AFTER
EARTHQUAKE
AND
FIRE

After Earthquake and Fire

A Reprint of the Articles

AND EDITORIAL COMMENT APPEARING IN THE

Mining and Scientific Press

IMMEDIATELY AFTER THE DISASTER AT

San Francisco, April 18, 1906

FIRST EDITION

FIRST THOUSAND

SAN FRANCISCO
Mining and Scientific Press
1906

CONTENTS

Our Offices at 330 Market Street, San Francisco.

PREFACE

This little book commemorates an experience which we shared with our neighbors. It is a tribute to the loyalty of our staff and to the goodwill of our friends. We give a photographic reduction of the single page that was sent out on April 20, in place of our issue of April 21, which was consumed, with all of our property—save the mailing list—early on the morning of April 18. The matter appearing in our issue of April 28 is given, omitting only the mining news, special correspondence, market quotations, and other material of purely ephemeral interest. In addition, we have reprinted all the articles dealing with the earthquake and fire, mainly from our issues of April 28, May 5, and June 16. The collection should have a scientific value and it will serve as an interesting record in days to come.

T. A. RICKARD.

August 29, 1906.

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TO OUR READERS

IN face of the calamity that has befallen the community in which we live, our own loss seems small. Our records, our library, the note-books of the editors, the manuscript ready for the printer, and the whole of the plant in our composing room, all lie buried under the ruins of San Francisco. But, owing to the customary precaution observed by two of us, complete copies of the weekly subscription lists had been taken to Berkeley, so that we possess that necessary record. Fortunately, most of the members of our staff live at Berkeley, where the earthquake was less severe and where no conflagration followed in the wake of this terrifying occurrence. As the earthquake occurred at 5:15 A. M., and the fire in San Francisco prevented people on this side of the Bay from reaching their offices, most of us were spared the horror of scenes that sear the memory. We are fortunate, therefore, as compared to many of our fellow citizens. And for other reasons. Our plant has been demolished; but this journal is built on nothing so ephemeral as paper, and on nothing so cheap as machinery; it is based upon the support of many thousand readers and subscribers who are never less likely to withdraw their support than at a time of misfortune. The goodwill of the Mining and Scientific Press is locked up in no safe, confined to no printing room; it cannot be shaken by an earthquake or consumed by fire. And, gentlemen, our friends, there is another something that is not destructible by physical misfortune or financial adversity, and that is the spirit that gives life to the printed word.

T. A. RICKARD,
Editor.

Berkeley, April 20, 1906.

TO OUR ADVERTISERS

OUR old offices at 330 Market Street, being in the very center of the most damaged section of San Francisco, have been totally demolished. We have lost our entire mechanical plant, including cuts, half-tones, type and the issue of April 21, which had already been set up; but fortunately, our complete and most recent mailing list has been saved.

We have secured ample offices in the First National Bank Building at Berkeley, which is on the east side of the Bay of San Francisco and close to the terminus of the trans-continental railroads. Through the courtesy of The Standard Publishing Company, we are in possession of proper facilities for printing. The Miehle presses, which will do our work, are new and of the most improved type. We will only be handicapped (for a few issues) by scarcity of paper; the rush of work at the local photo-engraving houses will prevent the use of half-tones with our reading matter, but we have arrangements pending to have this work done at Sacramento, which city was not affected by the earthquake.

We would urge all of our advertisers whose places of business have suffered, to communicate with us at the earliest moment, as our issue of April 28th will afford the best medium for advising their clients the world over of any change of address.

EDGAR RICKARD,
Business Manager.

Facsimile of Issue of April 21.

EDITORIAL.

April 28, 1906.

As stated in our last issue, the offices of this journal are now at Berkeley, where we have secured an excellent suite of rooms in the First National Bank building, a new five-story steel structure of the best type, which went through the recent severe test without a mark. In an adjoining building is the Standard Publishing Company, with whom we have made arrangements for printing. The linotype machines and the Miehle presses, together with other mechanical appliances, are all of the best; and in addition to this equipment, we have secured the cooperation of the public-spirited gentlemen who control the establishment.

It was a merciful coincidence that among the few structures which did not succumb either to the earthquake or to the sequel of fire, were the Mint and the Post-office. The millions of currency stored in the first will be a prime factor in re-establishing financial conditions, while the preservation of the mail service will promote organization. As the disaster came at dawn, there was not much mail in the boxes and chutes, they having been cleared before midnight; moreover, the earliness of the hour saved the incoming mail, which was on the trains.

A few hours after the earthquake, we telegraphed to the authors of contributions that were lost when our office in San Francisco was demolished. By reason of their prompt response, we received copies of many of the articles within the week following the disaster. This is one of the advantages of the modern use of the type-writer. Formerly, authors had to trust to the preservation of their original copy, so that fires consumed a vast amount of valuable manuscript of which no duplicate had been preserved elsewhere.

The value of a self-contained machine or complete unit is strikingly proved by the timely service given by the motor car during the conflagration. It is true there is many a wrecked automobile now lying in the streets of the ruined city, but the accident or damage that brought the activity of the machine to an end, did not take place until it had served a beneficent purpose, with wonderful efficiency. In removing wounded, in carrying doctors, in bringing dynamite for the blasting operations, in transporting food and, last of all, in aiding the escape of the terrified people, the motor car was of immense service. It was the only means of rapid locomotion.

"It is an ill wind that blows no one good." There is evidence forthcoming from the conflagration in San Francisco, such as will stimulate the demand for copper. Our friends who are engaged in mining the red metal will be interested to know that the offices in the Kohl building, one of the best, and in many respects the most modern in construction, of all the larger structures in San Francisco, was protected by copper. The doors, casings and bases, all the interior finish of the offices, together with window-sashes, are covered with sheet copper. The people who have offices in that building, above the sixth floor, have found their papers intact. This use of copper is comparatively recent and the evidence just quoted should do much to encourage the innovation.

It is our privilege to publish several special articles dealing with recent occurrences. That on 'The Cause and Nature of Earthquakes' is by Mr. G. K. Gilbert, of the United States Geological Survey, and a scientific authority second to none. Mr. A. O. Leuschner, who describes the seismograph records, is director of the observatory at the University of California. A suggestive article on 'Some Lessons from the Earthquake' is by Mr. S. B. Christy, professor of mining and metallurgy in the University of California. He needs no introduction to our readers. Finally, we are enabled to publish authoritative details concerning the Commission appointed by the Gov-

The Beginning of the Conflagration.

ernor of the State to gather evidence dealing with recent events, and we give an account of the proceedings at the first two sessions of the Commission. The contributions by our own staff will also be found interesting.

The first shock of the earthquake, as recorded by the Ewing seismograph at the observatory of the University of California, occurred at 5:12:38 on Wednesday morning, April 18. The earth wave traveled in a direction south-southeast to north-northwest. The principal shock came in two movements of maximum intensity, and it lasted two minutes. In violence, this earthquake far exceeded both that of 1868 and 1898. In each case the earth wave traveled in the same general direction. After the first great shock, several minor ones were felt. These came at 5:13, 5:25, 5:42, 5:59, 6:10, 6:27, 6:43, 6:47, 8:10, 8:15, 11:06 and 12:04. Those that were felt soon after eight o'clock were strong and were accompanied by a distinct rumbling noise. In the afternoon several shocks occurred at longer intervals and at 7:1 there was one, sharp and short, but enough to terrify people who were sitting at their evening meal after a long day of anxiety. At 3:17 on the 25th there was a tremor that caused discomfort to those members of our staff who, by that time, were busily occupied in preparing this issue for the press.

Oakland, being just across the Bay from San Francisco, and being peopled with a lot of generous folk, has received an immense crowd of refugees. The streets remind one of Cripple Creek or Leadville in the days of a boom, save that horsemen and rowdies are absent. An air of activity, and even of up-building, is given by the scaffolding and other temporary timbered structures necessary in making repairs to chimneys and to buildings that suffered from the earthquake. The tangle of wires and the accumulation of brick that marked the catastrophe were soon straightened or made to look tidy. By reason of the total destruction of every composing room and printing establishment in San Francisco, the daily papers all had to trespass on the courtesy of their contemporaries in Oakland, and as a consequence the number and frequency of special editions hawked by a multitude of small boys, gave Oakland the appearance of a town given up to a big political convention. Whatever the outward appearances, and they varied from grave to gay, from that which was tragic to that which was only amusing, there was, out of sight, in many hundred homes, a wondrous wealth of humanity and kindness that will long remain one of the compensating memories of a terrible event.

We tender most sincere thanks to our advertisers for their valued support in promptly forwarding us new cuts and copy. The response to our telegraphic requests has been splendid and the episode will knit closer friendly relations as only misfortune, when shared and survived, can do. It is our hope to exhibit practical appreciation of this support, given when most needed, by making the 'Mining and Scientific Press' a better paper than it has ever been; and the belief that this can be done is strengthened immensely by the fact that the members of our staff united to do their duty at a time when the sense of personal loss and discomfort was keen. It is a saying among the fraternity that a good mine must go through the baptism of a law-suit; few rich mining properties have escaped litigation in some form. Assuredly it is true that those who work together in an enterprise such as this journal, become united in purpose by such an experience as the recent unpleasantness, in a manner not to be effected even by a life-time of ordinary association.

In regard to the relation between volcanoes and earthquakes, it is necessary to distinguish between those usually minor but frequent tremors, that are a part of eruptive activity and those occurrences which take place at a long distance from volcanic centers and are related to them only remotely by reason of both being manifestations of structural change within the crust of the earth. The volcano nearest to San Francisco that has been active during the human period is probably a cinder cone situated about ten miles from Lassen

Peak in northern California, 170 miles from San Francisco. The forest that was buried by the scoria is still in evidence and it is estimated that the eruption took place within the last 300 years. Other extinct volcanoes are those of Mt. Shasta and several in the Kings River district. In the Mohave desert there are several perfectly preserved cones, and while they were active recently, from a geological standpoint, they became extinct in the beginning of human history.

Despite the effort of the Mexican authorities to stifle the truth concerning conditions in the Yaqui country, it is evident, from a letter that we publish on another page, that this part of Sonora is best avoided by mining men who do not care about prospecting the last hole of all. Our correspondent writes as one who is no tenderfoot, but on the contrary, is familiar with mining in Mexico, and he does not give expression to such strong statements without full warrant for them. The news, last week, of the murder of Samuel Williams, the assayer of the Giroux Consolidated Mining Company, and two other members of the same party, comes as an unpleasant corroboration. The Mexican Government has slowly won the goodwill and respect of the United States, and it is hardly to be believed that conditions such as exist in Sonora will be permitted to continue without investigation, followed by correction. In the meanwhile, the authorities on this side of the line will do well to attend to their duties. There is a pass 40 miles west of Nogales through which guns and ammunition find their way freely into the lawless region on the other side of the line. If one mentions the matter to a citizen of Tucson, he lifts his eyes to heaven with ingenuous astonishment. But such innocence is not in keeping with the air of the border, and it should not prevent an inquiry into a nefarious traffic, which is at the bottom of the atrocities that have disgraced the State of Sonora and discredited the government of Mexico.

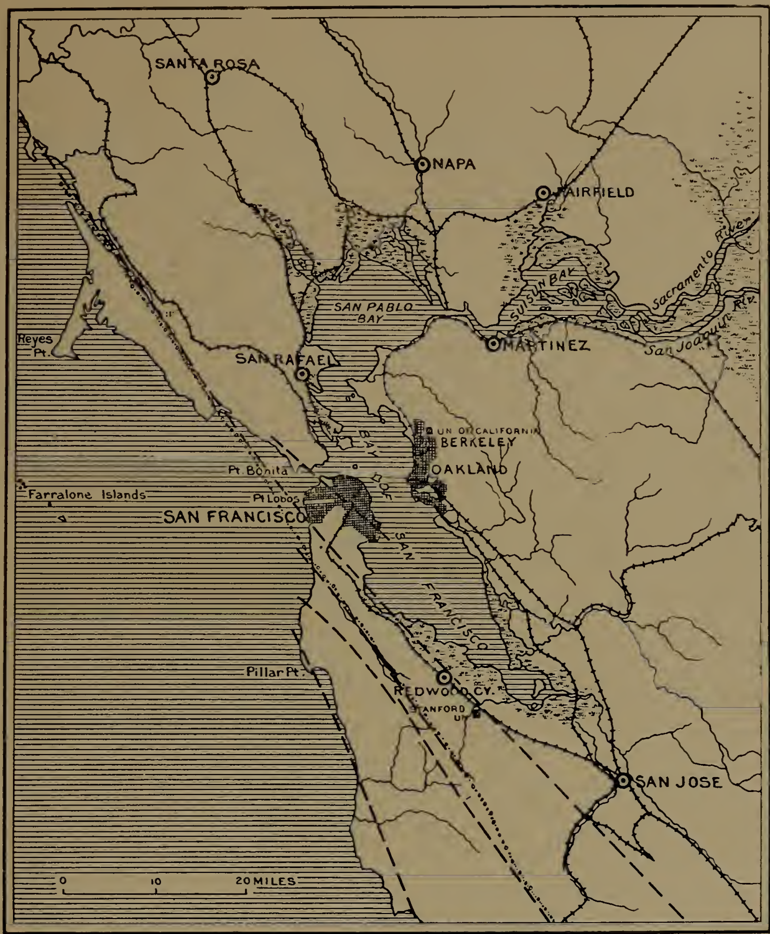
As seen from Berkeley, twelve miles across the Bay, the burning of San Francisco presented a succession of appearances. Within half an hour after the earthquake shock, a hump of dark smoke appeared over the City, growing during the succeeding hours until it rose through the quiet air like the clouds made by a volcano. When night came, the whole front of San Francisco was ablaze, the flames shooting upward at particular centers with the glowing discharge of a blast furnace; the light of the conflagration illumined the heavy clouds of smoke with a pink glow and the occasional rumble of a dynamite explosion gave the picture a suggestion of warfare. The next day (April 19) the clouds of smoke rolled skyward to a height of two miles, their lower layers dark, but the topmost billows sunlit and splendid. As evening came, a wind from the southwest blew the smoke over the Bay toward Mt. Tamalpais; the sun, like a red ball, threw a crimson light over the waters and there was more suggestion of horror than at any time. That night the big wooden houses in the residence portion were burning luridly, so that the flames rose high to heaven and glowing clouds pierced a starlit sky; the sight was one of desolating splendor. On the day following (April 20) the fire had pretty well exhausted itself and a dark murk of drifting smoke hid the ruins of the proud city of the Argonauts. But it was a quiet clear day, one of California's best; the sun that had set in a mist red as blood rose resplendent and full of life-giving promise. Already with the unconquered energy of a people that has developed a continent, the inhabitants began to talk of the re-building that was to give them another and a more beautiful San Francisco.

We are profoundly grateful to our friends who by word, by letter and by deed, came to our support during a time of trial. The response to the telegraphic request for articles and material for publication has been such as to prove abundantly the faith we had in the innate generosity of our people. The pages of the 'Mining and Scientific Press' during succeeding issues will demonstrate who helped and how effectively each one did it, by sending contributions of unusual interest. The editorial department rarely has dealings with the advertisers, but during the period of stress that followed the great conflagration, we were brought into closer touch with our clients on the business side of this enterprise, and it remains but to say that the evidence has been simply to prove, what we knew already, that men of the highest character and culture are now engaged in that essentially modern field of industrial activity which is termed advertising. Among so many proofs of generosity, we yet venture to single out one message as typical of a breadth of spirit that does honor to the name of American. Mr. G. W. Fuller, who represents the Cameron Pump, said to our New York manager: "We want our bills to run on just the same as if nothing had happened, even if you do not get out a paper for three months. We appreciate your effort in your advertiser's behalf and whatever you publish, if it has the single word 'Cameron' in it, will be fully satisfactory to us for months to come." We are reminded of a story told by Dr. Holland, chief of the Carnegie Museum at Pittsburg. On a certain pleasant occasion he informed us that the white hippopotamus was rare; in fact, there were only nine specimens in existence and one more, making the tenth, had been consigned to him and was then on the way from Africa. Well, we can state emphatically that 'white' men are not so scarce as white hippopotami, and as long as there are plenty of them, this Earth of ours will be a planet pleasant for residence purposes, despite such minor interruptions as are termed earthquakes.

It is fitting that we say a few words concerning the city that has given us shelter and a temporary place of business. At the beginning of the year Berkeley was a place of 40,000 inhabitants, the center of its life being the State University, whose beautiful oak glades and sloping lawns reach from the post-office to the foot of the Contra Costa hills. The group of buildings, of which three are of recent construction and one—the mining building—not yet finished, were uninjured by the earthquake and still stand in quiet repose facing the Golden Gate. Berkeley has always been a place of homes, beginning with the professors, instructors and students of

Berkeley.
The University in the Foreground, Facing the Golden Gate.

the University itself, and followed by a number of professional and business men who had offices across the Bay in San Francisco. The facilities for going from the home to the office have been much improved during recent years, there being a double service, namely, the old suburban train and ferry service of the Southern Pacific Railroad and the new trolley line and ferries of the Key Route. The convenience of living in a beautiful town situated on rising ground, overlooking the Bay, led to a great increase in the number of residents as soon as access to the City became easy. Now, of course, there will be a rapid accession in population and much of the business of San Francisco will take root here. Some of this will return to its former site when the City is rebuilt, but some of it will remain at Berkeley. While the Southern Pacific and the Santa Fe railroads both pass through the lower part of the town, the former has no station and the latter, one that is not much used, but it is certain that recent events will lead to an immediate improvement in this regard. The accompanying map shows the position of the cities that have grown up around the Bay of San Francisco. At the beginning of 1906 the metropolis had a population of 400,000; Oakland came next with 90,000; Berkeley, 40,000; and Alameda, 20,000. Los Angeles, in the southern part of the State, has a population of 200,000, so that Berkeley is the fourth in size. It was named after Bishop Berkeley, to whom is credited the saying: "Westward the path of Empire takes its way." It was Charles Kingsley, in 'Westward Ho' who originated the saying, but whoever said it, the town of Berkeley is one of those that fulfilled it.



Map of the Bay of San Francisco.
Dotted Line Indicates the Earthquake Fault.

THE EARTHQUAKE.

An experience such as that undergone a few hours ago by those who dwell on the shores of the Bay of San Francisco is apt to emphasize the fact that the earth we live on is still undergoing structural readjustment. At such times—or a little afterward, when chimneys have ceased falling and we have gathered wits somewhat perturbed by the unfamiliar sensations—we realize why the Greeks looked upon the Earth as a sentient being; the philosophers of the ancient world dwelt beside the Mediterranean, which from time immemorial has been the theatre of earthquakes, volcanoes and other manifestations of terrestrial unrest. It needs less poetry than fright to suggest the idea that, like a giant disturbed, old Earth is shaking himself awake, growling the while. As we write, at Berkeley, nearly four hours afterward, the clock, shaken to a standstill, marks 5.14 as the moment of the most severe shock. Across the Bay huge clouds of smoke, sunlit at the top like a splendid cumulus, indicate that San Francisco is afire. As we conjecture what may have happened there come two short shocks accompanied by a rumble; the tremor, but not the sound, being such as would be caused by a blast in a stope three or four hundred feet underground. A mine-blast makes a click, not a rumble, when heard at a distance. Meanwhile, like a severely critical building-inspector, Mr. Earthquake has broken every poorly constructed chimney and in our neighborhood the brick towers of a public institution have been shaken, one tower tumbling to the ground, while another has collapsed. People talk excitedly and compare experiences, the birds chatter in a flurried way and there is a general air of tension. But the sunlight is steady and warm, as if old Sol was too far away to be bothered by happenings on such a minor planet as ours.

Earthquakes may happen anywhere, they are not necessarily connected with volcanic eruptions and they are not confined to rocks of any particular age or character. It is true, however, that the agitation takes the form of waves the amplitude of which is increased when transmitted through yielding rock. Thus the Charleston disaster, in 1886, was intensified by the fact that the Southern city stands upon sand and other deposits soft enough to propagate vibrations. Several observers at Charleston watched waves as much as a foot high run across the surface and these were met by another series going in an opposite direction, making complex movements which tended to loosen first one wall of a building and then another. Of 14,000 chimneys, not one hundred remained intact, but the number of fatalities was small, although the damage to property was estimated at five to six million dollars. But the worst catastrophe of the kind was that which befell Lisbon on November 1, 1755. This remains one of the great horrors of history. For several years preceding, the volcanoes of the Mediterranean had broken out with unusual violence and earthquakes had passed throughout Europe, without serious effect. Early in 1755 they became more frequent and on the night of October 31, Lisbon felt a slight shock. The next morning three severe vibrations were felt, the first of which lasted only six seconds but quite long enough to throw down practically every building in the city; Lisbon became a stone quarry. Shortly afterward there came a great sea wave and as it rolled toward the land, a huge fissure opened along the sea-front, engulfing a new marble dock which happened to be crowded with people who had rushed from under the falling houses to secure safety. They, the quay, and the boats moored to it all disappeared from view; the bottom of the bay was traversed by a chasm which closed over them, leaving no vestige behind. At a later date, soundings were made and these proved that there was 600 feet of water where once the quay had stood. Fires broke out in the city and destroyed what was left of it. It is estimated that 50,000 perished.

Charleston and Lisbon are occurrences concerning which we have reliable data, but the old records tell of many such catastrophes throughout human history. Antioch, though an inland city, has been the scene of an extraordinary repetition of earthquakes, the first recorded being that of 148 B. C. and the last in 1822. No place is immune from them and though they are common in volcanic regions, they may happen—possibly, from a different cause—in localities far removed from evident terrestrial disturbance.

To the miner they serve as an object lesson to bring home the fact that the faults and other ruptures which he sees underground, breaking his vein or dislocating his pay-streak, are due to causes which have not entirely ceased to exist. The earth is still proceeding through its cycle of change, and if the outward and visible signs of unrest appear to be infrequent, it is only because the duration of a man's life is so brief when compared to the time occupied in producing these geological effects, that he is apt to be unaware of them. The shocks felt by us today probably register a break in the earth's crust at some point—geologically—not far distant and the numerous minor tremors indicate a readjustment after the first break, which may be the culmination of a long period of strain among the strata above which our homes happen to be built. The earth in cooling is steadily shrinking and, like the skin of a dried apple, the outer rocky crust is contorted to the point of cracking, as it gradually adapts itself to a smaller interior. As the thickness of rock is ruptured, one side dropping relatively to the other, there is a shock which pulses through the overlying strata and reaches the surface in the form of earth-waves that prove too much for the structures built by man on the assumption of perpetual stability.

No part of the earth is safe from earthquakes; the place most free from tremors may be the scene of a shock the more severe for having a cumulative energy. The cause of these is only surmised, as due to a rupture within the crust, but the effects have been investigated and the movements measured so well as to indicate the center of the earth pulsation to be far beneath the surface. In the Charleston case, the shocks came from eight and twelve miles deep.

While volcanoes and earthquakes are manifestations that probably have a common origin in this shifting of the rocky integument of the planet we inhabit, it does not appear that earthquakes are necessarily and immediately associated with eruptive activity. The disasters at Charleston, in 1886; in the Mississippi Valley, between 1810 and 1813; at Antioch, on many occasions; and even at Lisbon, in 1755, all occurred at places several hundred miles distant from any volcanic vent. The active volcanoes nearest to San Francisco are those in Alaska.

In volcanic countries—in Central America, in New Zealand and in southern Europe—earth tremors are so frequent that the inhabitants have grown accustomed to them. The 'tremblors' preceding and accompanying a volcanic eruption take place at a comparatively shallow depth and they can be better diagnosed. An up-welling mass of lava, on reaching the ground-water, will provoke shocks, because the molten rock turns the water into superheated steam, which expands with explosive violence when it penetrates cavities underground; moreover the emanation of lava through a vent—frequently the crater of a volcano—will eventually leave a cavernous space which by the collapse of the overlying rock produces a settlement of the surface accompanied by vibrations, much in the same way, though on a different scale, as when the hanging wall of a stope falls in.

The relation between water and volcanic eruptions is one that is variously explained. The fact that volcanoes are found either near the sea or actually rising through the ocean floor, led to the theory that eruptive action is due to the penetration of sea water into cracks communicating with the molten rock, which, either as a sub-stratum or in isolated reservoirs, exists underneath the cold crust of the earth. The water was supposed to undergo tremendous expansion leading to violent escape, through vents which afterward allowed of an exit for the lava itself. But the best geological opinion holds nowadays that the volcanoes made the water, just as much as the water the volcanoes. The ocean marks an area of sedimentation, over which the detritus, worn away from the land and carried down by the rivers, is deposited. This accumulation of sediment proceeds until the thickness of material is measured by miles and until the pressure on the lower layers becomes so intense as to force out the water imprisoned in them. This water was carried down with the particles of sand and silt as they fell to the ocean floor and constitutes one-twentieth to one-fifth of the consolidated material. The successive layers present an impervious structure to the direct ascent of the water when it comes within the deep zone of high pressure and high temperature, so that an outlet is sought along the edge of the area of sedimentation, namely, along the rim of the oceanic basins. Hence centers of eruption become established along the coast.

