to appear as showing the plan of the investigation, and as affording some suggestions for the study of the industry which may be of use to others.

The trustees and officers of the American Museum of Natural History, New York city, very kindly placed at our disposal fine working rooms in the museum building, which were occupied during the period of compilation; and for this courtesy the sincere thanks of the authors are tendered.

S. F. EMMONS.
G. F. BECKER.

In the course of the repeated delays which have occurred in the publication of this volume since it left our hands, delays for which we are in no way responsible, and of the transfers of the manuscript material from one depository to another, a series of topographical maps, intended to accompany the geological sketches of the several states and territories, and colored to show the distribution of gold, silver, and quicksilver, has been lost. The further delay which would be necessary to reconstruct these maps is found, greatly to our regret, to be impracticable.