The above notes dealing with the geologic causes underlying earthquakes, were written before there was any knowledge of the conflagration that was to destroy San Francisco. As the train and ferry service stopped early that morning, the writer employed the time of anxious waiting to prepare some notes, not anticipating any such catastrophe as supervened. The earthquake itself, which was destructive enough to all save wooden houses or a few of the most scientifically-built steel structures in the City, was also a cause for terror at Berkeley, but it damaged seriously only a few buildings. The vibration seemed to lessen eastward, so that Berkeley felt it less than Oakland, and Oakland less than the City itself or the minor towns on the San Francisco peninsula. In the redwood frame dwellings at Berkeley, one woke up suddenly on that fateful Wednesday morning to find the house shaking, amid violent creaking and cracking, so loud as to drown the crash of falling chimneys. Recognizing that it was an earthquake, one expected it to cease every moment, but after a movement of less violence, the horrible shaking began again, with greater intensity, until it seemed that the house must collapse bodily. To those who were unwilling observers of the phenomenon, it seemed as if the house were being shaken much as a terrier shakes a rat, with a final wrench that promised to make an end—but it was succeeded by a gradual decrease of the vibration. This feeling of a wrench, that is, of torsional strain, was emphasized in some of the taller buildings and it was due probably to the crossing of two sets of vibrations. In regard to other evidence, it is too early to collect accurate data. In San Francisco the street-car tracks on Market street retained their alignment fairly well, but the roadway was depressed fully four feet. Market street is paved with cobbles; where there was an asphalt pavement in the lower parts of town below Montgomery street, the roadway

On Union Street, San Francisco.

was buckled so as to make tents, and in other spots there were depressions several feet below the normal level. Southward, along the San Francisco peninsula, the shock was particularly severe and, it is stated, actual fissures, five to seven feet wide, traversed the surface of the ground. Palo Alto felt this and, in consequence, the buildings of Stanford University succumbed. When a scientific investigation is made, as it should be made, either by the State or the proper department of the National Government, it will be found, we believe, that one fact stands out prominently, namely, that the earthquake was destructive in the City mainly from Montgomery street down—eastward—to the water-front. This area is 'made land'; the original shore followed an irregular line that coincides roughly with Montgomery street. By means of piles and filling, the City has encroached upon the shallows of the Bay. Visitors to San Francisco will have noticed how irregular was the level of the side-walk along the lower part of Market street; the pedestrian found the pavement three or four feet higher in front of one building than it was in front of the next. This was due to the City ordinance whereby the side-walk had been raised (to be followed later by a similar elevation of the level of the roadway) so as to secure greater depth for sewers, until they were below the basement floors. Many supposed that these irregularities marked the subsidence of the older buildings, but it was not so, as explained There was plenty of evidence, however, among the older and poorly constructed buildings, of subsidence, but the irregular side-walk was no part of this testimony. The structures erected on plank were, in several cases, out of the perpendicular and others had sunk, while those built properly on piles were all right. The original fill was made of all sorts of stuff that was deposited to a depth of about ten feet upon the blue mud of the Bay, under which there is a layer of gray sand, seven to eight feet thick and very tenacious. This is succeeded by more mud. The piles not reaching hard-pan are gripped by such material so that in many cases it would be difficult to budge them with a two-ton hammer a month after driving. In the best practice, piles 70 feet long are used wherever hard-pan cannot be reached; this means a depth of

75 to 80 feet below the street, because it is necessary to get below the level of the tide. After the sea-wall of the new ferry building was made, the ground tended to shift less and it seemed that eventually it would become stationary, for the wall hindered the tide in penetrating the filling and placed an obstacle to creeping. The sea-wall made tidal action sluggish within this 'made land,' and this did not affect the piles which still remained under water, but it did permit the plank to dry and therefore to rot, so that buildings on plank foundations have been sinking during recent years. This part of San Francisco felt the earthquake severely and in this respect the evidence agrees with that of Charleston. Similarly—although here the distance from the center of disturbance may be a factor—the lower alluvial flats of Oakland and Berkeley were seriously disturbed, while the parts of those cities that spread over the solid ground at the base of the Contra Costa hills felt the shock only slightly. It is apparent that the earth-wave caused by the rupture far below the surface, is propagated intensely in sand, alluvium, filling, made ground, or any other unfirm material. Build your house on a rock—or as near it as convenient—and if you find it necessary to live or to do business on yielding ground, see to it that the best engineering skill is employed, to the end that any natural obstacles may be surmounted by the application of scientific knowledge in construction.

Since the above was written we have been favored with Professor Leuschner's description of the records obtained by the seismograph. He also was prevented from going to the City on that Wednesday morning, although his anxiety to do so can be measured by the fact that his wife was there, having been to the opera the night before and remaining with relatives until the next day. During the interval, before he could offer help to those on the other side, as he did most effectively later in the day, this scientific man busied himself with collecting data and making observations on the phenomena connected with the earthquake. It is interesting to note his quotation from the report on the earthquake of 1868. This, of course, we had not seen, when we made the remarks in a preceding paragraph and similarly Mr. Leuschner knew nothing of the damage done to buildings upon the filling below Montgomery street when he also referred to the danger incurred by structures erected on ground of this nature. There is room for comment here on the short memories of humankind. Here was an authority—E. S. Holden—who reported on the last serious earthquake forty years ago, and emphasized the danger of building "on the made land between Montgomery street and the Bay." Nevertheless, during the years since that report was published, people have continued to build there in disregard of the evidence that it was dangerous to do so *without taking proper precautions.* We emphasize these last four words, because as yet the evidence all goes to show that the greatest damage was done to buildings badly built or constructed on designs that ignored the principles of sound engineering. The amount of dishonest construction that escapes undetected in a big city is appalling and it is this that the earthquake, like a relentless inspector, exposes.

In this way the calamitous effects are a visitation or punishment for wrong-doing and if only those who were responsible were punished, there would be nothing to say. Speaking of a catastrophe such as this as a punishment, reminds one that in days gone-by the earthquake and conflagration that have destroyed San Francisco would have been hailed as an act of God designed to wipe out a wicked and sinful community. While our people may be in a contrite mind and far from haughty at this time of disaster, they look upon the event as due to natural causes, the scientific reason for which they surmise vaguely. It is extraordinary to notice how much an elementary knowledge of geology has spread and how such knowledge has prevented the prevalence of superstitious fear or hysteric collapse. Whatever views people may hold regarding the general direction of the affairs of this Universe, even the most orthodox nowadays impute an earthquake to natural causes and this fact gives them a courage in adversity such as the ignorant and superstitious can rarely possess. Meanwhile, whatever little knowledge men may possess, concerning the methods of the Great Architect of the Universe, is not incompatible with gratitude for preservation from a great peril and with hope for the future.

THE EARTHQUAKE COMMISSION.

The Governor of California, with the approval of the National Government, has appointed a commission to make a scientific enquiry into the effects of the recent occurrence. The commission includes A. C. Lawson and A. O. Leuschner of the University of California, G. K. Gilbert and Fielding Reid of the U. S. Geological Survey, John C. Branner of Stanford University, George Davidson, Charles Burkhalter and W. W. Campbell.

The commission met at the University of California on April 24. Professor A. C. Lawson was elected Chairman, and Professor A. O. Leuschner, Secretary. After a general discussion of the scope of the work to be undertaken, it was decided, in view of the alarming reports which had been circulated, to issue a statement to the effect:

1. That the times of earthquakes cannot be predicted, and that any predictions such as have been current during the last few days are unwarranted.

2. That severe earthquakes are generally followed by a number of minor shocks extending over several days or even weeks.

3. That the physiographic conditions in the Bay region are such as to preclude any serious damage from earthquake waves, popularly called tidal waves.

At its session next day, the commission prepared the following request for the transmission to it of any observations made by those who happened to be within the area of disturbance:

It is of importance that the citizens of the State of California co-operate with the State Earthquake Commission in its investigation of the recent seismic disturbance. For this purpose it is essential that the Commission receive, as soon as possible, information on any or all of the topics outlined below. All communications should be addressed to the State Earthquake Commission, University of California, Berkeley, California.

Give information on the following:

1. Post Office address; town, county, and State.

2. Place and date of observation.

3. Name and address of the observer, if other than the writer.

4. Give estimate of the intensity of the earthquake on the Rossi-Forel Scale. The Rossi-Forel Scale as amended by the Commission is as follows:

I. Perceptible only by delicate instruments.

II. Very slight shocks noticed by few persons at rest.

III. Slight shock, of which duration and direction was noted by a number of persons.

IV. Moderate shock, reported by persons in motion; shaking of movable objects; cracking of ceilings.

V. Smart shock generally felt; furniture shaken; some clocks stopped; some sleepers awakened.

VI. Severe shock, general awakening of sleepers; stopping of clocks; some window glass broken.

VII. Violent shock, overturning of loose objects; falling of plaster; striking of church bells; some chimneys fall.

VIII. Fall of chimneys; cracks in the walls of buildings.

IX. Partial or total destruction of some buildings.

X. Great disasters; overturning of rocks; fissures in the surface of the earth; mountain slides.

5. Give any facts that you can as to the directions the Earthquake Waves seemed to travel. Describe the character of the shock, whether a tremblor or an oscillatory motion, etc., and whether you yourself or others had any clear impression as to the direction in which it was moving, the facts on which this impression was based and whether people agreed as to the direction.

6. Give also any further particulars of interest, whether they are from observation or hearsay. If any changes occurred in the ground, such as depressions or elevations of the surface, fissures, emissions of sand or water, describe them fully. Character of damage to buildings. General direction in which walls, chimneys and columns in cemeteries were overthrown. Springs, wells and rivers are often notably affected, even by slight shocks, and any information in regard to such changes will be valuable.

7. State as exactly as possible the time of commencement and the duration of each shock.

The exact time of the beginning of a shock (to the nearest second), one of the most important of all observations, is difficult to get correctly, because of the great velocity with which the wave travels, and because the watch or clock must be immediately compared with a clock known to be keeping standard time. If several hours have elapsed before the comparing is made, another comparison should be made an hour later, in order to find whether your timepiece is gaining or losing. The observation cannot be regarded as a good one, unless it is stated that this has been done. Telegraph operators, railroad officials, watchmakers, etc., have especially good opportunities for answering this question correctly, and their co-operation is most earnestly solicited.

If a clock was stopped, give the exact time it indicated (and anything known, as how fast or how slow it was), its position, the direction in which it was facing, and the length of the pendulum.

8. If the shock was not felt in your neighborhood, although noticed at places not very far distant, do not fail to answer the first four questions, as negative reports are of great interest in defining the limits of the disturbed area, etc. State also the nearest point to your station where the shock was felt.

9. Name of writer.

Note.—In replying to these questions, they need not be repeated; but the answers should be numbered to correspond to the questions.

[We trust that any of our readers that can help the cause of science and the safety of our people, by transmitting such data as are requested by the Commission, will do so at once, while their memory is fresh.—Editor.]

THE CAUSE AND NATURE OF EARTHQUAKES

By G. K. Gilbert,
United States Geological Survey.

The scientific study of earthquakes has made great progress in the last few decades. On one hand there is substantial agreement among geologists as to the ways in which they originate, and on the other there is agreement among physicists as to the nature of the vibrations.

Earthquakes have two general sources. One group, known as tectonic are by-products of the subterranean forces and processes which make mountains and elevate and depress portions of the earth's surface. The other group, known as volcanic, are by-products of the movement of lavas from below upward. The tectonic are far the more numerous, and include all the important earthquakes that have been recorded in the United States.

In the formation of mountains and other great features of the earth, the rock masses are forced into new shapes. They are pulled, pushed, twisted and bent; so that strata, for example, which were originally flat, become inclined and curved. If the changes are sufficiently slow, the component particles of the rock readjust themselves gradually; but if the changes are comparatively rapid, the rocks are broken. Before fracture occurs there is elastic yielding, or 'strain'; that is, the rock is compressed or stretched or bent somewhat like a spring; and when its strength is at last overcome the dissevered parts recoil. This recoil is instantaneous, violent and powerful, and is of the nature of a jar. The jar is communicated to the surrounding rock, and is passed on from particle to particle in all directions. Each particle is moved from its original position and returns again, thus making an oscillation. Some conception of what takes place may be derived from the dropping of a pebble on the smooth surface of a pond. A wave is started which travels outward over the surface in all directions, so that at any instant it has the form of a circle.

The motion within the earth is also called a wave—an elastic wave—but it travels up and down as well as horizontally and its form at any instant, instead of being circular, is spherical. Wherever this expanding sphere reaches the surface of the earth, there is an earthquake.

Volcanic earthquakes also are the surface manifestations of elastic waves, and many of them originate in the breaking of rock masses, but the initial jar is also given by explosions, and sometimes by the falling in of cavern roofs.

The fracture producing a tectonic earthquake may be a mere parting of the rock, but usually there is slipping along the fracture, constituting a fault. Some of the faults making earthquakes are visible at the surface. The Inyo county earthquake in 1872 was associated with a dislocation of several feet which can still be seen along the western margin of Owens valley. The greater number of fractures are not visible, but occur miles below the surface. The depth of the origin of the Charleston earthquake was estimated at 12 miles.

The fracture may be horizontal, or vertical or inclined, straight or curved. It may be miles in extent. It is not all made in the same instant but progressively, so that seconds or minutes may be consumed. The initial jar is thus distributed through space and time, with the result that the earthquake involves a very complicated movement. Some of the remoter readjustments appear also to consume much time, so that minor fractures take place at intervals after the main fracture —or, at least, that seems a rational interpretation of the fact that an important earthquake is followed by a long series of minor shocks and tremors.

An earthquake is complex in yet another way. Elastic waves are of two kinds. In one kind the to-and-fro movement of the particles agrees in direction with the progress of the wave; in the other kind the particles move in a direction at right angles to the direction of wave progress. Every earth fracture starts both longitudinal and transverse waves, and the two kinds are started together, but it happens that they travel at different rates, so that at a distance from the origin a single initial jar may be represented by two distinct shocks. The behavior of the two waves is also qualified in an important way by the material traversed. The longitudinal wave may be transmitted by both solids and fluids, the transverse by elastic solids only. When a transverse wave encounters loose, incoherent material, such as sand, and especially when it meets wet alluvium, is transformed into a wave of a different character, analogous to the surface waves of a body of water. It becomes visible as a surface undulation, its rate of progress is reduced, and its amplitude, or the space through which the particle moves, is greatly increased. It is for this reason that earthquakes are peculiarly destructive on alluvial lands.

Getting a Drink.

SOME LESSONS FROM THE EARTHQUAKE.

By S. B. Christy,

Dean of the College of Mines, University of California.

San Francisco, dear to the miners of '49, has been destroyed by fire many times before, but each time has sprung again to life more vigorous and beautiful than ever.

San Francisco, dear to the miners of today, has just passed through a new baptism of fire, but already she is shaking herself free from the ashes that cover her and will again hold the proud place she has won for herself more strongly, more grandly than ever. There is no fear for her future. The most permanent of human institutions are the great commercial centers. These are marked by Nature herself and nothing but the destruction of her noble harbor can prevent San Francisco from remaining the natural gateway for the commerce of the Pacific.

As the fires die out and the smoke clears away, some lessons of this great event stand out so boldly that it behooves us to profit by them for the future. In the first place, it is certain that with good foundations, good designs and honest workmanship, the earthquake damage in San Francisco would have been as it was in Berkeley, merely nominal. It was poor design and construction that caused the losses. Buildings that stood on a sound foundation and were wisely planned and honestly constructed were practically unscathed by the earthquake. At the University of California, which stood upon the solid ground of the Berkeley hills, the seismograph showed an earth movement of about half an inch. But although actual records are missing there is no doubt that in alluvial soil, loose wet sand, mud, and other loose materials such as covered the lower parts of San Francisco, the earth motion was greater and probably of a different nature from the vibrations in solid rock. Nevertheless there stand in San Francisco, on made land along the water-front, a number of buildings upon deep pile foundations that suffered very little from the earthquake. There is no doubt that the modern steel-frame construction, when properly placed on a sufficient foundation and wisely planned and honestly built, is practically safe from earthquake shocks.

San Francisco contained a number of old fashioned structures, many hurriedly and cheaply built on insecure foundations; these were known to be unsafe and should have been condemned long ago. I saw many "concrete foundations" that had a shell of cement half an inch thick on the outside that were filled inside with loose sand. It is no wonder these gave way and undermined the structures they did not support. The earthquake was a stern exposer of sham and it ruthlessly searched out the work of ignorance, cupidity and graft. The City Hall had long been known as such a structure and it was seriously injured by the shock. But at the University of California, at Berkeley, the California Hall, and the Hearst Memorial Mining Building, designed and erected by the University architect, Mr. John Galen Howard, came out without a blemish. The total damage to all the buildings of the University of California (chiefly chimneys) can be covered by the sum of five hundred dollars.

In San Francisco the wide-spread ruin came from the fire. This too can be avoided in the future, if the lessons of this disaster are wisely utilized. Some of these causes of disaster exist in all modern towns and the like may happen anywhere. Modern cities are too much centralized; just as was the case in San Francisco. The electric power and light, the water and gas services were all at once disorganized. Telephone and telegraph lines failed to work at the time they were needed most. Numerous stations for wireless telegraphy should be established by every large city to meet just such contingencies.

The paralysis of the power plants stopped street-car service, both cable and electric, while the old horse-cars would still have been effective. The automobile service during the fire proved to be of incalculable value. With street-cars idle, telephones down, the automobiles went everywhere. They carried messages, wounded, supplies, dynamite—anything with certainty and dispatch.

The shoddy construction of the cheap flats and tenement houses south of Market street started fires all over this territory; and as the water supply was centralized, an accident to a part crippled the whole. As it was impossible to fight fire without water, the fire spread more and more until it had eaten up three-fourths of the city. The wreck of the water supply was another example of the excessive centralization of modern cities. Many square miles of buildings were destroyed simply because they depended on the general water supply which failed; but the United States Mint, though surrounded by fire, was saved, partly because it was honestly constructed, but also because it had its own artesian well for fire protection and an independent steam-pumping plant. If all other large

Car-tracks on East Street, near the Ferry.

buildings had been similarly equipped, the fire might easily have been checked.

In the absence of water, dynamite was resorted to. This was very effectively used by the army engineers, but many others who handled it did not know how to apply it effectively and only spread the fire. Often when it was used, it was employed too timidly and was resorted to when it was too late. If the blocks in Chinatown between Kearny and Stockton had been promptly blown down Wednesday afternoon the entire residence district of the Western Addition might have been saved. A hundred California miners used to handling dynamite could have saved three-fourths of the burned district by intelligent and prompt blasting.

It was fortunate that the military and naval posts were so near, so numerous, and so efficient. The value of military discipline in an emergency was never more strongly demonstrated. It is difficult to imagine what would have happened in San Francisco during the dreadful nights that followed the fire, if it had not been for the presence of the regular troops. With a firm hand anarchy was suppressed every time it showed its head. Many a family owes its safety to the boys in blue. The militia and the cadets of the University of California also rendered very valuable service in protecting the lives and property of the citizens of San Francisco, Oakland and Berkeley. What these bodies lacked in experience was more than made good by superior intelligence and good-will. The University boys, under the able leadership of Captain Nance of the regular army, were hailed with cheers by the people as they marched to their stations, and petitions were circulated among the residents to protest against their removal when they were called back to Berkeley.

It would be a fatal mistake to rebuild on the old plan. San Francisco has a site of rare beauty. The Seven Hills of Rome are no more picturesque than hers. But the ugly streets which ascend the steep hillsides should be replaced by streets that closely follow the contours, on an easy grade, and the higher portion of the city should be laid out in terraces. The lower and flatter portion should be laid out in fire-districts covering not more than 160 acres each. These fire-districts should be separated from each other by broad boulevards fully as wide as Van Ness avenue; and at each corner of every fire-district should be a park covering at least one block; so that at the corners of each of these fire-districts there would be a park four blocks in area, serving as breathing places under ordinary conditions and as places of refuge in times of conflagration.

The space under the side-walks should be no longer encroached upon by property owners, but should be open to tunnel-ways belonging to the city, for the reception of sewer, water and gas pipes, and for electric power and telephone lines, and should be under the control of the city government. This would make possible the constant inspection, repair, and a maintenance of these important arteries of the city's life, and would facilitate the easy distribution of power to the various residence and business centers; and would avoid forever the constant tearing up of the streets which has caused the destruction of the sewer and water lines by the earthquake.

Each fire-district should have its own independent source of water and power, so that its total destruction could not cripple the rest of the city. In the flatter portions devoted to business and manufacturing interests there exists an adequate supply of water easily reached for fire protection by artesian wells, and each large building should be forced to provide itself with such a supply, with proper fire service worked by an independent steam-pumping plant that would be available in cases of general conflagration. In the fire-districts and the hilly portions of the land there should be reservoirs always kept full of sea-water which can be easily supplied by properly distributed pumping stations. This could be utilized for flushing the sewers, for bathing as well as fire protection. These systems of water supply should be independent of the supply of drinking water.

The police, the military, and the fire departments ought to organize an efficient automobile service with numerous garage stations, supplied with small supplies of gasoline, which, with other inflammable substances, should be kept in underground chambers.

San Francisco should appoint a competent commission of architects and engineers to study, with the greatest care, the effects of the earthquake and the fire upon buildings having different types of foundations and modes of construction. This should be done at once, and a prompt and thorough investigation should be published immediately for the use of those who are intending to rebuild the new city, and the most stringent laws should be passed controlling the types of construction that shall go up in the new San Francisco. Every large building should be supplied with an underground vault similar to those of the banks for the protection of records and plans. Blue-prints of all the power lines, pipe lines, and sewers ought to be stored in such fire-proof vaults in more than one place. The wisdom of this procedure is demonstrated by the fact that such copies as were on file in the University Library at Berkeley have proved of great service. The value of large areas of park land, such as Golden Gate Park, the Panhandle, and the Presidio, has been clearly demonstrated. These areas should be increased rather than diminished. The Burnham plans certainly ought to be made the basis of the new city, although some changes may possibly now be made with advantage which were not possible before the fire.

These measures are absolutely necessary for the safety from destruction by fire, and while it might not be possible to condemn property for public use for the purpose of beautifying the city, it certainly is justifiable to do so as a measure of public safety, and it ought to be done intelligently and promptly. The success of a properly devised system of assessment of damages and benefits resulting from such changes was clearly shown at Baltimore. No city ever had an opportunity so great as San Francisco has at the present moment for utilizing the ideas of modern science and engineering skill.

No one who shared the terrors and uncertainties of the dreadful days and nights of the fire can have failed to be impressed by the noble courage of the men and women who suffered from the disaster. They met the dangers and accepted the losses with a courage worthy of the descendants of the men of '49. No one who witnessed these scenes can have any doubt as to the great future of San Francisco.

THE EARTHQUAKE.

By A. O. Leuschner,
Director of the Students' Observatory, University of California.

An earthquake eclipsing in severity even that of October 21, 1868, occurred in San Francisco and the surrounding region early this morning. The earthquake came suddenly, without preliminary vibrations. The intensity of the first shock put the sensitive Ewing seismograph, of the Students' Observatory of the University of California at Berkeley, out of action, but a fairly complete record was obtained with the duplex instrument, of which the following is a preliminary account. The best record of the beginning of the heaviest shocks is furnished by the Standard clock of the Observatory which stopped at 5 hours, 12 minutes, 38 seconds Pacific Standard Time, while less severe shocks were recorded by Mr. S. Albrecht some 35 seconds earlier. The principal part of the earthquake came in two sections, the first series of vibrations lasting for about 40 seconds. The vibrations diminished considerably during the following ten seconds and then continued with renewed vigor for about 25 seconds more. But even at this writing, about 12 m., the disturbance has not as yet subsided, as slight shocks are being recorded at frequent intervals on the Ewing seismograph, which has been restored to working order. The principal direction of motion was from SSE to NNW. The remarkable feature of this earthquake, aside from its intensity, was its rotary motion. As seen from the record, the sum total of all displacements represents a very regular ellipse and some of the lines representing the earth's motion can be traced along the whole circumference.

The three severest earthquakes on record in this vicinity are those of October 21, 1868; March 30, 1898, and that of today. From their records an important conclusion may be drawn, which may be of value in constructing buildings in the future so as to guard as far as possible against destruction. The result of observation indicates that our heaviest shocks are in the direction SSE to NNW. In that respect the records of the three heaviest earthquakes agree entirely. But they have several other features in common. One of these is that while the displacements are large, the vibration period is comparatively slow, amounting to about one second in the last two big earthquakes. If today's shocks, as felt at Berkeley, had been instantaneous, inestimably more havoc would have been wrought among all kinds of buildings. The slowness of the vibration is the only redeeming feature in these calamities. The following account of the earthquake of October 21, 1868, as experienced in San Francisco, is taken from Professor E. S. Holden's 'Catalogue of Earthquakes, 1769 to 1897,' and will serve to show the features it had in common with that of today. "The first shock was 7 h. 53½ m. a. m. Its direction was northerly and southerly. Its duration was 42 seconds. The second shock came at 9:23 a. m., lasting five seconds. Lighter and briefer tremors occurred at intervals of about half an hour, till 12:15 p. m. The first shock was most severely felt on the eastern side of the City, on the made land between Montgomery street and the Bay. On the solid land no serious damage was done to any well-constructed house. The Custom House was badly damaged. It was poorly constructed. As in 1865, a small crevasse was opened on Howard street, beyond Sixth. The greatest damage was done in a belt several hundred feet wide, running northwest and southeast, commencing at the Custom House and ending at the Folsom street wharf. The tall chimney of the United States Mint was damaged. The ferry steamer Contra Costa was near Angel Island and felt the shock strongly. Shocks were noted at 7:53; 8:10; 8:15; 8:45; 9:20; 9:30; 9:35; 10; 10:30; 11:05 a. m., and 2:58 p. m. Waves came 15 to 20 ft. further inland than usual. There were about thirty casualties in the 150,000 inhabitants. Five deaths occurred from falling walls, etc. Not a single well-built house on the solid land suffered materially, whether of brick, stone, or wood. Wooden houses suffered least."

By following the trace of the pen on the record, it can be seen that the first large motion of the earth was due west. It measures two inches. As the instrument multiplies 4.3

East Street, at Pier 27.

times, the actual displacement of the earth's crust or amplitude of the wave, was about one-half inch. This also corresponds to the average amplitude of the resultants in the direction SSE and NNW. Taking the average period as one second, the velocity of the earth-wave during the heavy shocks is found to be roughly two inches per second, by far the greatest ever observed on the Coast. Heavy masses on fairly smooth surfaces were observed to move as much as three inches. The times of the several shocks were carefully noted by Mr. Albrecht, Fellow in the Lick Observatory, now at the University as a graduate student of astronomy, until 9 hr. 26 m. a. m. After that records were taken by Dr. Crawford and Mr. Einarson with the Ewing seismograph. The last shocks recorded are mainly from east to west. Observers throughout California are requested to send their records to the Students' Observatory. The vertical component of the shocks was also of great intensity but of less frequency. The maximum shock measured in a vertical direction being 0.8 inch.

If it were possible to have all the phenomena of the past presented to us, the convenient epochs and formations of the geologist, though having a certain distinctness, would fade into one another with limits as undefinable as those of the indistinct and yet separate colors of the solar spectrum.

The constant widening of the intellectual field has indefinitely extended the range of that especially human faculty of looking before and after, which adds to the fleeting present those old and new worlds of the past and the future, wherein men dwell the more, the higher their culture.

FIRST OBSERVATIONS OF THE CATASTROPHE.

By D'Arcy Weatherbe.

These notes were made on Saturday, April 21. One who felt the shock in Berkeley at 5.15 a. m.—saw the results throughout Berkeley and Oakland between 8 a. m. and 3 p. m.; spent from 4 p. m. until 8 p. m. within the fire area and the business section of the doomed city of San Francisco on the first day of the disaster, and on the third traversed the wastes from the ferry to St. Mary's College on the Mission road, and from there to the water front end of Van Ness avenue, and back through the burned district to the ferry, should at least be aware of the prevailing conditions, in however poor a mood for description his experience might leave him. Not even the pen of a Zola could properly describe the impression received and stamped in a lasting manner on the mind of any-one of the odd half million people residing in the vicinity of San Francisco Bay on that fatal morning of April 18, 1906. In meager mechanical words, the general effects were a terror that left the recipient in a hopeless, mentally numbed state, followed by a physical nausea, the causes of which are akin to sea-sickness. It appears, too, that a common impression was that the end of the world had come. The reaction naturally was severe. The immediate and complete annihilation of the city by fire and the ensuing panic and consequent wild flight of the inhabitants in every direction was succeeded, as might be anticipated, by cases of starvation, together with looting, violence and demoniacal deeds perpetrated by the half crazed or debauched portion of a cosmopolitan community. Many instances of plundering the dead, wilful incendiarism, persistent selling of liquor, and violence to women were summarily punished by shooting on the spot, and in most instances the punishment was well deserved at such a crisis, though the example to some of the youths in soldier's clothes was bad, particularly as many of these were under the influence of liquor.

Men who are appointed to judge on the spot whether a fellow man merits death and then to act as summary executioner should be specially selected, and it is doubtful whether it were not better to altogether forego such method of punishment than to have law-abiding and respectable citizens butchered on the streets, as has been the case in San Francisco.

Scenes pitiful or ghastly were the rule at hundreds of points through the blazing city. The fire, which commenced south of Market street, near the water front, gained rapid headway and, almost unhindered by the helpless firemen, who were without water to combat the flames, it passed up town, licking up everything in its way, all the magnificent business structures, one by one succumbing to its fury. At the St. Francis hotel the main rotunda was crowded with the guests, who sat in the dusky twilight (no lights being available) with their hand baggage between their knees and waiting for they knew not what. This magnificent hostelry, which was thought, however, to be comparatively safe, was, seven hours later, completely gutted, the guests fleeing for their lives. With incredible swiftness the conflagration traversed the business portion of the city and seized with greedy tongues of flame upon the handsome residential and the other thickly populated districts. Governed only by the wind, it reached Van Ness avenue late on Thursday and followed north from Market street along the east side of Van Ness. Crossing this beautiful avenue, it wiped out a block on the west side and then, reluctant to give up its prey, turned northeast to meet the other fire which had previously devastated Nob, Telegraph and Russian hills in its path northwestward toward the Golden Gate. Thus the entire area bounded by Market, Van Ness and the bay is laid waste; on the south side of the main artery—Market street—the devastated ground is roughly bounded by Dolores street on the west and by an irregular line following from about the corner of Dolores and Twentieth streets, down Twentieth to Kansas, and thence across to Twenty-fifth street and easterly by that street to the bay, and on the north by the water front.

Collapsed Building on Made Ground.

The streets of Chinatown, which we passed through, were thronged by fully 3,000 Mongolians of all castes and ages. Some of the older men and women looked more like leprous animals than human beings, and many had probably not been out of their over-crowded dens for years. Their squalid effects, piled in every conceivable shape, impeded progress through the narrow streets, and passing through their district toward dusk we hastened our steps ferryward, traversing that disreputable locality known as the Barbary Coast. Here beasts in human shape in every stage of drunkenness, and delirious from stolen liquor taken from the wrecked saloons, shouted or sang in a perfect pandemonium. Within a few blocks the roar of the flames, the noises of constantly falling walls, and the dynamiting supplied a sufficiently hellish accompaniment to that orgy.

Refugees from the densly populated Mission district fled along the Mission road toward San Mateo, and the sights on this highway on Friday, the 20th, are never to be forgotten. An endless procession had left the city on Wednesday and Thursday with carts, buggies, motor cars, and vehicles of every possible description, including hand carts and wheel barrows. Part of the throng camped wearily in the fields on the outskirts of the city, while others kept on toward the southern towns. On the fire burning itself out in this direction some of the refugees returned, and the scene on Friday morning was pitiful in the extreme. Under a blazing sky, the heat of the sun being intensified by the pall of smoke that hung over the city to the east, were seen old men and women helplessly and aimlessly carrying bundles hither and thither. Children with fevered faces and women with babes in arms, trudged through the dust, which lay nearly a foot deep on the road, and was raised in blinding clouds by the passing of wagons; this intensified a thirst already strong by reason of the unnatural conditions. Fortunately, water in this, as in most of the outlying suburbs, became available in reasonable amount, though even this was carefully husbanded. The fearful contingencies that may arise in these enforced camps are famine and disease, the latter spreading quickly on account

The Palace Hotel After the Fire.

of the necessarily unsanitary state of affairs. Similar conditions are the case at the Golden Gate Park and the Presidio, though here more facilities are provided for the comfort of the homeless people. In the streets bricks from the ruined structures are everywhere piled in the form of ovens, and meals are being cooked in the open. Crowds surround the occasional relief wagons that have gained access to the city. Flour is received from the cart in hats, in hands or in any available utensil, and is quickly converted into flapjacks or partially cooked dough. In the poorer districts the fact must be emphasized that more kindness and less greed were displayed than in those which could better afford generosity. In the Mission district almost every small grocery or food shop gave away gratis its entire stock. Even then an armed guard was necessary to preserve order. Men and women, with hands outstretched, thankfully took whatever was offered —tinned stuff of all kinds, meat, vegetables and fruit, and even bottles of sauce were thankfully received.

The handling of the conflagration by the fire department, the police and the military, was probably, on the whole, fairly well done, though being from the first without water, it was a hopeless proposition. That it took as long as it did (five square miles laid practically flat in three days) was due entirely to the favorable condition of the atmosphere, which at first was without wind, and at a critical time changed so as to turn the flames back partly over the already consumed area. Dynamiting, unless done under skilful direction and carried out with experienced assistance, is practically useless and should be strongly condemned. Some of the methods used in the San Francisco fire did certainly not display either experience or even good judgment. In the district covered by frame houses from 75 to 150lb. of 40 or 50% powder was used. It was generally carried in bulk into the lowest floor of the building, placed in the center and set off with a foot and a half of fuse, taking about one minute to burn; the effect, in the cases that I witnessed, was almost entirely lateral, allowing the ruin to fall upon itself. So far so good. Fire in several cases started from the explosion, and it should have been carefully followed up by the little water available to prevent fire. Moreover, the strip to be dynamited in each case should have been decided upon long before the fire had reached it, so that when the flames arrived a more or less barren patch would be presented. As it was, a handful of independent men without any head waited until the flames were within one or more buildings before exploding the edifice, the flying debris in some cases actually taking fire in the air. Several blocks were lost that might have been saved by taking the precaution to examine the contents of the building before blasting. In one case noted it contained explosives and spread the fire. It is, of course, easy for any one to criticize, though not so easy for the same people to have done better. My criticisms are meant in a friendly way. Moreover, we have no precedents of such magnitude as to serve for an example. It was, however, apparent, to almost everybody that there was want of organization and system in the city. On the contrary, at Berkeley, the energy and systematized arrangements for relief will long stand as a shining example of prompt "first aid to the injured." Many lessons are to be drawn from the disaster and particularly from the effects of shock and fire on structures designed and built to resist both. It cannot be said that tall buildings will not resist shock if well built, for we have the case of the Chronicle and Call buildings. On the contrary, the Monadnock building, also a steel structure, though lower and of large base in comparison, was badly wrecked by the shock. However, the shearing strain on rivets and bolts must have been enormous, and it is probable even had there been no fire it would have been necessary to take down the majority of the large buildings for safety, even though apparently uninjured—as seen from the outside. However that may be, it is early to draw conclusions, and it is hoped that the subject may be gone into thoroughly and used as a text for some useful expressions of opinion.

THE YAQUI COUNTRY.

The Editor:

Sir—From the standpoint of a mining engineer who has been into other parts of the Yaqui Territory before, and who has just now ridden over two hundred and thirty miles of country lying in and about the hot-bed of these Indians, and also speaking with the authority of one who has recently discussed the Yaqui question with those in high authority—with prominent citizens of Mexico as well as with the peasantry in the disturbed sections—I am prompted to ask for space in your columns to protest against what, in my opinion, is more ignominious than the scandal that attaches to the question in general; that is, that it should have been possible to circulate a proclamation denying the Yaqui danger, which proclamation is manifestly designed to attribute to bandits such depredations as have been perpetrated, and at the same time intended to minimize the danger of travel in Sonora in respect of possible Yaqui attacks.

It is scarcely to be believed that such a proclamation was in fact addressed to the Department of Fomento, City of Mexico, that is, to Government headquarters, and found the willing or unwilling signatures, as the case may be, of more than one hundred names, including merchants of Hermosillo, Guaymas and Magdalena, native and foreign alike. These were the names of business men, mine owners, mine managers, mine superintendents, bankers, storekeepers, etc., including even the name of the American consul of at least one of the towns named. I ask the question, does force of circumstances justify this written outrage on public credulity?

Among the names of those who signed this malicious document was that of Don Pedro Meza, presidente of the little mining town of La Dura; he has paid for this the penalty of death, even though he carried an escort of forty soldiers, a fact which in itself gave the lie to the assertion that the Yaqui danger was exaggerated, if it existed at all.

A Los Angeles newspaper of March 26 comes out with an article under the head line, "Story of Massacre Fully Confirmed," and in describing the assassination and butchery of Don Pedro Meza, his wife and three grown girls, Mr. Hoff and his wife, this newspaper indulges in a vivid, distorted and false version of the circumstances of this horrible outrage.

It was my chance to come upon the scene of the ambush two days after its occurrence and to look over, and take photographs of, seven partly burned bodies of the Yaqui dead, which numbered nine altogether, and I saw besides from fifteen to twenty dead horses that marked the direction of the fight. A day later we crossed the trail of this same band of one hundred and fifty Yaquis, who were carrying their wounded, as we knew from a quilt which they had discarded, and from blood stains. The signs at this time were very fresh and indicated, what was corroborated afterwards, that we were very close to the band that had killed Meza and Hoff and their families.

What we saw here, taken in conjunction with the fact that seven men and women traveling in the Meza party were killed and five of Meza's personal servants—constituting his guard —one officer in command and two soldiers of an escort originally forty strong, proclaims only too plainly the horrible truth. No ground is left for dramatic journalism under these circumstances, when the passengers are assassinated and the escort is saved. There is but little doubt that the battle belonged to those who did not survive to tell the story of their brave part in this inglorious episode.

The party with which I was traveling went out under the direction of Mr. George M. Ryall, of New York City, who is a concessionaire of some of the best mining territory contained within the Yaqui zone. It included, in all, five Americans under escort of eighteen rurales and two officers of the rank of lieutenant. In coming upon the scene of the ambush below Otate pass, east of Suaqui Grande, we had followed for two hours the trail of the Yaqui band going in the same direction and had noted the single mule-prints of the animal which was ridden by their chief.

These facts speak for themselves, but that is not enough.

I raise my single voice in unwavering protest against the many who in the signing of the shameful proclamation have signed away the lives of tens, and probably hundreds, of men and defenceless women who dare to venture outside the walls of their little towns upon errands that make their travel imperative. It is true that there have been American citizens murdered in ambush; and there will be more to swell the list if they go out into the Yaqui country trusting to the misrepresentations that have been made to the Mexican Government by mining and mercantile interests, and even by their fellow countrymen who have wantonly signed the lying document and cleverly worded death trap that has been so carefully prepared by some of those in authority. If I have the qualifications to enable me to make a statement of the real condition of things as I have seen them, I have also the courage to declare against American citizens who are weak enough to lend their names to such outrageous purposes.

Looking a little closer toward home, there comes an official order from Washington, D. C., according to which American citizens going in and out of the Yaqui infested zone do so at their own risk and peril. I believe that I voice the sentiment of other Americans when I ask, "Is that all the protection the United States citizen is to expect from his Government?" and "Are not these same United States authorities aware that there is virtually no ammunition to be had in the larger towns of the State of Sonora in the region of the Indian trouble?" and further, "Are not the Yaquis getting their rifles and ammunition from Tucson and Nogales and other points about, and north of, the United States frontier?"

In answering such interrogatories our Government will have to admit that there is no restriction placed upon the sale of arms and ammunition to the Yaqui people, and will have to face the fact that our frontier habitations support many Indians who are in constant communication with their fellows in the field. That they are being aided in defense of lands which they claim by right of possession, is poor consolation when one runs the risk of being ambushed at every turn in the road. Many Yaquis are still employed by American interests in mines near the frontier.

The daily importation of ammunition* along the border line, the harboring of Yaquis on the American side, and the employment of Yaqui labor by American interests on the Mexican side, can be verified in each respect by anyone who wishes to inform himself of the Yaqui question, and if he be in the mining profession and he thinks upon the ambush of mining men whom he may have personally known, he may well stop to ponder as to how much the United States Government is doing to protect the lives of its citizens when engaged in developing the mining interests of Sonora before he looks across the line to criticize the Government of a sister Republic. He will find slim consolation either way.

I have talked with the Mexican Government scouts, whose duty it is to post the army authorities on the disposition, movement and numbers of the several bands of Indians that constitute the Yaqui people today. These scouts can, and do, furnish the information required, but in the meantime fatalities are frequently reported in the form of the ambushing of a stage or of a coach party, or of Mexican families, or of the killing of a foreign traveler—sometimes traveling with an escort and sometimes without. It has all happened before and it will happen again. In the course of time it becomes the tearful gossip of a mourning, poverty-stricken people, but the news is never published and information of it is quickly suppressed. The newspapers are under the ban. On the other hand, there is the deserted ranch and houses, roads unused, wells abandoned and cattle left to run wild with two-year-olds unbranded. That is what the traveler will see today in going from La Colorado to Tecoripa, to San Javier, to La Dura, to Suaqui Grande and back again. As it is true of this section, it is likely to be equally true of the country in the vicinity, whether it be more infested or less infested, and if there be any reader who questions such description as I have given of the territory within the bounds named, let him go a few miles to the north and northwest, to Cobachi mountain

* The Yaqui generally carries the discarded arm of the Mexican army, a 45-90 Remington single-fire rifle, with peep sight; the guns that they are importing are Winchester 30-30's and other modern weapons.

and Mazatan mountain, and he will find something still more interesting.

My final word to professional friends is to advise them to stay out of the Yaqui country until there is some better assurance of security of travel and safety to life than anything that exists today, whether going under escort or otherwise.

Under conditions involving so many conflicting statements concerning these Indian troubles, the man who has business that takes him into the Yaqui country has been in the same position as the man who is cautiously watching the questionable maneuvers of a dog that barks and wags his tail at the same time. He is in no position to know which end of the dog to believe. To mining engineers who will take this word of warning I say that the tail of this beast wags deceitfully.

El Paso, Texas, April 11, 1906.

FORBES RICKARD.

The scientific man accepts his limitations and does not expect to arrive at absolute verity. He observes, and when he has advanced far enough to begin to generalize, he formulates his ideas as an hypothesis to serve as a basis on which to work until someone has suggested something better.

Within a finite time past the earth must have been, and within a finite period of time to come the earth must again be, unfit for the habitation of man as at present constituted, unless operations have been, or are to be, performed which are impossible under the laws to which the known operations going on at present in the material world are subject.

A fact in itself has no significance; neither have a thousand facts. What gives facts their value is their relation to each other; for when enough have been collected to suggest a sequence of cause and effect, a generalization can be made which scientific men call a 'law.' The law amounts only to this, that certain phenomena have been found to succeed each other with sufficient regularity to enable us to count with reasonable certainty on their recurrence in a determined order.

THE SEPARATION OF GOLD IN ANTIMONY ORES.

By F. H. Mason.

Some time ago it fell to my lot to attempt to find a process for the separation of the antimony from the gold in an auriferous antimony ore. An idea of the nature of the ore may be obtained from the analysis of a concentrate made from samples broken in different parts of the mine.

Insoluble matter (principally silica with a little slate)	19.90
Antimony as sulphide and oxy-sulphide	30.00
Antimony as native metal	8.99
Lead	3.75
Zinc	0.53
Arsenic	0.21
Iron	7.35
Alumina	2.15
Manganese oxide	1.65
Lime	3.11
Magnesia	0.43
Sulphur	16.33
Carbonic acid	2.86
	97.26

It will be noticed that there is not sufficient sulphur to satisfy the antimony existing as stibnite, lead, zinc, arsenic and iron, so that the balance of the percentage, to make up the hundred, may probably be accounted for by oxygen, a little organic matter (which almost invariably accompanies a concentrate) and, possibly, a little fixed alkali, which was not determined. The concentrate contained 1.566 oz. gold per ton of 2,000 ℔. This concentrate was made by Mr. E. P. Brown, of Bridgewater, Nova Scotia. Mr. Brown, in his report upon the concentration test, states that while 90% of the antimony was contained in the concentrate, only 38.4% of the gold was retained; so that it would be necessary for the tailing, which contained $4 in gold and one per cent antimony, to undergo some form of treatment for the recovery of the gold. Mr. Brown expresses the opinion that probably there would be no difficulty in treating the tailing by bromo-cyanide.

The first experiments with the concentrate consisted of various modifications of cyanidation with the view, if possible, to removing the gold and leaving the antimony for subsequent treatment. Straight cyanide with solutions varying from 0.1 to 1% were tried over periods of from one to five days, the cyanide being brought up to strength from time to time. The ore decomposed the solution rapidly, and practically no extraction was obtained. Mixtures of potassium cyanide and bromo-cyanide were next tried; the bromo-cyanide prevented the decomposition of the solution, but failed to attack the gold to an appreciable degree. The best results obtained were less than a 10% extraction in 24 hours; and to obtain this the concentrate had to be ground to pass a 100-mesh screen.

Some experiments with cyanogen chloride were tried, which were exceedingly interesting, not from a commercial point of view, but because the liquid, after filtering, gave a remarkable cobalt-blue color, which turned to a claret on acidifying. The color remained permanent for days at an ordinary temperature, but on attempting to crystallize the salt by evaporation, the color (whether the alkaline blue or the acid claret) disappeared with precipitation of sulphur. Apparatus for crystallizing in a vacuum was not at hand, so the matter was dropped for the time. The reason for the failure of the bromo-cyanide and chloro-cyanide to attack the gold, was attributed to the presence of metallic antimony, causing re-precipitation. The solution, after 24 hours' contact, did not show serious decomposition and would attack gold leaf actively. Addition of other oxidizing agents, such as hydrogen peroxide and sodium peroxide, to the cyanide solution, failed to make the latter effective in attacking the gold. It is a little doubtful even if a fair percentage of the gold could have been removed by cyanide whether it would have left the antimony in a merchantable form. It was absolutely necessary, in order to get any attack at all by the cyanide, that the ore should be in a very fine state of division; buyers, as a rule, do not want all the ore in the form of fine.

About this time some people arrived in Halifax, from Ontario, who were prepared to make a demonstration of a process they had devised by which they could save all the antimony, gold and sulphur in the ore; and, further, they could recover all the reagents used in the operation. This was a nice, modest claim and so anxious were the owners of the ore to see it in operation that the inventors persuaded them to put up the necessary funds for the demonstration.

A shop was rented and the necessary plant installed, the latter consisted of a row of small wooden vats and a second row of similar vats above them; all the vats were sealed and connected with lead pipes. In these vats the ore was placed, together with hydrochloric acid, and they were heated by steam from a small boiler. The escaping vapors passed through a leaden worm placed in running water, where they were condensed. It was my duty to investigate the process on behalf of the owners of the ore. Three gentlemen arrived with the outfit; two of them appeared to have duties of a purely financial nature, while the third was introduced to me as the chemical wizard. The wizard shot off a good deal of popular chemistry to a motley crowd who listened eagerly and took in nothing; he was a good talker, and carried the crowd with him. On an old counter, he had arranged a number of test glasses, in which antimony had been precipitated from its chloride as sulphide, by hydrogen sulphide; as oxy-sulphide, by sodium thiosulphate; as oxy-chloride, by water; as ferrocyanide, by potassium ferrocyanide; and as metal, by old nails. These formed a few of the pigments the wizard could make from the ore.

Wishing to draw the wizard out and at the same time not to appear too critical, I asked a few inane questions; he at once pounced upon his prey and a conversation ensued somewhat after the following:

Q. Do you know anything about chemistry?

A. A little.

Q. Very good. Now that ore is being dissolved in hydrochloric acid, and I can precipitate the antimony as any of these pigments, all of which are very valuable. The gold is left in the residue; having removed the antimony I can get the gold into solution with nitro-hydrochloric acid. Do you understand chemical equations?

A. If they are not too complicated.

Q. Very good. Now take that orange precipitate you see there; how do I get it? Why, I take the sulphureted hydrogen I get, while the ore is being dissolved and with it I precipitate the antimony chloride formed, and thus I get back the whole of the hydrochloric acid, see?

$$Sb_2 S_3 + 6HCl = Sb_2 Cl_6 + 3H_2 S$$

Very good; now

$$Sb_2 Cl_6 + 3H_2 S = Sb_2 S_3 + 6HCl$$

I am bound to say I was struck with the way the wizard used these equations for his own purpose; both the equations given, as far as they go, are accurate, but unfortunately a chemical equation does not take temperature into consideration, nor does it consider water unless it absolutely undergoes decomposition during the reaction.

The first of the wizard's equations expresses a reaction which takes place with cold concentrated hydrochloric acid or hot medium dilute acid. The second equation expresses a reaction taking place with moderately concentrated cold acid or hot dilute acid with an excess of hydrogen sulphide. Thus the acid obtained from the second equation is powerless without concentration to bring about dissolution of fresh ore.

Unfortunately for the wizard, the ore provided for him to treat had nearly 20% native antimony, and upon this hydrochloric acid had no appreciable action, so that he had to retire from the field of his own accord; otherwise, I verily believe he might have persuaded the owners to erect a plant, notwithstanding my efforts to the contrary; so excellent a talker was my friend the wizard.

But to return to my own experiments. At this time the owners were shipping selected ore to England; by the time transportation, brokerage and treatment charges were paid, this ore only realized about one-fourth its assay-value. Added to this, consideration has to be taken of the fact that it probably required the removal of from six to ten tons of ore to obtain one ton of selected material. The ore shipped ran from 40 to 45% antimony and about $50 in gold. My next experiments were on some of this selected material. It occurred to me that possibly by raining a small amount of metallic antimony through molten sulphide, the gold might leave the sulphide and follow the metallic antimony, and if so, the same metal could be used over and over again on different charges of sulphide until it attained a richness, the degree of which would have to be found by experiment, when it would have to be treated for the gold. To test this theory a quantity of the ore was liquidated. The following is the result of the liquation:

Liquated regulus	76.6 per cent
Residue	16.8 " "
Loss by volatilization and adhering to crucible	6.6 " "

The regulus contained 2.66 oz. gold and the residue 0.7 oz. gold per ton.

The residue which contained about 12% antimony was smelted and the metal obtained contained practically all the gold in the residue; this metal was crushed and showered on the top of molten regulus contained in a crucible; the crucible was allowed to remain for a time in the fire to give the metal a chance of settling, and the contents poured. No metal was found at the bottom of the ingot of sulphide, but the regulus had increased in weight by more than the weight of the added metal. It is assumed that the powdered metal oxidized and formed with the sulphide a regulus of oxy-sulphide. This regulus was returned to the crucible and fine iron turnings were added and stirred in; two lots of iron were thus added. Each addition was arranged to reduce 10% of the metal; on pouring, 25% of the metal was found to have been reduced, which on assay proved to contain 84.3% of the gold in the regulus. A number of other experiments were tried on these lines, but nothing practical promised. Another set of experiments was made by fusing the regulus with soda ash and pot-ashes and adding varying quantities of metallic iron to precipitate a part of the metal. It was found that it was necessary to precipitate from 20 to 25% of the metal in order to get over 90% of the total gold concentrated in it. It was evident that it was necessary to precipitate too large an amount of antimony for this process to be of any practical utility.

Leaching the ore with sodium sulphide with a view to removing the antimony, was tried next. For these experiments, the concentrate previously mentioned was used; it was treated with a hot 15% solution of sodium sulphide for six hours, and 82% of the antimony went into solution; but when the residue was assayed, it was found that 17.8% of the gold had gone into solution also. As only 77% of the antimony existed as sulphide, it will be noticed that the sodium sulphide had attacked the native metal; this was expected, and it was for this reason that the sulphide was used in preference to the hydroxide; the sodium sulphide first coats the particles of metallic antimony with sulphide, which is dissolved in excess of the reagent. Of course sodium sulphide was known to be a feeble solvent for gold, but such a marked attack upon that metal was not expected. Solutions of sodium sulphide, both hot and cold, and of varying strengths, were tried, but to get any attack upon the native antimony, invariably meant an attack upon the gold also, and for this reason the use of sodium sulphide had to be abandoned. Wet reactions on the raw concentrate, for the removal of either the gold or the antimony, having proved futile, it was now decided to subject the ore to a preliminary roast. When antimony ore is roasted, two oxides are formed, namely, antimony trioxide, which is volatile and passes out of the furnace, and antimony tetroxide, which is fixed and remains in the furnace with the gangue. The tetroxide is not appreciably attacked by solutions of acids, alkalies, cyanides, chlorine or bromine, so that if no gold were lost in roasting the ore, there appeared to be no reason why the precious metal itself should not be recovered from the residue, by either chloride or cyanide. The proportion of trioxide formed by roasting varies with the temperature at which the operation is carried out; a low temperature appears to favor the formation of tetroxide. Of course the temperature must be kept very low during the early stages of the roast, on account of the low melting point of stibnite.

The concentrate was found to lose from 14 to 30% of its weight by roasting; the variation depending entirely upon the temperature and being due to varying amounts of the trioxide formed. A number of roasts were made and in no case was as much as three per cent of the gold lost during the operation. Chlorination of the roasted ore was attempted first. The chloride of lime used (the best that could be obtained locally) was of poor quality and only yielded 20.5% available chlorine, while material of good quality should yield 35% available chlorine.

A large number of experiments were made, and it was found that 75% of the gold could be extracted from the roasted ore by agitating it for 24 hours with three per cent (of the weight of the ore) chloride of lime and six per cent sulphuric acid. The best results were obtained when all the acid and one per cent of the lime chloride were added at the beginning of the operation, a second portion of the lime chloride after eight hours and a third portion after 16 hours' agitation. The large amount of acid was necessary in order to neutralize the lime in the ore itself. An addition of two per cent of salt was made at the termination of one of the roastings with a view to cutting down the acid necessary and, if possible, of improving the extraction. On assaying the roasted ore, it was found to have lost 49% of the gold, by volatilization. Cyanidation of the roasted ore was less successful than chlorination; the best result obtained was an extraction of 27% of the gold by agitating for 60 hours with 0.2% potassium cyanide and 0.5% cyanogen bromide.

It was now decided to reduce the antimony tetroxide to trioxide, and remove as much of the antimony as possible out of the furnace. The concentrate was mixed with 20% its weight of powdered anthracite and roasted, when most of the sulphur was burnt off. The temperature was raised sufficiently to ignite the anthracite. The quantity of air entering the furnace was now reduced and the charge, which had to be rabbled energetically in the early stages of the roast, was now only turned over every few minutes, when fumes of the trioxide had almost ceased to come away; more anthracite was added and mixed with the charge by energetic rabbling. Anthracite was added from time to time in this way, until its further addition failed to produce fumes of trioxide of antimony; which was the signal that the roast was completed.

In the small-scale experiments made (200 to 500 grams) it was found that this concentrate required about 40% its weight of anthracite in order to remove nearly the whole of the antimony; powdered coke answered equally as well as anthracite. Experiments showed that the residue could be relied upon to contain 97% of the gold, and in several of them it contained over 99%. By carefully regulating the draft, the antimony contents of the residue have been reduced to as low as 0.6%, but it more often ran from 1 to 1.5 per cent.

The theory of the process is, of course, evident. The tetroxide is reduced first to trioxide and then probably to metal, while the incoming air oxidizes the metal first to trioxide and then to tetroxide; in this way, the antimony is oxidized and then reduced, and at each oxidation and reduction it passes through the stage of trioxide when it is volatile and has a chance to escape out of the furnace. The antimony trioxide is collected in condensing chambers and is in a condition well suited for direct reduction to metal by fusion with carbon. The condensing chambers will also contain the arsenic and zinc as oxide and a little of the lead also as oxide, but as the two former exist in such a small proportion in the original concentrate, they will probably not seriously affect the antimony produced. With regard to the residue, it contains from 5 to 6% lead, together with 1 to 1½% antimony and is clearly suitable for smelting, as it contains in itself nearly sufficient base metal in which to concentrate the gold. A sample of the residue was submitted to the American Smelting & Refining Company for a quotation, and they offered to pay for the whole of the gold at $20 per oz., 4.5c per lb. for the lead, less 1.5c importation duty and to charge $6 per ton for treatment.

Here then appears, as far as it is possible to tell by laboratory experiments, a process by which the gold and antimony may be successfully and commercially separated from each other. If the ore were closely concentrated, so that the concentrate contained only from 10 to 15% gangue, the amount of material to be smelted—compared with the original ore—would be quite small. Experiments were tried with both chlorination and cyanide upon the residue, but in neither case was an extraction obtained which would commercially compete with smelting.

Mr. J. S. McArthur—of cyanide fame—has given this ore some attention; unfortunately, his experiments were conducted upon a sample which contained little or no native metal. He has devised an exceedingly pretty process which, however, is not suited to ore containing much native metal. He removes the antimony by leaching it with a two per cent solution of caustic soda; this solution is treated with carbonic acid, which re-precipitates the antimony as sulphide, and the solution—after the removal of the sulphide—is regenerated by the addition of caustic lime. The reaction may be expressed by the following equations:

$$Sb_2 S_3 + 6NaOH = Na_3 SbS_3 + Na_3 SbO_3 + 3H_2O$$

$$Na_3 SbO_3 + Na_3 SbS_3 + 3CO_2 = Sb_2 S_3 + 3Na_2 CO_3$$

$$Na_2 CO_3 + Ca (OH)_2 = 2NaOH + CaCO_3$$

The residue, after the removal of the antimony, Mr. McArthur first roasts and then cyanides.

In conclusion, it may be of interest to give the method used for determining the antimony. The quantity of material taken for the assay is such that it contains in the neighborhood of 0.2 grams antimony; to this is added 15 c.c. hydrochloric acid and a like amount of water, and it is digested at a temperature of 80° C. until sulphureted hydrogen ceases to be evolved.

Nitric acid is now added, a drop at a time (the beaker containing the assay being replaced for a few minutes on the hot plate after each addition), until the native metal is dissolved. The solution is then filtered from the residue and the latter is washed with a 10% solution of hydrochloric acid. The antimony is precipitated from the filtrate by adding three grams of spongy tin and the solution is kept at about 80° C.;

the precipitation of the metal takes from one to one and one-half hours. The antimony is allowed to settle and the liquid decanted through a filter, and the metal washed by decantation, with a 10% solution of hydrochloric acid; the washings, of course, going through the filter.

The metal is washed into a flask, 15 c.c. of strong hydrochloric acid and a few crystals of potassium chlorate are added, and the solution is made up to about 50 c.c. The flask is placed on the hot plate and when the antimony is dissolved, it is boiled briskly until free from chlorine; it is then cooled, three grams potassium iodide added, the solution made up to 200 c.c. with water and the liberated iodine titrated with standard thiosulphate from which the antimony is calculated.

In order to get the antimony in the roasted ore into solution it is first gently fused with potassium cyanide which converts the tetroxide and any insoluble antimonates into the metal. The mass is leached with water and the residue treated as a soluble ore.

The extraction of gold from its ore by free milling process consists of two operations: the pulverization of the ore to free the gold from its matrix, and amalgamation of the particles of gold with quicksilver. These two processes, simple in themselves, have many modifications in the practice of various districts, the variations being necessitated by the difference in the character of the ores. Concentration is wholly independent of amalgamation. Some gold ores require no concentration; others can be worked in no other way than smelting.

MUNTZ METAL PLATES.

By A. R. Parsons.

The Bamberger-DeLamar Gold Mines Company is grinding ore in a 0.15% cyanide solution, the pulp being allowed to flow direct from the Chilean mills to amalgamating plates. Formerly copper plates 1-8 in. thick with one ounce of silver per square foot were used. These rapidly became rough and pitted, and at the end of two months were found to be ragged at the lower end and practically destroyed, unfitting them for amalgamating purposes and necessitating their removal.

As a trial two muntz metal plates 1-8 inch thick, with one ounce of silver per square foot were installed and they proved such a success that the copper plates were replaced by muntz metal throughout. The life of the latter is more than four times that of the former. The muntz metal amalgamates readily, the amalgam being easily detached, facilitating a rapid clean up. The amalgam is not absorbed by muntz metal to such an extent as by copper. This was recently proved on bars formed by melting two old copper and two muntz metal plates, the latter having been in use much longer than the former. New plates from the alloy do not require the careful attention and manipulation that is necessary with new copper plates. The discoloration and appearance of "verdigris" experienced with copper is no longer noticed.

Care must be observed in using mercury for dressing, as the muntz metal will not hold the mercury like copper, and if a slight excess is used it will collect in globules, and for this reason it is advisable to brush the plates more frequently than is customary with copper. We unhesitatingly recommend their use where amalgamation is carried on in a cyanide solution.

A NEW METHOD OF SMELTING BUTTE ORES.

By William A. Heywood.

Since August, 1905, the smelter of the Pittsburgh and Montana Copper Co., situated on the flat about two miles east of Butte, Montana, has been running continuously and producing about 100 tons of copper per month by the Baggaley process. While the entire plant invented by Mr. Ralph Baggaley has not yet been installed, enough has been done, that is different from the usual methods of treatment, to demonstrate the success of his ideas in eliminating water concentration and roasting, substituting the use of a basic-lined converter producing copper from matte of low copper tenor and employing silicious ore for flux in the converter.

The smelter is situated close to the No. 2 shaft, from which all the copper ore now being mined by the company is raised. The ore has the following average composition:

Copper, 2 to 4 per cent; silica, 52 per cent; iron, 14 per cent; sulphur, 17 per cent; alumina, 7 per cent; magnesia, 1 per cent, and zinc, 2 per cent.

The company also owns the Spring Hill mine near Helena, from which it gets about 50 tons per day of pyrrhotite ore, having the following composition:

	First Class	Second Class
Silica,	9 per cent	30 per cent
Iron,	48 "	31 "
Sulphur,	32 "	13 "
Lime,	5 "	23 "
Copper	None	None
Gold,	$7 per ton	$2 per ton

Some experiments in smelting this ore pyritically, using Butte ore for flux, have been made, but as the quantity of silicious copper ore is far in excess of the pyrrhotite, a partial pyritic charge has been found more satisfactory. The fuel value of the sulphur in the pyrrhotite is used as well as the iron for flux. The extra base required for flux is added in the form of limestone.

The blast furnace used was designed to experiment with the Garretson process. These experiments proved a failure and the furnace has been used as an ordinary blast furnace. It is built of cast-copper water-jackets, 38 by 158 in. at the tuyeres. It has 14 three-inch tuyeres on each side. The distance from the tuyeres to the charge floor is nine feet.

The materials smelted since September 1, 1905, are as follows:

	In blast	Lime-rock	Butte ores	Pyrrhotite	Matte	Converter and blast furnace slags	Total	Coke
	Days	Tons	Tons	Tons	Tons	Tons	Tons	Tons
Sept.	22	775	2097	1495	180	170	4717	528
Oct.	31	933	3053	1307	825	624	7078	637
Nov.	25	814	2786	1235	584	302	5723	474
Dec.	31	1143	3551	1631	112	262	6699	606
Jan.	31	1316	3589	1389	200	166	6660	664
Feb.	28	1263	3308	1062	267	225	6125	612

The average of the slag and matte is as follows:

	Cu in. matte	Cu	SLAG ANALYSIS SiO_2	FeO	CaO
	Per cent	Per cent	Per cent	Per cent	Per cent
Sept.	8.6	0.11	46.1	21.1	20.4
Nov.	20.6	0.24	42.2	29.7	17.2
Dec.	24.2	0.24	43.6	25.5	18.7
Jan.	28.2	0.21	43.8	21.9	21.4
Feb.	23.8	0.19	44.0	22.0	20.0

These slags also contain 7.5% Al_2O_3; 2.5% MgO; 2.5% ZnO and 0.5% sulphur.

No effort was made to obtain a high rate of concentration in the blast furnace. Employing iron sulphide (pyrrhotite) as a flux, reduced the grade of the resulting matte, but lowered materially the amount of coke necessary to smelt the mixtures and the copper lost in slag. It will be noted that these slags are the cleanest ever produced from Butte ores. As our matte was treated in a basic-lined converter using silicious ore as a flux, this low-grade matte produced in the blast furnace was not a source of expense in converting, as it would be if an ordinary silica-lined converter were used. It might be argued that this occasioned greater loss in converter-slags on account of the greater volume of slag made in the converter from these low-grade mattes. These converter-slags, from November onward, were poured in molten state into the blast furnace, consequently the assay of the blast-furnace slag includes the copper loss of the converters. It will be noted that 624 tons of converter-slag were smelted during October. During this month the slag from the converters was cooled, broken up and added to the blast-furnace charge.

During November, December and January the tonnage of converter-slag is much less, as no account is taken of the molten converter-slag poured through the blast furnace. The slag weighed during those months represents the 'hulls' left in the ladles and the necessary cleaning up about the converters and blast furnace. The amount of slag made per ton of ore smelted varied with the different charges from 1900 to 2300 lb., and the slag-loss is from 5.4 to 6 lb. copper per ton of ore smelted.

Our extraction of copper in the blast furnace has been about 90%. Taking the Butte ore at 4% copper, this would produce 320 lb. of 25% matte per ton of ore. The iron in this matte when fluxed with Butte ore would form about 300 lb. converter-slag. As this slag was discharged at 0.24%, the loss of copper in converter-slag equals 0.72 lb. copper per ton of ore smelted in the blast furnace, or a total smelting loss in both blast furnace and converter of less than 7 lb. copper per ton of ore smelted. I have not taken into account flue-dust losses, as with proper chambers and flues the losses in this way are small and are no greater by our method than by the older plan of treatment. At this point it may be interesting to compare our loss of 7 lb. copper per ton of ore smelted with some of the results of other smelters. At Granby, with self-fluxing ore and a charge of nothing but ore and coke in the blast furnace, I am informed that the blast-furnace slag loss is 7 lb. copper per ton of ore smelted. At the plant of the Tennessee Copper Company, with a low-grade pyrrhotite copper ore using barren quartz for flux and a double pyritic smelting, the loss of copper is about 9.4 lb. per ton of ore smelted. What the copper loss in the treatment of Butte ores by other companies may be, is difficult to say. Neither the Amalgamated nor the Montana Ore Purchasing Company (United Copper Co.) publishes any data regarding their extraction. We do know, however, that a 4% copper ore such as we have been smelting would be consigned to the concentrator and the best saving claimed for water concentration in the Butte district is 80% of the copper. On this basis 16 lb. of copper would be thrown away in tailing. In other words, they lose more than twice as much copper before they start smelting as we do during our entire process.

1. We smelt directly our low-grade ores. Others classify their ores and send the high grade to the blast furnace and the low grade to the concentrator. The standard of what constitutes first class ore is gradually being lowered and is now about 5% copper or over. This lowering of the standard indicates the trend of metallurgists to avoid the wasteful practice of water concentration.

2. We employ pyrrhotite or iron sulphide ores for flux. If this has an assay-value it is a much cheaper flux than barren limestone, because it materially reduces the quantity of coke required to smelt the charge.

3. We make a low-grade matte in the blast furnace and thereby make the cleanest slag and the lowest copper loss ever obtained from Butte ores. The employment of a basic-lined converter and the smelting of silicious ore in the converter as flux for the iron in these low-grade mattes enable us profitably to convert low-grade matte where the cost of continually relining a silica-lined converter would be prohibitive. Since the other Montana companies started lining their converter shells with ore and adding silicious ore to the converter-charge there has been a gradual reduction in the grade of matte that it is profitable to convert, and there has followed a diminution in their blast-furnace slag-losses.

4. All our converter-slag, except the small proportion that chills in the ladles, is poured molten into the blast furnace. This cleans the slag by allowing the particles of matte to settle; there is a beneficial effect on the blast furnace by scouring it out, and saving the cost of handling and resmelting.

Prior to October 7, the converter plant was not used except in experiments. The old vertical blowing-engine having broken down, a new horizontal cross-compound Reynolds engine was purchased and installed. The blast-furnace matte made up to October 7, was either sold to the Montana Ore Purchasing Company or stored.

The converter employed in the Baggaley process is composed of steel rings 11 in. thick and 18 in. wide. It is lined with one course, 9 in., of magnesite brick. The cap is not lined. The total length of the converter is 13 ft. The length inside the brick lining is 9 ft. 6 in. The outside diameter of the converter is 8 ft.; the diameter inside the lining is 4 ft. 9 inches.

The method of operating is as follows: About 1000 lb. ore is placed in the converter and a tap of four or five tons of low-grade matte poured in. The charge is then blown with the addition of ore in 1000-lb. lots until the matte is 'high', that is, the iron has been eliminated.

The slag is then poured off and a fresh tap of matte added with more ore. When it is desired to finish a charge, the white metal in the converter is blown to copper in the usual manner, without the addition of ore.

The converter works freely and quickly, and its large size permits large quantities of matte to be handled. With matte containing 10% copper I have added 60 tons before finishing it and kept the charge blowing for 48 hours before pouring copper. With matte containing 30% copper we have finished a charge in three hours. The size of the copper charges as poured depends, of course, on the grade of the matte and the number of taps added; we have finished charges of less than a ton of copper and also charges of seven tons of copper. As the lining remains the same size, there is much greater freedom and elasticity in the sizes of charges than with a silica-lined converter.

From October 7, 1905, to January 31, 1906, we have made over 500 tons of copper. The same magnesia lining that was in the converter at the start is still in use. The only repairs have been the renewal of some of the bricks about the tuyeres, on four occasions, when they had become dislodged or broken by the punching of blocked tuyeres. Our blast furnace being small and our ores low grade, we have been unable to keep the converter supplied with matte. If we had all the matte the converter could handle it would turn out over 500 tons of copper per month. As our matte is much lower grade than that which anyone else attempts to convert, to the best of my knowledge, this is better work than was ever done by a silica-lined converter.

With this kind of converter not more than five tons of copper, from low-grade matte, could be made before the converter would require re-lining, that is, the converter would be lined 100 times for our 500 tons of copper. The labor and power used in re-lining is at least $10 per shell, so the saving in labor of re-lining alone is $1000 up to January 31. We have smelted 1118 tons of silicious ore in the converter at practically no cost. The labor required on each shift is one skimmer, one puncher and one helper. The converter has given less trouble than any converter I ever ran, although I had never before attempted this method of converting and the entire force of men was inexperienced in converting in a basic-lined converter.

The following table shows the amount of Butte silicious ore (50% SiO_2; 14% Fe) required to form a converter-slag of 30% SiO_2, 60% FeO with 5 tons of copper mattes of various grades:

Copper in Matte.	Ore Required.
5 per cent.	9350 lb.
10 "	8700 "
15 "	8050 "
20 "	7450 "
25 "	6800 "
30 "	6200 "

The desirability of using a basic-lined converter and introducing the necessary silica by some other means than the destruction of the lining has been recognized since the introduction of the Bessemer process in treating copper mattes. Until it was successfully accomplished at the Pittsmont smelter, it had never been done.

Mr. Herman Keller, while superintendent of the Parrot smelter, at Butte, about 1890, attempted converting in a shell lined with magnesite. A record of his attempts and failures, written by him, is given on pages 570, 571 and 572 of 'Modern Copper Smelting,' by Peters. The three reasons given by Mr. Keller why the basic-lined converter was a failure and the process abandoned at the Parrot, have never been in evidence at the Pittsmont, in the special converter patented by Mr. Baggaley. Taking the three reasons separately I would reply as follows:

1. The outside of the converter has never been "dangerously hot." Considering the grade of the mattes treated, the converter works much quicker than any silica-lined converter I have ever used.

2. We have never experienced any difficulty in adding silicious ore to the converter in such a manner that it would combine with the ferrous oxide.

3. As the same lining has lasted five months and is still in service, there cannot be any 'shelling' of the magnesite brick worth mention. Moreover, if the magnesite lining were now completely destroyed, it has paid for itself in the saving of labor alone required in re-lining a silica-lined converter.

The following are the points of difference between our blast-furnace practice and that of other companies treating Butte ore.

At least 10,000 tons of copper ore are now mined daily in Butte. Probably one-fourth, or 2500 tons, is considered first-class and smelted directly in the blast furnace. The remainder, 7500 tons, is consigned to the mills for water concentration. This ore averages over 30% copper, consequently the loss of 20% in tailing entails a daily loss of over $15,000 before smelting commences. This loss represents at least $2 per ton of second-class ore treated or nearly double the smelting cost at Tennessee or Granby. In order to obtain water, to wash 20% of the values away, most of the ore has to be hauled by railway to Anaconda and Great Falls. The concentrate containing the 80% of the value saved is too fine for pyritic smelting in the blast furnace and contains too much sulphur for reverberatory smelting, consequently it is roasted. This roasting is a waste of the fuel (sulphur) contained in the ore, in addition to the expense of the operation. The roasted concentrate is too fine for the blast furnace, so it is treated in reverberatory furnaces. Reverberatory smelting is not only more costly than blast-furnace smelting, but the losses in slag are much greater.

I am informed that in the blast furnaces of the Washoe smelter at Anaconda, they have tried a mixture of all their Butte ores in the proportion they were received for a year with very satisfactory results. They obtained a 50% matte, lime being used as a flux. If iron sulphides were employed to replace part of the lime, the loss in slag would have been lowered, as the blast-furnace matte would have been of lower grade, and the coke consumption materially lessened.

In the Mineral Industry for 1901, page 698, Dr. Franklin Carpenter states: "I have smelted many thousand tons of Butte copper ores at the Deadwood plant and have no hesitancy in stating that the whole of the concentrating and roasting machinery employed around the Montana smelting works is unnecessary, provided the process of pyritic smelting is employed that was first developed at Deadwood, S. D." Considering the strides in pyritic smelting since 1901 and in view of our experiments, how much more wasteful and unnecessary does the present method of water concentration and roasting appear!

To treat the Butte output pyritically a large amount of iron sulphide ore would necessarily be employed. When the large amount of first-class ore is considered, much less iron and lime would be needed than we have employed in treating only the lowest grade and most silicious of Butte ores. Whether it would be more profitable to bring iron ores to the copper ore or haul the copper ore over the mountains to obtain water to wash away 20% of their value, can easily be demonstrated. Without a large quantity of iron sulphide ores and using only limestone for flux, with what iron ores of any kind that can be obtained, the treatment of Butte ores in blast furnaces and converters has been demonstrated to be more economical than the methods now employed by all companies in Montana except the Pittsburgh & Montana Copper Company.

EDITORIAL.

May 5, 1906.

The recent occurrence shook a lot of the smallness out of humanity and made it big in generosity and in courage. It is curious how the old spirit of the pioneer days has descended on men who never expected to face the simple realities of life, as their fathers knew them in 1849. The spirit of the Argonauts has been transmitted and the people of San Francisco—nay, the people of California—are as full of life and hope in the rebuilding of their great City as were those who reclaimed the sand dunes, filled the marshes and leveled the hillslopes on which San Francisco was erected forty years ago. We used to date the beginning of the State from the rush of 1849, henceforth we shall speak of the new awakening that followed the event of 1906.

It recalled old times in Colorado to see a train of supplies from that State arriving at Berkeley, in aid of those who suffered by the San Francisco conflagration. But when we saw two cars labeled from Denver and another from Breckenridge, it seemed like a message from personal friends. Good little Breckenridge, famous the world over for the wonderful specimens of native gold, has proved the possession of a warm heart and a helping hand—something that gold does not buy and more exquisite than the most gorgeous of the crystalline aggregates that come from the mines of Farncomb hill. Indeed, one of the great compensations of a disaster that appeals to the imagination and sensibilities of mankind, is the stimulation of sympathy and the emphasis placed upon the essential kinship of the race. We do not doubt as to who is the most enriched, the sufferer who receives aid in time of trouble or the man whose whole nature is uplifted by a noble impulse.

The conflagration was so complete that many former buildings are indicated by a mere remnant of rubble. Whole blocks 300 by 500 feet were swept by the flames in three-quarters of an hour. The conflagration was of such a magnitude that the intensity of heat was terrific. Girders two feet wide can be seen tortured into strange curves. A few houses survive on the top of Russian hill and Telegraph hill; the Fairmont stands like a great acropolis overlooking the ruins of an ancient city. The few surviving sky scrapers look gaunt and ragged. Distance is killed by absence of landmarks and the erasure of high walls; the City appears to have shriveled, it seems no distance between points formerly too far to walk.

Russian Hill.
A Small Portion That Survived the Conflagration.

Squares we thought commodious air spaces have dwindled to insignificant enclosures. At a distance the streets meet the sky-line with a slight indent, the roadways make gray bands among rectangles of dark wreckage; a few chimneys stand tottering drearily above the ashes of vanished homes.

AFTER THE DISASTER.

San Francisco is known to mining men the world over as a delightful rendezvous; from the Nevada deserts, from the Arizona border, from the Mexican ports, from the hills of California, from Australia and the Orient, the seekers after mineral wealth come to the City by the Golden Gate, and there enjoy the rest, the pleasure and the associations that compensate for the weariness of travel and the stress of professional labor. To them it will be a matter of interest to learn how the City looks after having passed through earthquake and fire.

As you cross the Bay from Oakland or Berkeley, the City looks scarcely different; such prominent landmarks as the Ferry tower, the Call building, the Fairmont hotel and other familiar structures are visible, but as you look closer you note the absence of tone; it is all dull. The glory of life has gone, it is a ruin that you see. As the ferry passes Goat island and begins to approach the landing, the destruction becomes apparent. The Ferry building is there with bowed lines that tell of structural injury and the tower appears out of plumb. The flagstaff is bent and the clock still points to the moment when it was shaken to a full stop. It says 5:16, but then the ferry clock never was a reliable time-piece and the quake might well have discovered it one or two minutes fast. The scaffolding around the tower indicates the work of repair; it is doubtful whether it will not be necessary to rebuild at a later date. On emerging from the Ferry building, one was accustomed to the full-toned voice of a big town, intensified by traffic over the cobbles of Market street and the confused shouts of hotel runners, the strident cries of newsboys and the clanging of car bells. All these are silent; the noises are those of a village; the wagons, express carts, and men on horseback partially screen a ghastly background. Heaps of brick and tottering portions of walls stretch far and wide in pathetic desolation; and far above them, like the surviving giants of a mighty forest that has been stricken by fire, there looms the stately skeleton of the Call building and other 'sky-scrapers'— a popular term that has the sound of a sad irony. Most of the streets are blocked with a disorderly heap of brick and iron, although one or two main arteries have already been partially cleared so that it is easy to pass through the ruins.

The effects of the earthquake have been partially obliterated by the conflagration, for the disturbed surface is covered with rubbish and the buildings that collapsed were among the first to burn, with a fierceness of combustion that is readily appreciated when the cause is understood. The shock of the earth tremble broke the gas mains and their inflammable content was immediately ignited by the sparks from severed electric wires. Thus does the complexity of civilization add new terrors and until the aids to material comfort are safeguarded by the inventive genius that created them, man would better live as his ancestors did. Those who live in tents and know no illuminant save the camp fire, would have remembered an earthquake such as that of April 18 only as a dizzy moment when trees rocked and the tent-poles shook. But we live no longer as nomads; we raise structures that go far above the trembling soil. On Valencia street, between 18th and 19th streets, there was a hotel, a large wooden structure. The ground on which it stood sank the height of one story and the building collapsed, killing several people. The site of it is not recognizable, for the fire stripped it clean; but the adjoining tract affords interesting evidence. Valencia street has sunk 8 to 10 feet and looking east over the charred remains of two intervening blocks, one sees another frame building that has lurched like a drunken man. This particular part of the City—on the south side—stands on an old creek-bed that has been filled. Down 18th street also, from Valencia to Howard, the ground has sunk on the north side along the center of the cobble-paved roadway and there is a crack 12 to 15 inches wide along the line of rupture. Neighboring houses show the effects of disturbance. Evidence of a similar kind is obtainable elsewhere in this vicinity and it is noteworthy that the belt of deranged buildings and dislocated roadways follows exactly the line of the filling over the old creek. In another locality, at the southwest corner of the new Post Office, the street and sidewalk have sunk five feet from the building, which stands solid and safe on its own properly constructed foundations. At the corner of Steuart and Market streets, the roadway has dropped bodily fully five feet while the sidewalk stands at its former level; for the sidewalk and adjoining buildings were built on piles, and the roadway was not. On Van Ness avenue, between Green and Vallejo streets, the asphalt is buckled and cracked right across—east and west while the flagstones on Green street have slid northward 15 inches over the edge of the curb. Finally, in front of the Ferry building, the ground has sunk three feet and the asphalt is cracked along a line running nearly north and south. These few facts were collected in the course of a four hours' walk and they point to one conclusion, which is confirmed by other evidence not necessary to detail. The site of San Francisco included a large area of made land, reaching from about Montgomery street to the Bay; the city limits also included several swamps and creek-beds, all of which in process of time became filled with the material excavated from the higher ground. These weak spots were largely forgotten by the residents and disregarded by builders, but they are now rendered prominent and their memory is revived, because at such places the lack of special care in construction has caused buildings to collapse. There was no regional subsidence in San Francisco, as far as can be ascertained.

The fire has obliterated much valuable evidence in regard to structural defects in buildings, but enough survives to tell a perfectly plain story. No scientifically designed and honestly built structure was injured by the earthquake; many well designed and dishonestly built structures suffered and many more that were both faulty in design and wretchedly built did collapse. The earthquake is a master inspector; no political pull, no sham masonry, no certificate of an incompetent board of works will prevent the ruthless exposure of bad work when Nature sets about to make a crucial test. And there was lots of dishonest and foolish construction in San Francisco, as there is in every rapidly built city anywhere on

The Ruins of the City Hall.

this continent or even on some of the others. Of all the architectural frauds in San Francisco, the City Hall stood, as it fell, in a class by itself. During the long term of years occupied in the building of it, the City Hall has enriched a succession of contractors and it was notorious for bad work. It is a sorry sight; the big dome has been stripped of its stone, leaving a bird-cage of steel trusses, the roof has fallen and the walls have crumbled; it looks like the disheveled remains of a doll's house, shaken to pieces. The building that housed the City's administration and should have been an example of architectural skill and artistic taste, has collapsed miserably, because every stone of it was laid in putrid politics; it is a disgraceful ruin, the great dome is stripped of its veneer of stone as thoroughly as the iniquity of the builders stands plain to every beholder. Let the City Hall stay as it is for twenty years, a monument to greed and a warning to dishonest builders—"Lest we forget"; for in the rush and activity of a resourceful community, we are only too likely to discard the lessons of the past, and when the first hurt of the recent blow has healed we shall be in such a hurry as to become again complacent to poor construction and the condoning of dishonest contractors.

On the other hand, the structures erected by the Federal Government have proved their stability and the fact that they were in some cases provided with an artesian water supply also indicates a rare good sense. To these factors the community owes the inestimable good fortune of still possessing a post-office and a mint that can play their necessary part in clearing the confusion of business caused by the recent catastrophe. But there are many other buildings that exemplify the results of good work well done. Most of the tall office buildings, constructed of steel and erected on proper foundations of steel and concrete, have stood the test and will become the nucleus of a new hive of industrial life. Among these, the big Call building stands pre-eminent. To most men it had often suggested the question of safety during an earthquake and of all the proud sky-scrapers it seemed the one that most wantonly braved such a peril. It is sixteen stories high and

The Call or Claus Spreckels Building.

is surmounted by a big dome that contains three floors more. With a base 75 feet square, it is 300 feet high. Observers have spoken of telegraph poles that swayed wildly and that bent like a reed in the wind; what must have been the swing at the top of that great tower of steel and stone? Nevertheless, there it stands, unscathed, without a visible crack, devastated by the flame but triumphant over the temblor. Let us feel ashamed of the sordid dishonesty of the men who built the City Hall, but we can well afford to be proud of the scientific knowledge and the honest handiwork that dared—and yet not unwisely—to erect that splendid structure, which looks down today over a world of ruin and inspires the people of San Francisco to the proper recognition of the value of good building construction. Look at this picture and on that! Look down on the ruins of the City Hall and look up to the Call building, standing like a monolith. Now let the new City be built with similar skill and with a like honesty of construction, so that San Francisco shall be the best example of modern methods, a glorious monument to the science of the engineer and the genius of the artist, the home of the Argonauts and the pride of the Pacific Coast.

THE MISUSE OF EXPLOSIVES.

One feature of the conflagration will interest miners and if they had observed it, we believe that they would agree with us in thorough-going condemnation. We refer to the misuse of explosives in blasting buildings. If it had been planned systematically and carried out properly much of the City could have been saved, but it was far otherwise. The use of high-grade explosives by people ignorant of their strength and proper application, was instrumental in destroying a vast amount of property without the result desired, and in many cases it actually spread the conflagration. The work was done by Dick, Tom and Harry, until the very end of the operations when the naval officers from Mare Island took a hand and directed affairs in a scientific manner. Before that the police, the militia and volunteer firemen used a box of dynamite where a pound would have sufficed, they blasted on the wrong side of walls and did such foolish things as placing a keg of black powder in the center of wooden buildings, with the result that they set them afire instead of bringing them to the ground. Spectators could see that the explosion threw up a lot of dust, to be followed forthwith by flame. They dynamited buildings already on fire and simply made an avenue for the spread of the conflagration instead of creating an obstacle to its advance. Under such conditions, the explosion scattered brands right and left. On Van Ness avenue there was a deplorable amount of damage needlessly done to handsome frame buildings by the use of black powder, that utterly failed of its purpose. It was the veering of the wind and the persistent application of blankets and sacking soaked in the waters found in kitchen boilers by heroic volunteer firemen that eventually saved the Western Addition. However excusable the poor judgment shown during a time of great strain and excitement, there was nothing to palliate the stupidity exhibited in the attempts to blast dangerous walls when the conflagration was at an end. While such operations were being carried out on Market street, there was danger to anyone within three or four blocks; 150 pounds of dynamite were used where as much could have been accomplished by five or six pounds properly applied. Boxes containing 50 pounds apiece were placed against a wall with a light cover of sand and exploded with needless waste and danger. A drill-hole or two properly pointed would have thrown the wall in any direction desired. There was plenty of time to do it properly. A glaring example of such blunders occurred at the Post Office several days after the conflagration; this building was hardly injured by either fire or earthquake, but when the amateur blasters came on the scene, they nearly wrecked it in their childish efforts to pull down the walls of the neighboring Odd Fellows building. It is officially stated that the foundations of the Post-Office were hurt by the blasting and the south side was so wrecked that the damage is estimated at $100,000. It might be supposed that with so many experienced mining men in the community, it would have been possible to get their help in work which they understood and we can state that several of our friends did volunteer to give suggestions and to proffer systematic aid, but in vain. It is difficult to persuade a man that he does not understand what he is doing. San Francisco has reason bitterly to rue the misuse of the explosives that properly employed have proved so powerful an aid to the advancement of mining.

EARTHQUAKE LINES.

By W. H. Storms.

California geologists have long since agreed that the frequent earthquake shocks felt in this State have their origin along well-defined lines, some of which are known. Of these several lines of weakness and disturbance, the most important and interesting is that which passes in the vicinity of San Francisco.

Mountain ranges, broadly speaking, are built, either by the outpouring of volcanoes, the carving out by erosion of elevated plateaus, or by the slow, long-continued uplift of elongated rock masses due to the interior shrinkage of the earth, which causes wrinkles, as it were, to form on the surface. The first may be violent and spasmodic, like the recent eruption of Vesuvius, or the demonstration may be quiet, unaccompanied by explosion or destructive earthquake shock. Some of the volcanoes of the Hawaiian Islands are of this type, the lava quietly rising in the crater until it runs over, a molten stream, which flows down the mountain side. The erosion of an elevated tableland representing the second type, may proceed for thousands of years in a comparatively quiet way, gradually carving canyons and gulches in the rock-mass, tending constantly to reduce the elevation to the base level of erosion—the sea level. The third may also be of long duration, progressing so slowly that little or no change is noticeable during a century, but in time producing a marked topographical effect. This movement of the earth's crust is accompanied by occasional re-adjustments of the rock strata, producing what are really only minor tremors of the surface, but which are often fraught with the most serious consequences to mankind, particularly those who chance to dwell in the vicinity of the line of disturbance—the earthquake line.

This uplift of a region usually causes strains which pass beyond the limit of elasticity of the rocks, and a rupture results. If the strains continue a fault or displacement takes place, one side of the fracture sinking relatively to the other, and in time—a very long time—the rising side becomes a mountain range. Ordinarily, so slow is this uplift and readjustment of the moving mass that erosion destroys, or, at least, greatly modifies the abrupt scarp which would otherwise result if the movement were quickly accomplished, until no one but the geologist would notice the displacement or understand its significance. The great Sierra Nevada of California is a magnificent illustration of mountain building by faulting, and the subsequent modification of its topography by erosion. The west side of the Sierra is a long, low slope, extending from the east side of the great interior valley of California from 100 to 500 feet above sea-level to the crest of the range, reaching an altitude of 10,000 to 14,000 feet, though probably originally much higher. Its east slope is almost precipitous, descending rapidly to the floor of the Great Basin in Nevada. That line of weakness is also an earthquake line, and some very heavy earthquake shocks have been felt in that locality within recent time, notably in March, 1872, when a terrific shock did much damage in the Owens River valley. That shock was felt for hundreds of miles, but did not extend as far west as the Coast range.

It is the occasional sudden readjustment of the slowly moving rock-mass that causes the shock, and regions along these lines of weakness and displacement are therefore subject to earthquakes. No one can predict their coming or foretell their intensity. It is only safe to say that they are likely to occur at any moment. The more frequent they are the less danger there appears to be of destructive shocks. Almost invariably there is a series of shocks, of which the first is the most violent.

The causes which in past ages have built up mountains and formed valleys, are still at work in exactly the same manner and will continue, as they have, since the dawn of creation, and the recognition of an earthquake line, merely means that geologists have discovered another mountain range in process of formation.

The San Francisco earthquake line approaches the State from the northwest, coming from beneath the Pacific, reaching the mainland near Point Arenas, in Mendocino county, and follows down the coast; it has probably influenced the shape of the shore in that vicinity. It enters Tomales bay, in Marin county, and following that shallow sheet of water to its head, crosses a low divide to the head of Bolinas bay. The depressions occupied by these two bays are undoubtedly due to the fault-fissures. From the mouth of Bolinas bay the line extends out southeasterly into the Pacific again, reaching the

The Fairmont Hotel and Nob Hill.

coast near Mussel Rock, in San Mateo county, several miles below the Cliff House, and passing inland through Lake San Andreas, Crystal Lake and southeastward through Los Gatos, Loma Prieta, near Santa Cruz, Pajaro, San Juan, lower San Benito valley, Peach Tree valley, Stone Canyon, Chalome valley, Carrisa valley, west of Sunset six or seven miles, through the west fork of San Emedio canyon, crossing into the Mohave desert west of Lancaster, in Los Angeles county, and continuing in a generally southeasterly direction toward the Gulf of California.

Throughout this entire distance of nearly 600 miles this line of movement may be plainly traced by a succession of valleys, lakes and landslips. In several places the fault-throw exceeds 2,000 feet by measurement. It is thought that the fissure has an easterly dip and that the hanging-wall side is sinking relatively to the foot-wall or westerly side; it is a normal fault.

The fissure in Marin county may be plainly seen and followed for twenty miles, where it is as well defined as a road, and in some places resembles a railroad cut. Since April 18, the ground has cracked open, bulged up or settled, and springs are flowing where none existed before. There seems to have been a very pronounced horizontal movement, in this locality, to the extent of at least 12 ft. A causeway, solidly built, across the line of faulting was broken and thrown the distance stated, the west side going to the north. Buildings constructed on the line of the earthquake were wrenched apart by this horizontal movement, one being a large barn, owned by a man named Skinner, the other being Shafter's creamery. In that district, as elsewhere, the greatest damage was done to buildings cheaply constructed on insecure foundations. Most of the wooden structures destroyed, with the important exception of the two above mentioned, were built on stilt-like timbers from one to four feet high, without diagonal braces, and the buildings were simply thrown a distance equal to the height of the underpinning. The villages of Tomales, Olema, Bolinas and Inverness were completely destroyed and a tidal wave is said to have swept Tomales bay, which is a fan-shaped sheet of water having its broadest portion opening into the ocean.

THE EFFECT IN MINES.

None of the mines of the Pacific Coast suffered from a movement of rock. A day after the earthquake we wrote to the superintendents of a dozen representative mines asking whether they had observed any effect underground. The replies agree in a distinct negative. In the foot-hill region of the Sierra Nevada, the shock was felt only slightly even by those on the surface, while in the mines all was as usual, the occurrence passing unnoticed. At the Great Eastern quicksilver mine near Guerneville, three men were killed by a falling mass of rock that was loosened in the shaft and this accident occurred at the moment of the earthquake, but it has no bearing on the matter. The slight tremor precipitated a loose piece of rock that probably was about to fall and would have fallen a little later, in any event. At the time of the San Francisco disaster, an Associated Press telegram from Houghton, Michigan, announced that the earthquake had caused a collapse of ground in the Quincy copper mine, killing two miners. This also has no connection with the San Francisco earthquake, or any other such phenomenon. The copper mines of the Lake Superior region, more especially those having a large area of excavated ground, are subject to a sudden collapse of stopes, producing shocks that are felt keenly at surface. They are termed 'air-blasts,' because they are accompanied by a violent expulsion of the air displaced by the falling rock-walls, producing reverberations similar in a way to those that follow a dynamite explosion. The causes of them were discussed in these columns not long ago and we can only repeat that they have no connection with earthquakes. All the evidence goes to show that as regards earth tremors, the miner is safer underground than the people in the city.

FORMER EARTHQUAKES AND THEIR DISCARDED LESSONS.

From 1865 to 1869 San Francisco and vicinity were repeatedly visited by earthquake shocks, some of them severe. One of the most serious of these disturbances occurred on October 22, 1868. 'The Mining and Scientific Press' of October 24, 1868, contains the following account of an earthquake that visited San Francisco two days previous. Some of the facts stated bear a remarkable similarity to those observed recently.

As to facts, they can be condensed into a few paragraphs: "Time, 8 a. m., October 22, 1868; direction variously apprehended, but pretty positively either from southeast to northwest or the reverse; buildings generally having been thrown toward the southeast; motion of the surface during the severest shocks more horizontal than vertical, but in some of the subsequent tremblings almost perfectly vertical; size and height of the earthquake waves, and direction and degree of the force relative to the earth's center unknown, for want of proper instruments to record the same, and comparison of observations in different localities; duration of the principal shock, about 45 seconds; weather dead calm and foggy in town, at Point Lobos a light breeze and hazy, as it has been more or less for weeks; thermometers and barometers about as usual. In the evening the air became beautifully clear and invigorating. The reported focus of severity and damage was, according to many observers, not far from Haywards, in Alameda county; it is safe to say that it was within a radius of 16 miles from that place. As to the degree of damage done to property, it can be understood only by taking a walk through town and observing the houses, walls, cornices and copings that have been thrown down. Probably not over a dozen buildings were utterly destroyed, but hundreds were left with marked evidences of injury. Lives lost, so far as reported at the coroner's office, six; wounded or hurt, about four dozen. Whether the rumbling sound accompanying the earthquake proceeded from the interior of the earth, or from the motion of the loose bodies on the surface, was not apparent, but was settled both ways, by guess."

In the issue of November 7, 1868, appeared the following advice, by George Gordon, on construction of buildings:

First.—That extreme care be taken with foundations, no matter whether on solid or made ground: let the entire bed-frame on which the building rests be a unit, like a ship's keel, and strong enough to bear twice the weight of the building if set up on posts ten or twelve feet apart, and so tied together that you could lift it bodily with a derrick and swing it about.

Second.—Dispense with the use of brick, stone or cast iron, except as an exterior protection against fire. Give these materials nothing else to do.

Third.—Rely on timber and wrought iron entirely to carry the load and resist motion. Mortise all timbers and rivet all iron. Use boiler-plate with angle-iron riveted to it above and below all openings, as sills and caps. No form of iron procurable in this market is so simple, cheap and strong as these combined.

Fourth.—Dispense with lath and plaster, and face the inside walls, and make the ceilings with tongued and grooved lumber. Put up every board and lay every floor so as to form diagonals—bracing in every direction. In nailing, put every nail squarely through the face of the boards and discard the carpenter's foible of blind nailing.

Fifth.—The lower the ceilings and the more numerous the rooms in a building, the stronger the structure. * * * * It is certain that entire safety may be assured to life and property on solid ground by proper attention to the construction of buildings, though we should have earthquakes as severe as are recorded; and it is as certain that all improperly typed walls, or poor mortar and poor bricks, will be tumbled down to the peril of human life, as that earthquakes will occur as they have in the past. Especially should all walls with fronts veneered with stone be immediately taken down. It is mean and cowardly to patch up these structures and plaster up the broken chimneys, trusting that the shock that will hurl them to the dust will not come in your time, or until you have sold the property.

A book published in May, 1869, entitled 'Rowland's Earthquake Dangers, Causes and Palliations,' contains the following introductory paragraphs:

Truth compels the admission that a portion of California, including the locality around San Francisco, is, at indefinite periods, subjected to the action of earthquakes. It fortunately so happens that the physical geography around this city is of such a character as to largely modify, if not wholly obviate, many of the dangers which are found sometimes to occur when earthquakes take place at or near the seaboard. Allusion is more particularly made to earthquake (tidal) waves and landslips.

The first is found not generally destructive, excepting in the case of harbors immediately open to the ocean, or near the debouchure of bell-mouthed rivers or bays. Landlocked as the harbor of San Francisco is, even if an earthquake ocean wave 60 ft. high was to break on the outlying western shore, it could only penetrate into our harbor by the width of the narrow passage of the Golden Gate, and as it rapidly expands after its entrance to the north, south and east within a short distance from the narrowest part, and would have to travel some miles before its effect could be felt in San Francisco, ere its arrival at that point it would be much modified by the resistance it would have received.

The other danger we are not likely to encounter to any ruinous extent, is that which might probably arise from landslips, notwithstanding the extension of the city front into the bay from time to time, through the interested influence of speculating land-grabbers with former legislatures; as much as possible has been accomplished to bring about such undesirable events as landslips. Owing to the fact that our bay is a comparatively shallow one, we are not likely to witness a newly and solidly constructed wharf, as in the case of the earthquake at Lisbon, destroyed and replaced by deep water in consequence of a landslip. Though partial fissuring among the unstable ground of our water lots may take place, and irregular shrinking and elevation of foundations so situated may occur, sufficiently so as to be calculated seriously to damage massive and elevated brick or stone structures which may be erected on such made and generally unconsolidated ground; but a serious landslip need not be apprehended.

In fact, as is well known to its residents, the damage caused

Southwest Corner of the Post-office.

by earthquakes at San Francisco and around its bay almost wholly took place on alluvial soil, or made ground, as at Lisbon, the South American cities, and many other places; the next greatest amount of damage having occurred where buildings had been erected on foundations most nearly allied in character to those just noticed.

A STORY IN STONE.

By T. A. Rickard.

Look at it for a moment. Nearly oval in outline, warm gray in color, it has a surface of irregular texture suggesting that it is composed of minerals of different hardness which have been worn unevenly. It is a piece of granite. Without the aid of a magnifying glass you can see the clear blue-gray of the grains of quartz, the pink-white of the particles of feldspar and the shifting gleam of the bright spangles of mica. It is a waif from the mountains that overlook Denver, in Colorado; a stray bit of stone that was out of place on the tennis court where I picked it up, several years ago. Investigation proved that it came thither amid the sandy loam employed in preparing the smooth surface necessary to the finish of a good tennis court. The material used for this purpose came from certain excavations in a neighboring street where a successful mine-owner was building himself a mansion. Originally, long before Denver existed, even before the buffalo or the Indian roamed over the prairie, this pebble was swept down from the mountains by the flood-waters of the river Platte, which in receding, left the deposits of sand and clay now forming the foundations of the city. As a child wandering over the beach, picks up a shell and putting it to her ear, listens while the wind plays through the delicate portals of pink and white, and hears a voice like the murmur of the sea that tells of strange things far beneath the wave, so we also may listen while this pebble mutters to us garrulously, and tells of its distant home and future destiny. If time can bestow nobility then indeed this bit of stone may command respect. The life of a generation is to the age of this pebble as a dewdrop to the sea. When the morning stars sang together, it held up the foundations of the round world; and when man was yet an unthinking savage, it crowned the crest of the mighty mountains. Its birth belongs to the beginning of days and its childhood was chilled by the cold of the earliest dawn. To trace its origin we must penetrate through the mists of a dim remoteness guided only by that fairy of science which men call the constructive imagination. We judge of that which has taken place long ago by that which we see occurring today. The surface of the earth is the playground of a number of natural forces which have been at work since the beginning. The intensity of their activity has varied, but the method of their manifestation has been the same, because they are the expression of definite laws. Thus it is that the unseen frost which cleaves the mountain summit, the torrent that sweeps the shattered rock into the river which bears them onward, to lay them in the quiet depths of the ocean, indicate to us today how this pebble was formed in the ages past, when that mountain was an island and that river as yet unborn.

Draw back the veil of ages and look at the Earth as it was in the morning of time. A heavy silence broods over the dim vastness of the ocean; upon the frowning coast no bird sings and no flower grows; the winds wander over the leafless lands and stir the waters of desolate seas. There is no life, there is no sound of man or beast, there is naught save a weird expectancy that fills all Nature as in that hour when the darkness is paling before the whispering of dawn. The earth is very still, like an infant asleep. Into a quiet inlet a streamlet is falling. It is singing to the sleeping earth, telling it of the days to come when the great silence shall be broken by the voice of man, and life shall fill alike the darkling wave and the sunlit field. The waters of the streamlet mingle with the sullen surges, and bring to them the tribute of the river to the sea; not gold or silver is it, but grains of sand and bits of rock borne downward from distant hills. At times, when the wind blows and the rain falls heavily, the waters are deeply laden with dark clouds of silt and hasten to the sea as though eager to be unburdened. The sand, the bits of rock and the burden of mud are each delivered to the ocean, to be deposited in ordered sequence upon its outspread floor. This was the seed time when were laid down the unlike particles which Earth's alchemy should eventually transmute from silt and sand into crystalline granite. The epoch of which I speak is the oldest of which geology takes cognizance, it is vaguely called Archean; so remote is it that no trace of even the elementary forms of organic life have survived, if they existed; so distant that man was not, nor was the footstep of his oncoming heard; so long ago that Time, like the schoolboy who rubs the figures off a slate, has passed his obliterating hand over the faint record written on the rocks and left no sign behind. The record has indeed been rubbed out, but modern inductive science can restore the writing. We observe Nature's handiwork today and thus infer her method in that geologic past. This is the key to all geological research.

To return to our story. The burden of the river was laid down upon the bed of the sea. More material of the same kind covered it. This process of deposition and accumulation went on for a period to measure which the years are useless as units. It took place with the patient slowness that ever seems so admirable to man, whose brief life is but a span, whose existence one unseemly haste. The filling of the ocean by the waste of the land is a matter of every-day observation. The transfer of rock to the sea, by rain, rivulet and river, has been the subject of careful investigation and measurement. By estimating the quantity of sediment carried down to the sea by such rivers as the Mississippi, the Rhine, and the Ganges, it has been determined that the level of the surface of the continental areas is being lowered at the rate of one foot in six thousand years. This estimate takes account of only such material as is transported mechanically by the rivers, and to this must be added an amount, nearly as large, carried in solution. The latter consists mostly of lime which, being secreted by the multitudinous minute organisms of the deep sea, eventually leads to the building up of the huge thickness of limestone rocks so characteristic of lovely mountain-lands, such as Derbyshire and Savoy.

Thus an enormous depth of sediment was gradually laid down, covering those earlier silts and sands, wherein lay the elements of the pebble. The deep canyons of Colorado, made by the mountain torrents, afford natural sections of the earth's exterior and make it evident that the granite of the

Archean period was overlaid by other rock-masses several miles in thickness. At no one place do we see the complete succession of sediments, because wind and water, rain and snow, have been at work wearing them away during the ages that have passed since they emerged from beneath the wave; nor do we find a simple horizontal bedded series of them in any place, because of the twisting and tilting which they have undergone. This folding is due to the cooling of the earth's exterior and can be explained on the rough analogy of an apple, the skin of which shrinks and crumples as it dries. Thus the granite from which the pebble came, was formerly covered by a thickness of rock exceeding the height of our highest mountains. Such a succession of sediments could not be laid down unless we suppose the ocean-floor to have sunk at a slow rate at least equal in amount to the rate of the deposition of the material. Otherwise the filling of the basin occupied by the sea would put a summary end to the process of accumulation.

Such a supposition is borne out by evidence obtainable today. Proof of a depression of certain parts of the earth's exterior is to be found in the submerged forests which occur, for instance, along the east coast of England. It is but a geologic yesterday (the Pliocene period) that the Rhine flowed across (what is now) the bed of the North Sea and emptied itself within British boundaries. Conditions such as have been described, prevailed in the particular case we are considering. The floor of the Archean sea sunk slowly, while a great thickness of sediment was deposited. The lowermost layers became hardened and consolidated by the weight of those above them. The material destined to make the pebble, lay buried in the darkness of the underworld. Heat and pressure transformed the soft silt into crystalline rock. The transformation was brought about with an infinite slowness and amid an obscurity into which science cannot quite penetrate. We do know that at great depths below the surface of the earth, the temperature is very high. This fact has been indicated by observations made in the sinking of shafts and wells. The average of a large number of careful determinations proves that there is an increase of one degree Fahrenheit for every 48 feet of descent. At a depth of less than ten thousand feet we would therefore find a temperature equal to that at which water boils at sea-level. At the same horizon the pressure from the overlying rock-masses would be equal to about 4500 pounds per square inch. It is certain, moreover, that the rock which, in the after ages, gave us this pebble, was at one time buried under a thickness of sediments far exceeding that just mentioned.

Thus long ages followed each other. The depression of the ocean-bed ceased, and deposition came to an end. A movement of elevation began. Somewhere else, doubtless, a sinking of the earth's exterior helped to counterbalance it. Nature knows not idleness. Upbuilding compensates for destruction, distribution corrects excessive accumulation. Islands commenced to dot the wide expanse of the ancient sea. The material of the pebble, however, was yet far beneath the waves and formed an humble part of those islands that in time became the summits of the mountain range which now keeps guard over Denver. The slow elevation of land continued. As the sea receded, the islands grew both in number and in size until at length they were united into a large mass of land. The evidence of the elevation of parts of the earth's surface is similar in kind to that already given in support of the statement that depression takes place elsewhere. The Pacific side of South America is rising at the present day. On the coast of Norway, at an elevation of 600 feet above the sea, there exist terraces which, from the evidence afforded by the marine shells that they contain, have been proved to be raised beaches belonging to a geological age approaching our own times. Observations have shown that the Scandinavian coast is being elevated at a mean rate of 2½ feet per century. The maximum rate, at the North Cape, is nearly twice as much. Similarly, the land of the Arctic region is also undergoing rapid emergence from the sea.

In this way the land gradually made its appearance above the face of the waters. During this long time of waiting the particles of the pebble had been subjected to the silent forces continually at work in Nature's underground laboratory, so that from sand had come crystalline quartz, from shapeless mud had sprung clear flakes of mica, and out of disordered silt there had been formed an orderly arrangement of elements composing crystals of feldspar. The rock had been prepared with an infinite patience for that later day, when, from lying buried in the footstool of the earth and hidden in the gloom of the ocean depths, it should stand on the top of the wrinkled hills and crown the very summit of the mighty mountains.

Then at length, the rock of our pebble emerged from the sea. As soon as the land arose above the ocean there began that wearing down of the rocks which we term erosion. Tearing down and building up go hand in hand in the inorganic, as life and death in the organic world. The wind and rain, the frost of night, and the heat of day, were the agents which slowly removed the upper portions of the successive beds of rock which still covered the material of the pebble. After an interval of comparative repose the movement of elevation re-commenced. The island became a continent, the hill became the crest of the mountain range. The sun and snow, the ice and rain, are the patient tools that sculpture the shapeless mass of rock and chisel out the mountain's form. Our pebble became part of a granite peak. There it remained for untold years, a portion of a solitary pyramid of stone, day after day throwing the same clear shadow across the waste of waters, while the centuries went by as the unregarded sand that is tossed by the wandering winds of the desert.

Time, an ocean of time, flowed by. The vast duration of many a geological period passed away. The waters still washed the eastern side of the mountains and the sovereign desolation of the sea covered the prairies of Colorado and Nebraska. Even today if you ascend the Front range and look to the east, the unbroken line of the horizon and the witchery of distance will change the dull dreariness of the plains into the ocean's alpine azure.

At length, in that comparatively recent period known as the Cretaceous, the elevatory movement culminated and the granite peaks gained their maximum height. The sea so long at their feet receded, and its floor became a level plain. At a much later period, however, at a time when the Rhine flowed through the eastern part of England, the depression of a certain portion of this area resulted in the formation of a great fresh-water lake which overspread the present site of Denver. Think of it as it was then, a wide waste of waters that in storm dashed vainly against the battlemented cliffs that now overlook the towns of Boulder and Golden, and in calm, reflected the severe grandeur of those peaks which were the silent sentinels that guarded the treasures of Colorado when the Spaniard came, and are now the minarets of snow that end the picturesque perspective of Denver's streets.

The material of the pebble still rested on the mountain top. It typified those things which out of weakness are made strong. What was once soft sediment had become crystalline rock; once abased in the deep, it was now exalted above all the earth and "out of the substance of it the axe of God had hewn an Alpine tower." Long ages it stood on high, fronting the dawn and glowing in the sunset; beneath it the mighty hills bowed in serried lines, and far below the prairies faded away in tremulous blue.

But its destiny was yet unfulfilled. There came a day when a mightier power than the storm, a more resistless force than the wind tore away a fragment of that mountain peak and the original of this pebble rattled down the dark ravine and fell upon the snowy surface of a majestic glacier. A drop of the rain of heaven had found a resting place in a cranny of the rock, the cold of night and the heat of day had alternately contracted and expanded this particle of water, so as to make it a resistless lever which had wrenched the stubborn rock and sent the fragments headlong down the cliff. There is a lesson here. The natural forces which command our attention, are not the mightiest. The unseen hand of the frost is tenfold stronger than the raging torrent. Many a volcano in its sudden and catastrophic outpouring of molten rock fails by such fitful activity to eject as much material as the thermal spring whose stream, bubbling daily for centuries, delivers an unvarying quantity of salts dissolved in its beneficent waters. The daily tribute seems insignificant, but the total is more than the outpouring of a Vesuvius.

The glacier received the stone and carried it forward in majestic advance through the long files of onlooking mountains, until, at the opening of a sunlit valley it was delivered to the stream, the waters of which were fed by the melting ice. Borne along, now more rapidly, partly pushed and partly carried, it became worn by attrition so as to lose its sharp edges and to assume its present shape. The chip of rock broken from the mountain crest became the pebble of the stream. Rest it had none, continually traveling onward and downward, sometimes lingering at the bottom of a quiet pool while the trout darted past, sometimes making sweet music as it played among the harpstrings of dark water that fell down the sunless ravine, but journeying ever onward to fulfil its destiny.

The mountain torrent delivered it to the river; the Platte received it, and bore it to the plain.

Then came a day when the heavens were darkened by hurrying stormclouds, when lightning flashed from peak to peak, when floods of warm rain fell upon the snowfields and every rivulet became a river, every river a boiling torrent, when a great rush of water swept down from the mountains and spreading over the plains, covered them with the sand and gravel in which our pebble was found.

But the end is not yet. That pebble, like all created things, has a course to run and a destiny to fulfill. It must return to the condition from which it came, and so complete the cycle of change. We cannot stay its wandering, we may put it on a shelf or throw it into a corner, but it will fulfill its purpose nevertheless. The day will come when we shall be deemed "ancients of the earth," and this geologic age in which we live will recede into the distance to become the "morning of the times" to those that follow. Then this pebble, shivered by the frost of night and shattered by the heat of day, will again be resolved into fragments, to be gathered by the rain and given to the river; and the river will bear them to the ocean where they shall again "sow the dust of continents to be."

This ends the story. There is poetry even among the pages of geology. The history of this globe of ours is a grand epic the cantos of which cover geologic periods of vast duration. The ancients felt this, for they loved to speak of the earth as a sentient being whose changes were typified in their own lives. Much of that simple feeling has come back to us in spite of the artificiality of modern days, and has been voiced by the great poet of our time.

"There rolls the deep where grew the tree,
O Earth, what changes hast thou seen!
There where the long street roars hath been
The stillness of the central sea."

EDITORIAL.

May 19, 1906.

The recent catastrophe in California demonstrates once more the superiority of the miner's product as a medium of exchange. Thousands of dollars of paper money have been lost to the owners; and not only this, but those same thousands have been presented to the banks that issued the money. When a paper bill is destroyed the owner loses and the bank that issued it gains. The destroyed bill can never be presented to the bank for redemption.

The daily press states that the wife of ex-Governor James Budd has foretold another catastrophe and it is claimed that she predicted the recent disturbance. Such statements after the event are not uncommon; so many people foretell things and they foretell so many different things that like the shot from a 'scatter gun' something is sure to be hit. It appears that despite her belief in an impending cataclysm, the lady in question bought a $1500 piano two days before April 18. We are informed that the lady possesses a private observatory, for she uses a strong glass whereby she "keeps tab on the peculiar antics of several stars" that have stayed up late and otherwise misbehaved. As to the "strong glass,"—that is a fruitful stimulent to soothsaying; but we want to know whether it was Scotch or Bourbon.

The days of soothsayers are evidently numbered; the time was when prophesies of disaster, especially such as emanated from elderly ladies, were calculated to create a panic. There was Mother Shipton who scared the ignorant in the year 1881 and now there is this Mrs. Budd in California who has predicted fearful things. All the daily papers quote her, so it must necessarily be true. But the spread of an elementary knowledge of natural phenomena has given men the chance to think intelligently on these matters and no foolish talk will now distress the general run of people as it used to do twenty-five years ago. The good sense and the recovery from disaster so noteworthy in our midst during the past four weeks, are to be credited to the spread of scientific knowledge—enough of it at least to give mental balance even when the earth reels and the skies seem afire.

In a recent issue we referred to the fact that, as far as known, no mine in California has suffered injury underground from the earthquake. It appears that this holds true of the oil-wells although the casings of deep artesian water-wells in the Santa Clara valley suffered fracture. There were a few breaks in the pipe-lines of the Coalinga district, but these were quickly repaired and entailed only slight loss of oil. There were minor breaks also between Coalinga and Monterey, and near Salinas, but there was no damage to the wells themselves. The oil production of the State is about 20,000,000 barrels per annum, worth about $6,000,000 at the wells and costing the consumer a dollar per barrel. As this product of the State has proved an important factor in lessening the cost of fuel necessary for generating power in our manufacturing industries, the preservation of the oil-wells and pipe-lines is gratifying news.

EARTHQUAKE SOUNDS.

There is no question as to the fact that earthquakes are audible before they are felt. We noted this on April 18, not in case of the big shock, when our faculties were otherwise engaged, but in connection with several later movements on the same day. Other trustworthy evidence has been secured since. An intelligent lady who had experienced the earthquake of 1868, being awake, at 5 a. m. on April 18, 1906, heard the sound of the oncoming disturbance; it seemed to her like the sound of a mighty rushing wind and knowing what it presaged, she instantly alarmed the inmates of the house. As they escaped outdoors, the tremor came; it shook the earth so that they found it hard to stand and in the meadows close-by the live oaks swung from side to side so as to touch the ground. In the City, several men who happened to be out-doors early on that morning, found it impossible to keep their feet, while a ripple of movement—a sardonic smile —passed over the face of the earth. Others have testified to the noise preceding the arrival of the shock; it varied in intensity according to the distance from the line of actual fracture. This traversed, among other localities, the canyon of Los Gatos, in the Santa Cruz mountains. A trustworthy witness living there, informs us that there was a rumble and a roar like cannonading and that it was "defeaning." We also have professional testimony. Mr. John B. Farish, a mining engineer known to our readers, offers valuable evidence on this point. He says: "On the eventful Wednesday morning I was awakened by a loud rumbling noise which might be compared to the mixed sounds of a strong wind rushing through a forest and the breaking of waves against a cliff. In less time than it takes to tell, a concussion, similar to that caused by the near-by explosion of a huge blast, shook the building (the St. Francis hotel) to its foundations and then began a series of the liveliest motions imaginable, accompanied by a creaking, grinding, rasping sound, followed by tremendous crashes as the cornices of adjoining buildings and chimneys tottered to the ground." The first of these seismic sounds are referable to the rupture of the rock and the subsequent shifting of the broken parts. Sound travels faster in rock than in air. In air the speed is only 1,100 feet per second. It is stated that the earthquake of April 18 was felt at Tokio 11 minutes later than at San Francisco, but this does not mean much until further data indicate at what point the shock originated. It may have been under the Pacific ocean, and in that case the local movement along the old fault-plane in the Santa Cruz mountains would be accessory to a bigger fact. According to good authority, the small earth-waves that make the sounds, travel faster than the big vibrations that cause the shock, the difference in speed being due to the fact that they pass through an imperfectly coherent medium. From the sifting of plentiful data, it was ascertained that the Charleston quake had a velocity of 5,184 meters per second, or 190 miles per minute. The average velocity of the big shocks was 120 miles, while that of the tremors was 180 miles per minute. On the other hand the velocity of sound in granite is 15,000 to 18,000 feet per second, or 170 to 200 miles per minute. This seems to explain why the rumble and roar of a big earthquake precede the shock.

MISUSE OF DYNAMITE.

In regard to the misuse of dynamite during the conflagration in San Francisco and the blasting operations afterward, we have received several letters endorsing the criticism appearing in these columns two weeks ago. Mr. Frank A. Leach, the superintendent of the Mint, informs us that he offered to supply the services of experienced men, but the individuals doing the blasting claimed that they understood the use of explosives in demolishing buildings better than any miners. Mr. Leach now possesses a piece of iron weighing a quarter of a pound that landed in the court of the Mint when a blast was fired in the Phelan building several blocks away. Other similar pleasant projectiles were hurled to the same spot from other blasts far away. In contrast to the foolish doings of the amateur miners, we quote an instance of the intelligent—and therefore safe—use of explosives in removing masonry. When electric power was installed at the Mint in place of steam and the 150-horsepower engine, which was placed on the main floor of the building, was removed, the huge foundation of brick-work laid in cement, which filled the space in the basement underneath, was useless, and, room being needed, the superintendent concluded to remove it. It was a solid mass about 30 feet long, nearly 20 feet wide, and 12 feet high. Mr. Leach put some men at work with picks, gads and hammers, but they made so little headway that it began to appear a hopeless task, when one of the Mint employees, Andrew Cuneo, came along and said that if Mr. Leach would allow him to use dynamite he could guarantee to tear the foundation down in good time. He was asked if he was sure he would not damage the building. He replied by saying that he would not only not damage the building, but would not break a pane of glass of the three windows situated not more than six feet away. He was allowed to proceed with the undertaking, and fulfilled all his assertions. This story confirms what we have said, that dynamite is a safe and wonderfully effective agency in experienced hands, and it needs no further remark from us to emphasize the inefficiency and danger of powerful explosives when employed by the inexperienced.

CALIFORNIA'S OPPORTUNITY.

The destruction of San Francisco is a calamity of such magnitude that few realize the problems which reconstruction involves. Fully seven square miles of the best and most substantially built portion of the city is destroyed. Here and there stand buildings practically uninjured—constructed of steel, brick, and stone,—but by far the greater portion of this area, say about 95%, is a vast ruin marked by foundations, fragments of walls, and tottering chimneys, with occasionally a tangled mass of steel, iron and earthy structural material. It has been determined, once and for all, which material best resists the terrific heat of a general conflagration. Granite structures, or such portions of buildings as were built of granite, spawled or crumbled under the blast, until the stone looks now as if it had been subjected to the action of weathering influences for centuries. Square blocks of granite were reduced to rounded boulder-like forms, their outer portions crumbling to coarse sand. Marble pillars were quickly converted into caustic lime. Even sandstone ordinarily well suited to withstand fire, cracked and crumbled before the fiery blast. Steel and iron were warped or bent, and in some instances they were even melted. Nothing resisted the intense heat but good brick. This is no new experience. Chicago, Boston, Baltimore and other cities that have been devastated by fire, all have proved that nothing better withstands the advance of a conflagration than a solid dead wall of red brick. There were many substantial buildings of steel, brick, stone and tiling in the burned district; they were supposed to be fireproof, but in several instances these were scattered singly among blocks of frame structures the burning of which created a heat so fierce that even those materials ordinarily considered non-combustible, and proof against fire, went down before it, as though charged into a blast furnace.

What of the future? Without the slightest hesitation, the men of San Francisco have decided that the city shall be rebuilt; and it will be, as fast as the material can be supplied. The city must be made safe not only against earthquake shock, but against the possibility of another great fire. It has been shown that a proper regard for solidity of construction in both foundations and superstructure, with the employment of good materials and honest work, will withstand the effect of earthquakes even of a severity as great as that of April 18. Little damage was done to the Federal buildings in San Francisco, for these were honestly constructed of first-class material, while more showy but less substantial structures were severely damaged. The walls of one building, for example, on Haight and Webster streets, though solidly built of stone, prove to be little better than a pile of loosely cemented rubble, neatly pointed on the outside. Large portions of such so-called stone walls were destroyed. The Palace Hotel, though not strictly modern, was solidly built of brick with many interior walls and partitions. The damage to this building was due almost wholly to fire, proving that brick structures, even with much less steel than is used in modern buildings, are practically proof against earthquakes, but not against the effect of acres of fiercely flaming wooden structures amid which they may be situated.

San Francisco must be rebuilt substantially. The proper materials for construction are steel, iron, brick and stone. Upon these points all are agreed, but the most serious problem is to secure sufficient material to carry on the work promptly. There is no lack of energy and determination to rebuild, and there will be no shortage of money for the purpose; but whence can the materials be obtained with reasonable promptitude?

Naturally the East is expected to supply the steel and iron; California alone is able to provide much, if not all, of the brick, terra-cotta, and stone; while California, Oregon and Washington will furnish the lumber. Lumber is the most readily obtainable, and this fact may again lead to the use of too large an amount of inflammable stuff. Much of the brick from the destroyed buildings can be cleaned and used again; indeed, this must be done from necessity, for otherwise it would take too long to make the quantity required; as it is, the brick-yards and terra-cotta works of California and neighboring States will have to run at their fullest capacity for years to supply the demand from San Francisco alone.

The most serious problem is how to secure the necessary steel and iron as fast as wanted. Every mill in the East that makes structural shapes is said to be from one to two years behind on its orders. Even before the fire it was difficult to get steel fast enough to continue steadily the construction of large buildings. Here is the real obstacle. Reconstruction cannot proceed without steel and iron in large quantities. If the East cannot supply what is required, the remedy is plain. The necessary structural steel must be made on the Pacific Coast. It is well known that large deposits of iron ore are available. Heretofore it has been argued that the time had not arrived when local iron furnaces and rolling mills could compete successfully with those in the East. The present situation upsets such an argument. The iron mines of California, Oregon, Washington, Alaska, Utah and Mexico can supply the ore; a great and permanent industry may now safely be established here. Several methods of producing iron are available; the ordinary blast-furnace practice of the East; the making of blooms in reverberatories, oil being employed as fuel; furthermore, the advocates of the electric furnace have a grand opportunity, and the same may be said of the enthusiasts who have written so much about the value of the iron sand of this Coast as raw material for the manufacture of iron. Now is the time to prove it! Heretofore the main drawback to the founding of a steel industry was the lack of a local market; that market has been created suddenly; a great opportunity has arrived. The iron ore is here and can be made accessible; California produces 20,000,000 barrels of crude petroleum annually; therefore a cheap fuel is available. Why should not San Francisco make her own structural steel?

LONDON COMMENT.

The London 'Spectator,' the paper rendered illustrious by Addison and Steele, founded 150 years before San Francisco existed, has this to say of our misfortune: The dominant note of the news from San Francisco has been one of unconquerable optimism.

The salient fact is the immediate decision to rebuild, to resume again the ordinary routine of life as soon as human effort can make it possible, upon the same spot, under the same skies, on the very foundations even which lie with their superstructures in dust above them. Is it reasoned decision, or mere impulse, which underlies that sudden determination? If there is reasoning, it would seem to be that what has only happened once will not happen again. The earthquake of 1868, in the words of one of the sufferers, "was nothing more than the rocking of a child's cradle," as compared with the earthquake of 1906. "There is no record of a great city having been twice destroyed by convulsion or eruption; the earth will not heave again, or, if it does, it will be at a time so distant that the contingency need not be considered." And so the plans go forward. If all the arguments are pressed home, the outstanding conclusion must be the essential sanity of the decision which determines upon reconstruction in the face of all hazards. For what are the alternatives? In which direction is safety to be sought? Away from the latitudes in which earthquakes tear down cities? But can those latitudes be limited? For, remember, the knowledge possessed by man of the causes of earthquakes is, and will possibly always remain, extremely small. All that can be said to be known, that is, apparently rightly reasoned from certain premises, is that the planet on which we live has cooled down from a glowing mass of molten matter, and is still cooling; that during the lapse of unnumbered and innumerable aeons the almost cold crust has clothed itself with the power of giving and supporting life; and that of all living beings it has been ordained that man alone shall be able to understand and reason about the vast laws of his existence. He is allowed to build huge cities where he pleases, to carve the thin stone under him to pile up palaces a hundred feet high, with more than forty million feet of unknowable matter between him and his fellow palace-builder the other side of the globe. Beneath the ground he treads, it may be but one short mile away, huge forces wake and sleep, move and are still; some unseen power shifts uneasily, writhes and rolls, and the caked coating above quakes as a bog-crust might shiver over a buried bull. Under which spot of all the surface over which he may roam will the monster writhe next? He cannot tell that; he knows only that here and there, during the few hundred years of which he has record, may be found tracts of land which hitherto have not been shaken, or have been shaken only slightly. What he does not know is whether the same laws which have hitherto prevailed can be counted on to prevail for the future. And if he does not know that—if, that is, he cannot stamp his foot on a square yard of ground and say, "Here at least it is certain that the earth will never be riven," is it not just as sane to rebuild where buildings have been shattered as to build afresh where no buildings have stood?

The builder will face that risk in his own way. He may watch his houses overwhelmed by the resistless march of lava, and with easy fatalism the next day sip wine over their ruins. Or, with the alert sanity of a nation buoyant in her belief in her mission of work, he may set himself with steady energy to make better what was good before, to use his broken buildings to teach himself lessons of knitting more soundly stone and steel and wood, to set together a new city, greater, compacter, and cleaner than the old. That is the task which has been set the San Franciscans by the genius of the great nation to which they belong. It is the genius of the American nation to grasp essential points, to rise greater than calamities, as though calamities gave wings or spurs; the greater the need for decision and courage, the greater capacity emerges for bravery and action. The descendant of the colonists who faced a new world with fresh thought and untired arms, in the crash of misfortune

"Turns his keen, untroubled face
Home to the instant need of things."

With the deep sympathy that has been felt by the English-speaking race for the sufferers in the ordeal of the last ten days there is yet mixed a high pride in the recognition of the qualities of cool steadfastness, courage, and strength which have nerved those who have sustained the greatest losses, and

The Ruined City as seen from Clay and Leavenworth Streets.

which are admired above and beyond other great and abiding qualities by their kinsmen.

EARTHQUAKES IN GREAT BRITAIN.

In a recent issue of 'The Nineteenth Century,' there is an interesting article on 'Earthquakes in Great Britain.' We quote a portion of it:

At places near the center of disturbance, the first sign of the coming earthquake is a low sound like the sudden rising of the wind. Almost immediately a faint trembling begins, such as is felt on a railway platform when an express train rushes by. Rapidly this increases in strength, the sound becomes louder, more rumbling and grating in character, and resembling that produced by the rapid passage of a traction-engine or a heavy motor-car. It is a sound so deep as almost to be more felt than heard. Then, after the lapse of four or five seconds from the start, the tremors merge into sharp rapid vibrations, accompanied by loud explosive crashes in the midst of the rumbling sound. These may last for two or three seconds, after which the vibrations shade off again into tremors, the sound becomes a mere rumbling and finally all movement ceases, the sound dying away as a low monotonous groan like the last roll of very distant thunder. Farther away, at distances of from 50 to 100 miles from the center, the phenomena are much simpler. There is no change in the nature of the sound, which merely increases in strength with the tremor, and then both die away together. The movement is, however, less rapid and jolting, and more like that felt in a carriage with good springs traveling over an uneven road.

Nineteen out of every twenty earthquakes in this country are fairly represented by the above descriptions. The remaining earthquakes are somewhat more complex. The shock consists of two distinct parts separated by an interval of two or three seconds, each part being similar to the shock of a simple earthquake. In some, the two parts are connected at places near the center by a weak, tremulous motion, which, at a short distance, becomes imperceptible; in others, the interval between the two parts is everywhere one of absolute rest and quiet. The parts generally differ slightly in duration and intensity, and occasionally in the nature of their vibrations.

To earthquakes of this class, the name of 'twin' has been given, because, as will be seen, the double shock is due to two distinct impulses resulting from a single generative effort.

The strongest earthquakes in this country are just capable of producing slight damage to buildings. Others are strong enough to overthrow ornaments and vases, or to make pic-

The Effect of Fire on Granite.

tures and chandeliers swing, to give a perceptible movement to the observer's seat, to make doors, windows, etc., rattle, or, finally, to be just perceptible to a person at rest. The waves of any earthquake, as they radiate outward from the origin, pass gradually through these different degrees of intensity. Knowing the degree at a large number of places, it is possible to draw on the map of an earthquake a series of isoseismal lines, or lines of equal intensity. Rough though this scale of intensity may be, it would be difficult to overestimate the service which it has rendered in the investigation of earthquakes.

In any earthquake, the outer isoseismal lines are nearly circular in form, while the inner curves are elongated (approximately in the same direction), the innermost curve of all being as a rule the most elongated. It is, however, when considered in connection with the geological structure of the districts that the significance of these elongated isoseismal lines becomes apparent. Their longer axes are then found to be parallel, or nearly so, to the axes of the great crust-folds of the underlying rocks. The initiation of these folds dates from long-past geological ages, and their formation has proceeded slowly and gradually ever since. In close connection with the folds, however, are nearly parallel and perpendicular systems of faults or fractures, along which movement takes place intermittently, the crust on one side advancing over that on the other by a series of slips, rather than by imperceptible creeps. When we consider that these faults are often many miles in length (two, for instance, cross the whole of Scotland), and that the total displacement may amount to thousands of feet, even to miles, when we think, further, that in each individual slip the crust may not advance by more than a fraction of an inch, though it may be by several feet, we can realize, though but dimly, the enormous number of displacements that must contribute to the growth of a great fault. At the same time, if we consider the mass of the rock that may be subjected to one of these slips and the friction that must thus suddenly be brought into action, we can understand how the resulting vibration would produce a shock that may be as weak as the faintest tremor felt at Comrie, or, on the other hand, as mighty as one of the great convulsions that have devastated Lisbon or Calabria, or ruined the coasts of Chili and Japan.

EDITORIAL.

June 16, 1906.

To flee from earthquakes is about as philosophic as to try to dodge a thunderbolt and therefore we are not surprised that our immediate neighbors are so willing to remain in California. On another page we quote the observations of an authority upon British earthquakes, indicating that even the little islands set in the silver sea are subject to these disturbances. It has been said—on this side—that it needs an earthquake to perturb the stolidity of the British character, and obviously Nature is not unmindful of her duty. Here, in California, we realize that an occasional tremor is a small price to pay for a beauty of climate and a glory of sunshine that make life worth living indeed. In this connection we quote a brilliant young geologist at Washington who recently discussed the earthquake of April 18 in a scientific publication and was criticized for prognosticating further departures from California serenity. He says that he did "not predict bigger quakes but merely pointed out, what any intelligent man must realize, that earthquake probabilities in the future must be calculated from the data of the past. The recent great shock has probably relieved a strain that may have been 50 or 100 years in accumulating and which may be a century or more in again assuming dangerous proportions. Personally, I should be glad to take my chances in California, preferring the risk of the occasional earthquake to the inevitable visitation of our Eastern summer heat." All of which appeals to us as being true, so we expect to see our friends coming to California as of yore, to get rest, to obtain sunshine and to look upon the face of Nature where she is young and beautiful.

EDITORIAL.

June 16, 1906.

To those who take no interest in earthquakes and their geological relations, we apologize; for this issue is rich in matter relating to this subject. But it won't occur again. In our issue of April 28 we gave the impressions and facts available immediately after the disaster of April 18, and now we publish the well-considered views of leading scientific men who have had an opportunity to investigate the facts. After this we expect to drop the subject. To those who, for reasons prompted by science or humanity, are interested in the explanation of the events that led up to the destruction of a great city and permitted of the observation of a rare geological occurrence, the pages that follow will be welcome.

When the earthquake occurred a Japanese professor made calculations by which he ascertained its occurrence in place and time. We refer elsewhere to Mr. Omori's formula and we publish the substance of a lecture delivered by him here during the last few days. While he was at work at Tokio, Mr. Frederick L. Ransome, of the United States Geological Survey, wrote an account of the probable causes of the earthquake a few hours after the news of it reached Washington, and this was prepared long before any facts were obtainable from the locality of the disturbance. And yet he also was enabled to make a scientific forecast, for, possessing an intimate knowledge of the geology of California, he knew her lines of structural weakness and placed his finger figuratively on the very fault along which the destructive slip occurred. A few days after the event we published an article by our Mr. W. H. Storms in which he described the earthquake line, correctly, as facts now show. His knowledge was based on data gathered while field-geologist on the staff of the State Mining Bureau. A former chief of that Bureau, Mr. A. S. Cooper, contributes a short article, with useful drawings, describing the now familiar earthquake line of California.

The disastrous effects of the earthquake upon the fine group

The Crippled Ferry Tower. The Clock Has Stopped at 5:14.

of buildings comprising Stanford University are well worth careful study by the architect and student of structural engineering. The building scheme has been beautifully carried out in the so-called 'mission' style and the yellowish tinted veneer of sandstone with the pale red tiled roofs is picturesque in the extreme. The framing is generally of light wood and the main portion of the structure is of brick (in some parts of which railroad iron was used) laid dry in mortar—not laid wet in cement. This is covered with slabs of the soft yellow sandstone mentioned, which is obtained near San Jose. This stone is a building material admirably adapted to the climate, though liable to scale and crack in countries where there is frost. The effect of the earthquake on this method of construction is shown by a photograph which we publish on another page. The same effect may be observed on a large scale in San Francisco at the City Hall and elsewhere throughout the neighborhood of San Francisco Bay. On the other hand, Roble Hall and the central block of the Museum and Art Gallery, both of which were built of tinted cement blocks, appear to have withstood the shock well. In some parts of the quadrangle and other places the work was done by day's labor and consists of solid stone; here the walls have stood better than the combination of brick with stone veneer—done by contract work. In many places the keystones of the arches along the corridors have slipped down, although the supporting pillars have apparently not spread. This could probably be obviated by designing the arch-stones of greater width, giving them a consequently greater keying power. The tower of the new library building is framed of structural steel and has remained intact, though the covering of masonry was demolished. Fortunately for the progress of education, few of the injured portions had as yet been occupied and there will be but little interruption to the classes at the University.

BAD LANGUAGE.

We do not refer to profanity but to a scientific terminology that limits the usefulness of a geological pamphlet. It happens to be one of particular interest at this time, namely, the report of the Earthquake Commission. This report was prepared for the State of California at the instance of several scientific men and by order of the Governor. On the face of it, the report is intended to allay alarm and to explain to the public the scientific facts of the case. This is a laudable purpose. And the findings of the Commission are decisive. It did good work. But why in the name of common sense should a document intended for non-scientific readers be written in language that is needlessly and awkwardly technical? The first sentence of the actual explanation starts out with reference to "a line of peculiar geomorphic expression." The expression is as peculiar as the line; a 'peculiar topography' or 'an unusual earth-form' would have conveyed the same idea with much less of irritation to the average reader. Then mention is made of factors that will "contribute much to geophysical conceptions." The frequent use of "coseismal curves" and "fault scarps," without any explanation, is calculated to cause stumbling among laymen. All such terms are known to the scientific and they can be worried out with the help of a dictionary even by the average citizen, but here is a report, of unquestioned value and interest, prepared by first-rate men, and intended to allay the fears while ministering to the knowledge of the general public, and yet it contains a large number of technical terms, some of which are unnecessary, while others that are necessary appear without such explanation of their meaning as courtesy demands. It is a good example of the supercilious attitude of the scientific hierarchy. We are reminded of an incident in a play called the 'Merry Monarch.' A lady asks a foreign minister, "What is this diplomacy you speak of so respectfully?" The reply is, "If you did know what it meant, it would not be diplomacy."

CONCERNING THE EARTHQUAKE.

May 16, 1906.

On another page we publish the chief portion of the report of the Commission appointed to investigate the earthquake that led up to the San Francisco conflagration. It is calculated admirably to fulfil the purpose for which it was designed, namely, to allay the alarm based on popular misconception of the occurrence and to ascertain the immediate geologic cause of the disturbance. While the report is the work of a committee consisting of eight men, aided by capable assistants, it is obvious, from internal evidence, that it is to be credited mainly to Mr. A. C. Lawson, professor of geology in the University of California, who took the first steps that led to the appointment and subsequently organized the investigation. The report is signed by him, as chairman, and by Professor A. O. Leuschner, as secretary.

It is a conclusive contribution to science. The earthquake is proved to have originated along an old line of faulting which traverses the coast of California, and though the ultimate source of the movement must ever remain an obscure problem, the immediate cause is ascertained. The center of disturbance was at the head of Tomales bay, 32 miles from San Francisco, but the shock was transmitted along a zone that follows an old fault for 375 miles. The maximum horizontal dislocation was about 20 feet, but over the 185 miles actually examined the surface movement averaged 10 feet. The vertical break was much less, the maximum observed being not more than four feet. Destructive effects extended for a distance of 25 to 30 miles on each side of the rift, although these observations are complicated by the possible occurrence of other lines of movement. The report does not refer to it, but it is likely that there was another rupture, traversing the eastern side of the Contra Costa hills, across Mare Island and through Sonoma county. The main line of disturbance, and the only one positively ascertained, cuts obliquely through the Santa Cruz mountains and is independent of such topography as it is due directly to ordinary erosion. It had been noted and described several years ago, for this reason. That is to say, it is the track of an old break in the earth's surface of a magnitude far exceeding the recent small slip and the movements which it marks must have been as much greater than the recent disturbance as a railroad collision surpasses the encounter of two persons in a crowd. The big fault originated far back in geologic time; it probably antedated man's

A Crack Across Van Ness Avenue.

first appearance and each succeeding movement involved intervals of time so great as to make human history an inadequate measure. Therefore, from a practical standpoint the proof of earlier disturbances and the suggestion of others yet to come, need cause no alarm, for it is the geologist who speaks, and he deals with time extravagantly. As to the effect on buildings, the Commission's report confirms the first inferences, which were those made on the occasion of previous earthquakes—and disregarded. Structures built on made ground or on alluvial soil suffered severely, because in such foundations the earth-waves are of maximum amplitude. If a jelly be placed in a porcelain bowl and if the latter be tapped, the vibrations pass through the highly elastic medium of the bowl in swift but minute waves that produce no apparent effect, but when they strike the jelly, their amplitude is enlarged and their period increased so that the jelly wobbles freely. A building on made ground behaves like a crumb perched on the jelly, but if piles be driven through the mud or gravel to the solid rock, then the building is anchored to the rock and moves with it—hardly at all. The same is true, with more assurance, of structures standing on the solid rock itself. It is the horizontal vibration that does the damage, the vertical component being slight and rarely destructive. On April 18 the vertical vibration was insignificant; the horizontal was about three inches in San Francisco itself. To most people even this seems wholly inadequate to account for the fearful result, but it must be remembered that the effect of each vibration of three inches becomes magnified by the acceleration of gravity, in other words, a pendulum motion is started, which may culminate, if the vibrations continue long, in a swing of a foot or more. The earthquake of April 18 was so destructive because it lasted a relatively long time —one minute and five seconds. The actual collapse of chimneys, copings, and structures in general, occurred toward the end of the second portion of the shock. Since the fateful day there have been many shocks, some of them severe, but all so short as to have done no harm. We presume that the final report of the Commission will be a volume, well illustrated with photographs, but it is not likely to add much to the essential facts as already given. No disturbance in nature producing great loss to humanity has ever been so quickly diagnosed or so successfully explained. And while man may justly pride himself on the quickening of his perception of the causes of things, he will remain humble in the face of his inability to ascertain the ultimate cause.

AN EARTHQUAKE FORMULA.

Editorial May 16, 1906.

Among the most interesting episodes connected with the scientific study of the recent disturbance in California, was the determination in Japan, by Mr. F. Omori, professor of seismology in the Tokio Imperial University, of the exact locality and time of the shock. This was done by an empirical formula, based on numerous observations of earlier earthquakes; the formula had been tested on several previous occasions, by its author, an acknowledged authority on the subject, and it had been printed eight years ago in the publications of the Earthquake Investigation Commission, of Tokio. Professor Omori's determination on this occasion was based on the record of his own seismograph at Tokio and the known fact that the length of the preliminary tremors indicates the distance of the point of observation from the place of origin of the earthquake.

We have Professor Omori's account of the calculations as published in Japan; as this is no place for them, we summarize by stating that the time the earthquake commenced at Tokio was 10 hr. 24 min. 35 sec. (Japanese time) on the night of April 18, the total duration being about five hours. The first preliminary tremors lasted 9 min. 49 sec., from which the approximate distance was calculated to be about 8,700 kilometres or, say, 5,400 miles. The actual distance from Tokio to San Francisco is 5,403 miles. By another formula he determined the time of the earthquake to have been 5 hr. 13 min. 5 sec., which many of us can testify to be an extraordinarily close approximation. The standard clock at the observatory of the University of California at Berkeley stopped at 5 hr. 12 min. 38 seconds.

The preliminary tremors represent those vibrations of small amplitude and short period which travel faster than the earth-waves that cause the heavy shocks; these smaller vibrations are also the ones that carry sound with them and while they originate at the same time, they travel so much faster as to precede the earthquake proper. At the Lick Observatory on Mt. Hamilton, the Ewing seismograph registered the introductory small movements for ten seconds, from which it is inferred that the central part of the great disturbance was at a distance of 80 miles. From Mt. Hamilton to the head of Tomales bay it is 83 miles. At the Berkeley observatory the Ewing seismograph was thrown out of adjustment by the violence of the shock, the magnitude of each component exceeding the range of the machine. The record of the preliminary tremors also is wanting.

Another feature is interesting. It appears that the first preliminary tremors were recorded at Tokio 11 min. 30 sec. after they were felt at San Francisco. As the direct spherical distance between these cities is 5,403 miles (as calculated from difference of longitude along an almost equal latitude), the velocity of propagation was 7.8 miles per second. On the other hand, at the observatory of the United States Weather Bureau at Washington, the preliminary tremors began at 8 hr. 19 min. 50 sec.; they were felt in Berkeley at 5 hr. 12 min. 6 sec., from which after deducting the three hours difference between Eastern and Pacific time, it is apparent that they took 7 min. 44 sec. to travel the 2,413 miles to Washington, or at the rate of 5.2 miles per second. This appears to be a discrepancy, but it is not. The explanation would be highly technical; suffice it to say that the velocity of propagation varies with, or is a function of, the distance. At Washington the preliminary tremors lasted 5 min. 10 sec., as deduced by us from an examination of the printed seismographic record; taking this interval, the Omori formula gives an estimated distance of 2,443 miles from the place of earthquake origin; the measured distance being 2,422 miles. At London the shock was recorded twice and possibly three times, the first being that which was propagated along the shorter spherical distance, while the second was the vibration that traveled the other way around the globe; the third being the first after a complete circuit of the earth. Until recently it was believed that the vibrations took two paths, a shorter one through the earth, along the chord of the arc, and a longer one in a line parallel to the curved surface; but now the Japanese base their measurements on the latter, while the English seismologists, led by John Milne, stick to the first. At Tokio, Professor Omori records the vibration at 10 hr. 24 min. 35 sec. (Japanese time) as that which came direct along the shortest spherical route or minor arc, while another series of vibrations commencing at 31 minutes after midnight, or 2 hr. 6 min. 35 sec. later, he attributes to the vibration propagated along the major arc of the earth, from California southeastward through South America, the Atlantic and the Indian oceans, to Japan. Of course, the passage of these vibrations is affected by the composition or coherence of the rocks through which they pass, but over long distances there is a tendency to average, so that this perturbing factor becomes eliminated.

The test of scientific theory is prediction; Mr. Omori dates his 'Note on the San Francisco Earthquake' at Tokio on April 25, but we understand from him that his calculations were made before the cable had told him when and where the earthquake had originated. Therefore his was a notable achievement.

THE PROBABLE CAUSE OF THE SAN FRANCISCO EARTHQUAKE.

By Frederick L. Ransome,
United States Geological Survey.

Most authorities on earthquakes distinguish two main classes—(1) volcanic quakes and (2) tectonic, or dislocation, quakes. The former originate in districts of active vulcanism and at comparatively shallow depth. According to Major C. E. Dutton, the greater number of such shocks are initiated at depths less than two miles. They are characterized by a fairly definite centrum, a relatively short radius of influence, and the absence of subordinate after-quakes. They are phenomena that could probably be closely imitated by the explosion of a large quantity of dynamite at the bottom of a deep mine. Tectonic quakes, on the other hand, may originate at a greater depth; they usually have indefinite or elongated centra, they are characterized by a greater radius of activity, and the main shock is usually followed by after-quakes. Most of the great destructive earthquakes recorded in history belong to this class. Such, for example, was the Mino-Owari earthquake in Japan, which in 1891 killed over 7,000 people, wounded over 17,000 more, and destroyed more than 200,000 houses. This quake was plainly caused by movement along a fissure which appeared at the surface as a fault about 70 miles long, with a maximum throw of 20 ft. Prof. John Milne, after an exhaustive study of the seismological records of Japan, concluded that shocks are most frequent in districts that exhibit evidence of elevation or subsidence still in progress.

Four kinds of waves are generated in most earthquake shocks: (1) normal waves, (2) transverse waves, (3) surface waves, and (4) epifocal waves. The first three depend upon the elasticity of the rocks traversed, are not visible, and although propagated with different velocities, are not always distinguishable. The last are the visual waves, resembling, as Major Dutton says, flat waves on water. They are characteristic of the epicentral tract of many great earthquakes and are highly destructive. They bear no clear relation to elasticity and result from the passage of the deeper waves from an elastic medium (solid rock) into a feebly elastic medium, such as soil or unconsolidated sediments. They thus account for the ruin often wrought in valleys and in low ground when structures on nearby hills escape.

The frequency of earthquakes in California is well known, and tremors sufficient to rattle the windows of dwellings in San Francisco have in the past been so common as to excite little alarm and arouse but passing interest. The number of quakes recorded in San Francisco from 1850 to 1886 is 254, and 514 additional shocks were noted in the same period in other parts of California. They are undoubtedly more prevalent in the region surrounding the Bay of San Francisco than in the northern or southern extremities of the State. While most of the southern quakes have effected no damage, others, such as the great shock in 1868, which injured San Francisco, the Owens Valley earthquake in 1872, the Vacaville earthquake in 1892, and the Mare Island earthquake in 1898 were notably destructive. In general, it may be said that the earthquakes in California exhibit the features characteristic of tectonic quakes, and the Owens Valley shock is generally ascribed to movement along the great fault limiting the Sierra Nevada on the east.

A section across central California, say, from Monterey bay to Mono lake—shows three well-marked topographic divisions. On the northeast is the gentle western slope of the Sierra Nevada, about 70 miles broad, which rises gradually from the eastern edge of the main interior valley to the crest of the great scarp overlooking the deserts of Nevada. The range is essentially a huge fault-block composed of Jurassic and older rocks and partly covered by Tertiary lavas.

The Great Valley is in the main an alluvial plain 50 to 60 miles wide, its northern part drained by the Sacramento river and its southern part by the San Joaquin. Both streams flow into the head of Suisun bay and their waters find their way across a depression in the third topographic division, the Coast Range, through San Francisco bay and the Golden Gate into the Pacific.

The Coast Range separates the Great Valley of California from the Pacific ocean. It comprises numerous nearly parallel ridges separated by narrow alluvial valleys and constitutes a generally mountainous belt 60 miles in width. Both in lithology and structure it presents a marked contrast to the Sierra Nevada, although the relations of the two ranges in the northern and southern parts of the State are not as yet fully understood.

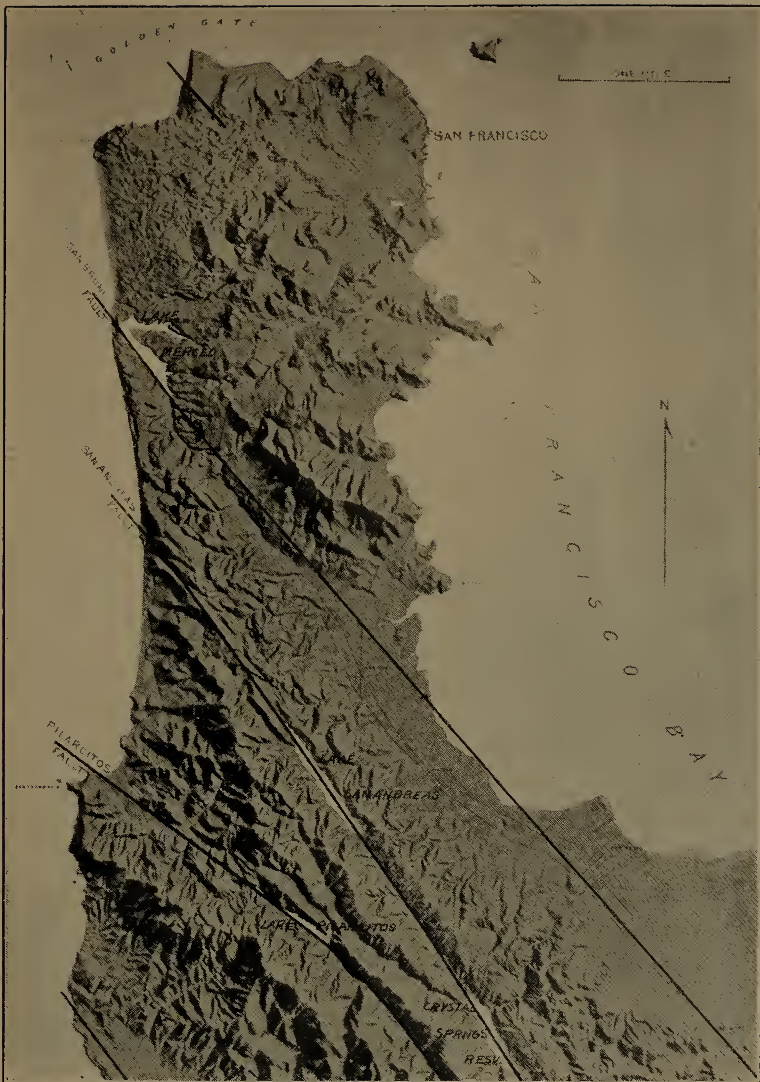
The oldest rocks known in the Coast Range are limestones and quartzites, with some crystalline schists, and are exposed at various localities from Point Reyes, north of San Francisco, to San Luis Obispo. These rocks, which are probably Paleozoic, are cut by granite supposed to be of the same general age as the main granitic intrusions of the Sierra Nevada, which are known to be post-Jurassic. All of these rocks, after being above sea-level long enough to be extensively eroded, were submerged and were covered by a series of sediments several thousand feet thick, known, from its characteristic development at San Francisco and on the north side of the Golden Gate, as the Franciscan, or Golden Gate series. Although the Franciscan consists mainly of sandstone such as forms the well-known Telegraph Hill in San Francisco and the larger islands in the bay, it contains also some of the most interesting and characteristic rocks of the Western coast, such as the serpentines, the blue glaucophane schists, with their wonderful mineralogical variety, and peculiar jaspery rocks made up in part of the silicious skeletons of radiolaria. The age of the Franciscan series, which forms a large part of the Coast Range, is still open to question. It is thought by some geologists to be Jurassic, by others to be early Cretaceous.

The deposition of the Franciscan sediments was ended by an upward movement of the sea bottom. They were folded and faulted, lifted above sea-level and eroded by streams and waves. Again, however, the land went down, the Franciscan rocks sank beneath the sea and were covered by thousands of feet of fossiliferous Cretaceous, Eocene, and Miocene deposits. The sediments of the last period alone attained a thickness of over 8,000 ft. At the close of the Miocene and after minor oscillations of level the rocks were again raised above sea-level and were crumpled and faulted by the energy of the uplift until they formed a well-defined range separating the ocean from the interior valley. In Pliocene time the land again subsided, although the Coast Range was probably not wholly submerged, and marine deposits of this period were laid down in sounds or inlets.

Here belongs the San Pablo formation, a thick accumulation of sandstone with intercalated volcanic tuffs. Apparently during the later stages of San Pablo deposition new movements of the land took place whereby fresh-water basins were formed, in which accumulated over 3,000 ft. of sediments and lava flows—the Berkeleyan and Campan series of Professor Lawson. Nor is this all. Still later in the Pliocene was deposited the Merced series, which is exposed along the ocean beach west of San Francisco. This remarkable deposit, described and named by Professor Lawson, is a mile in thickness and has at its base the well-preserved remnants of a coniferous forest. Thus a portion of the Tertiary land upon which pines, indistinguishable from the species now growing at Monterey, sank beneath the waves to a depth of at least 5,000 ft., and so rapidly that the trees were buried under sediments before they could decay. Finally the Merced series, carrying in its upper beds fossils of Quaternary age—the mere yesterday of geological time—have been elevated above the sea, tilted up at angles as high as 75°, and dislocated by a fault of at least 7,000 ft. throw.

If anyone will look at a good map of California he can scarcely fail to notice the striking parallelism of structure shown by that part of the State lying north of Tulare lake and south of Red Bluff, near the head of the Sacramento valley. This parallelism is not confined to the two main ranges, the Great Valley and the coast line, but is conspicuously shown by the ridges and valleys of the Coast Range. In the absence of local geological knowledge, this feature of the topography might be ascribed to regular folding, such as that of the Appalachians. The actual complexity of the folding, however, and the fact that the structural details of the ridges show little accord with the general topographic regularity referred to, dispose effectually of this suggestion. There can be little doubt that the principal longitudinal ridges and valleys of the Coast Range are due to faulting modified by erosion. Much detailed work remains to be done before the positions and throws of all these faults can be determined, but such careful structural studies as have been made of definite areas have invariably revealed the great importance of dislocations having a generally north-northwest trend. This is particularly true of the San Francisco peninsula, which, as Prof. Lawson has shown, is traversed by at least three great faults belonging to this dominant system (page 19). These have been plotted on the outline map of the region about San Francisco bay and relief map of the peninsula (next page). The San Bruno fault has a throw of 7,000 ft. near San Francisco, the southwest side having dropped relative to the northeast side. In all probability this same fault determines the positions of Bolinas and Tomales bays, north of the Golden Gate, and the straightness of the coast line as far as Point Arena, 100 miles northwest of San Francisco. Toward the south the same fault, or one belonging to the same zone, is said to be traceable almost to the Gulf of California, and in parts of southern California, is locally known as "the earthquake crack." The San Andreas fault, which, as may be seen from the small relief map, is followed by a rectilinear ravine occupied by a chain of ponds and lakelets whose existence is proof of recent disturbance. The third, or Pilarcitos, fault has not impressed its presence upon the topography of the peninsula in so conspicuous a manner as the other two. It is highly probable that future careful work will discover other great faults generally parallel with those mentioned. There is a strong suggestion, for example, of a fault passing near San Jose, along the eastern margin of the bay (see page 19), through Santa Rosa, and northwestward along the valley of the Russian river past Ukiah.*

* Abstract from the current issue of the 'National Geographic Magazine.'



San Francisco Peninsula in Relief.

ANOTHER EARTHQUAKE THEORY.

In 'Popular Science Monthly' there is an important article, taken from the London 'Times,' and written by Mr. H. H. Turner, professor in Oxford University, dealing with earthquakes. Professor Turner says:

Professor Milne, in the tenth report of the British Association committee, refers the 'world-shaking' earthquakes observed in the six years 1899-1905 to thirteen great earthquake regions, designated by the first thirteen letters of the alphabet. Three of these, I. J and L, are responsible for only five, three and two shocks respectively, and are thus of small importance compared with the others, which average about forty shocks each. Excluding them for the present, the remaining ten regions lie approximately in two rings on the earth's surface, a configuration which is most strikingly apparent when the regions are marked on a globe. The more important ring includes the following seven regions: A (Alaskan coast), B (Californian coast), C (West Indies), D (Chilian coast), M (South of New Zealand), F (Krakatoa region), E (Japan). Its center is among the conspicuous group of islands which includes Tahiti, and the radius of the ring is about 65 degrees. The other ring has its center at the opposite point of the earth, which is in the Sahara desert; and at a radius of 50 degrees from this center lie regions G (between India and Madagascar), H (the Azores) and K (Tashkend). Now, this is not merely a convenient geographical summary, but a physical fact of vital importance, according to recent researches by Professor Jeans. In a remarkable paper read before the Royal Society in 1903 he gave reasons for believing that the earth is by no means a sphere or a spheroid, as we have been accustomed to think, but is a pear-shape. Under gravitational stress it is continually approaching the spheroidal form, the pear is being crushed into a sphere by its own attraction; and the result is a series of earthquakes. These naturally occur in the weakest places, and if any one will experiment in crushing a pear towards a spherical shape, or even draw a diagram and consider where the weakest points would be, the reasons for the existence of two rings of greatest weakness will readily suggest themselves. The ends of the pear are the centers of these rings, one in Africa, one in the Pacific; and when once this is pointed out, the pear-shape of the earth is, according to Professor Sollas, "obvious to mere inspection; it is a geographical fact and not a speculation." Professor Sollas is indeed responsible for the particular suggestion above sketched; for Professor Jeans had originally proposed a different axis, which he withdrew in favor of the obvious improvement. The confirmation of Professor Sollas' view from the distribution of earthquake centers is remarkable. It does not seem, however, quite certain which is the blunt end of the pear; it has been hitherto placed in Africa, but there seem to be several reasons for regarding Africa as the stalk end. This point cannot, however, be dealt with here. The important thing is that there seems to be a real reason for the occurrence of earthquakes in these particular regions, and that they will probably continue to occur there. Professor Jeans' conclusions have recently been examined by Lord Rayleigh, who announced at the Royal Society only a few weeks ago that he found them generally confirmed, and that we must regard our earth as at present in a state far from stable.

We come to the second point, the distribution of earthquakes in time. Are there seasons of special activity such as the recent occurrence of several disasters seems to suggest? Here our knowledge is slighter still, and the observed facts have not yet been co-ordinated by a mathematical investigation. Still there seems to be some evidence in support of the view that exceptional irregularities in the rotation of our earth may be responsible for an increased number of earthquakes at particular times. That the evidence is slight must be attributed to the shortness of the time during which it has been possible to obtain it, and not necessarily to inherent weakness in the evidence itself. The brevity of the earthquake record has been mentioned above; that of irregularities in the earth's rotation is longer; but the discovery that such irregularities existed was made only twenty years ago.

OBSERVATIONS OF DISTANT EARTHQUAKES.

By F. Omori

Professor of Seismology in the Tokio Imperial University.

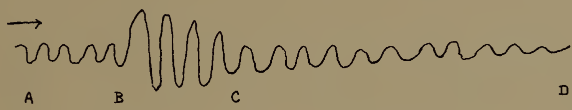
The motion of an earthquake consists of several sets of vibrations, the amplitude and period of which differ widely. It is convenient to divide this motion into the sensible or macro-seismic, namely, that which can be felt as tremblings or shocks; and the insensible or micro-seismic, which can not be felt. In the former, quick vibrations co-exist with slower ones, while in the latter quick vibrations are either absent or extremely minute. Some of the vibrations in the insensible motion are as large as those that are felt in local earthquakes; they are insensible only because their period is long and, consequently, their acceleration small; the lowest acceleration of the sensible motion being about 17 mm. or 0.67 in. per sec. The waves of quick period and short length are dissipated with increase of distance from the center of disturbance, more rapidly than the slow and long waves; the result being that the motion due to a distant earthquake is simpler in character than that due to a near one; it is entirely micro-seismic or insensible. By a "distant earthquake" is meant one whose epi-central* distance from a given station is at least 2,000 km. or 1,200 miles.

The earth's crust may be regarded as an elastic medium through which seismic waves are propagated. They are recorded and measured by the seismograph, a modern instrument of extreme sensitiveness. By the aid of it we can observe a great earthquake in any part of the world, the motion due to such a disturbance lasting generally from one to five hours.

Near Earthquakes. In an ordinary earthquake, the motion, as observed with a seismograph, begins always with vibrations of small amplitude and comparatively short period. These are known as the 'preliminary tremors' and last from a few seconds to a few minutes; next come those of large amplitude, constituting the 'principal' part; and finally the earthquake ends with feeble movements. When the origin of the

* The epi-centrum is the point on the surface vertically above the place where the earthquake originated.—Editor.

disturbance is near to the observer, a sound resembling distant thunder or a rushing wind is heard just before the arrival of the ground-trembling. These sound phenomena, which are of frequent occurrence in a rocky district, but rare on the plains, are credited to the rapid vibrations existing in the 'preliminary tremor.' The fact that animals show signs of disquietude just before an earthquake, is probably due to their acute senses, enabling them to feel the first movement of the preliminary tremors. The duration of the preliminary tremors does not depend on the magnitude of the earthquake; on the contrary, it varies with the radial distance. Thus, if Y denote the duration (in seconds) of the preliminary tremors



A B. Preliminary tremors.
B C. Principal part.
C D. End portion.

of an earthquake at a place, whose distance (in kilometres) from the origin of disturbance is X, we have the following empirical equation:

$$X=7.27Y+38$$

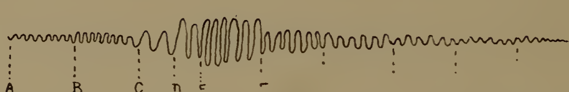
which is to be used for values of X between 100 and 1,000 km. This equation enables us to estimate, from the diagram taken by a sufficiently sensitive seismograph, the distance of the earthquake origin. And if the seismograph records be simultaneously taken at two or more stations, we can determine the approximate position of the origin. As an example, I refer to the excellent Ewing seismograph record taken by Dr. Campbell at the Lick Observatory. According to that seismogram, the preliminary tremor on April 18 lasted about 10 to 12 seconds, from which it may be inferred that the central part of the great disturbance was at a distance of about 120 km., or 75 to 80 miles, from Mount Hamilton.

The duration of the strongest part of the principal portion of the vibrations ordinarily varies between 4 and 10 seconds, but in cases of destructive disturbance, it reaches 30 seconds or more. From the Lick Observatory seismogram, the duration of the principal portion in the recent great shaking seems to have been about 40 seconds.

In slight earthquakes, the movement of the ground is small, a mere fraction of an inch. When the motion reaches half an inch, the earthquake becomes strong and may cause damage. When, however, the motion extends into inches, the effect is destructive, and ordinary brick houses, chimneys, etc., succumb. The motion in the strongly shaken parts of San Francisco was probably three inches.

In ordinary cases, the vertical component of earthquake motion is much smaller than the horizontal, being even when greatest, unable by itself to produce serious damage. In fact, in this regard the vertical component is only of secondary importance; in other words, the seismic damage to structures may, with rare exceptions, be regarded as due wholly to the horizontal motion.

Distant Earthquakes. A careful examination of seismograms shows that the motion consists of several phases, in each of which the period remains essentially constant, while the amplitude is also on the whole constant, except for the occurrence of maximum and minimum groups.



Diagrammatic Representation of the Earthquake Motion Proceeding from a Distant Origin.

a b. First preliminary tremors.
b c. Second preliminary tremors.
c d. First phase of the principal portion.
d e. Second phase of the principal portion.
e f. Third phase of the principal portion.
f g. Fourth phase of the principal portion.
j. End portion.

The successive phases of the earthquake motion, illustrated in the figure, are as follows:

The 'preliminary tremor,' which consists of vibrations of small amplitude and of short period, is divided into the earlier portion or the first preliminary tremor, and the later portion or the second preliminary tremor. Commencement of the latter is marked by an increase of amplitude and, in many cases, also by the appearance of slow undulations.

The 'principal portion' denotes the most active part of an earthquake, and consists of movements of larger amplitude. The earlier part is further subdivided into three successive stages as follows: (a) The first phase, consisting of a few very slow movements; (b) the second phase, consisting of slow movements, whose period is generally shorter than in the first phase; (c) the third phase, consisting of vibrations of a period much quicker than that in the preceding two phases. The third phase is followed by others of small amplitude. In earthquakes of near origin, the motion, on account of the existence of quick vibrations of macro-seismic character, is much more complex than in distant earthquakes, and it becomes difficult to subdivide the principal portion into the different phases.

Lastly, the 'end portion' denotes the feeble finishing part of earthquake motion.

As in the case of near earthquakes, the duration of the preliminary tremors at a given place is found to depend on the distance from the origin: Thus let X denote the arcual distance *(in kilometres) between the epicenter and the observing place, and Y the total duration (in seconds) of the first and second preliminary tremors, then we have the following empirical relation:

$$X = 6.54Y - 720$$

which has been deduced from the observation of different earthquakes when X varied between 2,000 and 14,000 km. Again, if Y_1, denote the duration (in seconds) of the first preliminary tremor, X having the same signification as before, we get the following formula:

$$X = 17.1Y_1 - 1360$$

Each of these equations may be used for determining at once the distance of an unknown earthquake, from the record taken at any given place.

The time (T) of occurrence at the origin of any distant

* That is, as measured along the curvature of the earth, or the arc-distance.

earthquake may approximately be calculated, from the seismographic record, by the following empirical formula:

$$T = t - 1.165Y$$

where Y has the same meaning as before, and t denotes the time of earthquake occurrence observed at a given place.

Pulsatory Oscillations.—Before going further, let me refer to a phenomenon called 'pulsatory oscillations.' These are small and slow pulse-like movements that are not of earthquake origin; they denote the fact that the ground is in a state of vibration even when there is no earthquake at all. As the period of these pulsatory oscillations varies but little, and remains constant for several successive hours, it may be supposed that they represent the proper vibrations of certain portions of the earth's crust, such for instance as the plain of Musashi on which Tokio is situated. The different portions of the earth's crust appear to be in continual movement, and the period of some of these vibrations ought to be determinable in each case from the geotectonic circumstances of the locality. For instance, a careful examination of the horizontal pendulum diagrams obtained at Tokio shows that the pulsatory oscillations are essentially vibrations with a period of about 4 seconds, more or less mixed up with those of a period of about 8 seconds. The vibrations of 4 seconds' period occur frequently, but cases are not wanting, where the vibrations of the 8 seconds' period predominate. Again other cases occur, in which the two kinds of vibrations are recorded in different parts of one and the same diagram. The average values of the periods of these two series of vibrations are respectively 4.4 seconds and 8 seconds. We may perhaps assume that the 8 seconds' period vibration constitutes the fundamental oscillation proper to the Tokio plain, the 4 seconds' period being one of its harmonics.

The average period of the principal pulsatory oscillations at Osaka, Formosa, Gottingen, and some other places, is either nearly 4 seconds or nearly 8 seconds. It may be that the period (or periods) of the pulsatory oscillations is approximately constant all over the world.

Pulsatory oscillations generally accompany a cyclone; the effect of a great atmospheric depression being sensible at a distance of several thousand kilometres. In a few cases, however, pronounced storms of pulsatory oscillations occur on days when calm weather prevails all over Japan. In Tokio, earthquakes occur rarely while pulsatory oscillations are active. On the other hand, shocks are frequent when these oscillations come to a state of minimum activity.

Periods of Earthquake Vibrations. The predominating periods in the preliminary tremors of the distant earthquake motion observed at Tokio were those of about 4.5 and 8.5 seconds, corresponding thus with the pulsatory oscillation. Moreover the periods observed in the preliminary tremors do not depend on the distance of an epicentrum from the observing station, nor upon the nature of the disturbance at the seismic origin, but they are characteristic of a particular region—in this case Tokio. A similar conclusion probably holds good also for the periods in other stages of the earthquake motion. The conclusion is that the principal vibrations in the preliminary tremors of distant earthquakes and the pulsatory oscillations are identical phenomena.

The explanation is as follows: The waves of the preliminary tremors are transmitted along a deep layer of the earth's crust with a velocity (about 14 km.) of which I shall speak presently, and communicate a stress to the superincumbent surface layer of the earth's crust in the region about the observing station; the latter being, in consequence, thrown into its own proper vibrations. Thus, the preliminary tremors are nothing else than the pulsatory oscillations, caused by the waves transmitted along a deep layer of the earth's crust from the origin of an earthquake.

The Velocities of Propagation of the Vibrations. In calculating the velocities of propagation of distant earthquake waves, it makes a great difference whether we suppose the waves to be propagated along the chord of the earth (joining the origin to the observing station) or parallel to the surface. Calculated on the latter supposition, which seems to be more probable, the velocities of the different waves of the earthquake motion come out approximately the same, irrespective of the arcual distances, those cases in which the epicentral distance is small, say, under 30°, being excluded. On the chord supposition, the corresponding velocities come out quite different, according to the distances.

If we denote by V_1, V_2, V_3, V_4, V_5, V_6, V_7, and V_8, the velocities of propagation (supposed parallel to the earth's surface) of the waves at the commencement of the successive phases of the earthquake motion, their mean values are as follows:

V_1	13.7	km. sec.	V_5	3.3	km. sec.
V_2	7.2	"	V_6	2.8	"
V_3	4.6	"	V_7	2.4	"
V_4	..	"	V_8	2.1	"

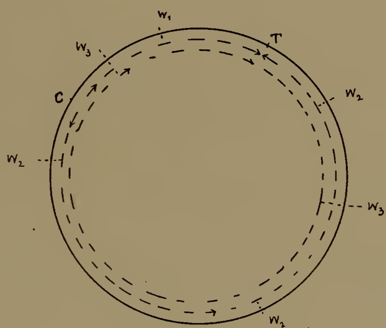
Now the velocity of propagation of the vibrations at the commencement of the principal portion of a near earthquake is 3.3 km. (or two miles) per second, which is the same as V_5 above. Here it is evident that the vibrations in the 3rd phase of the principal portion are transmitted along the surface of the earth's crust.

The transit velocity of the vibrations of the 1st preliminary tremor, namely V_1, is very great and no known rock has an elastic modulus sufficiently large to permit of it, whether the vibrations be longitudinal or transverse. Hence we must conclude that the waves of the 1st preliminary tremor are transmitted along some path within the earth's crust. As, however, the duration of the 1st preliminary tremor at a given station is very nearly proportional to the arcual distance between the station and the earthquake origin, it seems likely that the waves of the 1st preliminary tremor are transmitted parallel to the surface of the earth and at a constant depth below it; the supposition being that the waves of the 1st and 2nd preliminary tremors and of the principal portion are all generated simultaneously at the earthquake origin, becoming gradually separated from one another (on account of the difference of the transit velocities) as the disturbance extends. The layer along which the high velocity (V_1) waves are propagated may mark the limit beyond which the seismic waves are, on account of certain physical properties of the underlying medium, unable to penetrate; or there may be, as Professor Nagaoka suggests, a maximum transit velocity. A rough calculation, based on the relation of the duration of the 1st preliminary tremor and the epicentral distance, and on the value of the different velocities, gives 600 kilometres or about 400 miles as the probable depth of the layer along which the vibrations of the 1st preliminary tremor are propagated.

It is probable that the waves having velocities V_2 and V_3 are transmitted along layers at smaller depths within the earth's crust.

Propagation of the Seismic Motion Completely Around the Earth.—Let T be the observing station and C the earthquake origin. Then there are three sets of motion, which can be distinguished; they may be denoted respectively as W_1, W_2, and W_3.

The W_1 waves are those propagated from C to T along the



shortest path, parallel to the surface, namely along the minor arc; the W_2 waves are those propagated from C in the opposite direction and arriving at T after passing through the antipode of C, namely, along the major arc; and the W_3 waves are the W_1 waves which are propagated beyond T in the same direction, and again arrive at T after making one complete circuit of the earth.

The identification of the W_3 waves is possible only in a few cases; that of the W_2 waves is, however, more definite, being characterized by the fact that their period is much slower than those of the preceding vibrations, which form the end portion of the W_1 waves.

The average period of the W_2 waves is, with a few exceptions, uniform and gives a mean value of 20.4 seconds, which is identical with the predominating period in the 3rd phase of the principal portion; the period of the W_3 waves is also nearly the same as that of the W_2 waves. These facts seem to indicate that the W_2 and W_3 waves are the same as those which constitute the 3rd phase of the principal portion of the earthquake proper.

The time interval between the arrival of the W_1 and of the W_3 waves is 3 hr. 20 min. 46 sec.; this agrees with the time that would be taken by the vibrations in the 3rd phase of the principal portion in making one complete circuit around the earth, with the velocity of 3.3 km. or two miles per second.

The San Francisco Earthquake Observed in Tokio. The time of commencement in Tokio of the earthquake was 5 hr. 24 min. 35 sec. a. m. (Pacific time); the total duration of motion being five hours. The duration of the 1st preliminary tremor was 9 min. 49 sec., from which the approximate arcual distance between the origin of the earthquake and the observing place was calculated to be 5,400 miles, and the time of the occurrence at the origin of the shock to be 5 hr. 13 min. 5 sec. a. m. (P. T.).

The 1st displacement of the well-defined horizontal vibration at the commencement of the 2nd preliminary tremor was directed toward S 27° W; the counter displacement being directed toward NE. It will be observed that the directions of these movements correspond to the great circle joining Tokio with the origin of disturbance.

At 7 hr. 31 min. a. m. (P. T.), or 2 hr. 6 min. 35 sec. after the commencement of the disturbance, there began vibrations which correspond to the same earthquake motion propagated along the major arc of the earth, that is, from the center in a southwestern direction, through South America, the Atlantic, and the Indian Oceans.

As other examples of large earthquakes which disturbed the west coast of the American continent, I may mention the following: The Alaska earthquake of September 3 and 10, 1899, and on October 9, 1900; Central American earthquakes, on April 18 and September 22, 1902; Panama, Colombia and Ecuador earthquake, on January 1, 1906.

The whole Pacific coast, which forms one of the most active seismic districts in the world, is frequently visited by earthquakes of different size and intensity. Large destructive earthquakes have, however, a tendency to happen in groups, that is, they occur along different parts of a given zone in the course of a few years. Thus, as mentioned above, there were, between September, 1899, and January, 1906, a series of six extensive disturbances which affected the whole coast from Alaska down to South America, indicating that these earthquakes were of no local character, but that there was great stress along the Pacific border, such as to lead one to expect the extension of the seismic disturbance to California. The great earthquake of April 18 last may therefore be regarded as having completed the continuity of the manifestation of the seismic activity along this part of the world. Now, the earthquake is caused by the existence of a weak point underground, which, reaching the limit, finally gives rise to a sudden disturbance that becomes the source of the wave motion that is propagated through the rock and the soil. An extensive earthquake such as that of April 18, may be regarded as having removed the instability existing in this part of the earth's crust; those regions most violently shaken becoming seismically the safest place for a certain interval of time. As a matter of fact, there is no case recorded in which great earthquakes have originated successively at one and the same center. The small after-shocks which will continue to shake the western coast for a few years, are not of a dangerous nature. On the contrary, it is absolutely necessary that these small shocks should occur, as they enable the disturbed earth's crust to settle into a condition of equilibrium.*

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* This paper forms the substance of a lecture delivered before the Astronomical Society of the Pacific, at the University of California, on June 9, 1906. Reported and abstracted by the Editor.

REPORT OF THE STATE EARTHQUAKE COMMISSION.

One of the remarkable features of the Coast Ranges of California is a line of peculiar geomorphic expression which extends obliquely across the entire width of the mountainous belt from Mendocino county to Riverside county. The peculiarity of the surface features along this line lies in the fact that they are not due, as nearly all other features of the mountains are, to atmospheric and stream erosion of the uplifted mass which constitutes the mountains, but have been formed by a dislocation of the earth's crust, or rather a series of such dislocations, in time past, with a differential movement of the parts on either side of the plane of rupture. In general this line follows a system of long narrow valleys, or where it passes through wide valleys it lies close to the base of the confining hills, and these have a very straight trend; in some places, however, it passes over mountain ridges, usually at the divide separating the ends of two valleys; it even in some cases goes over a spur or shoulder of a mountain. Along this line are very commonly found abrupt changes in the normal slope of the valley-sides giving rise to what are technically known as scarps. These scarps have the appearance of low precipitous walls which have been usually softened and rounded somewhat by the action of the weather. Small basins or ponds, many having no outlet, and some containing saline water, are of fairly frequent occurrence and they usually lie at the base of the small scarps. Trough-like depressions also occur bounded on both sides by scarps. These troughs and basins can only be explained as due to an actual subsidence of the ground, or to an uplift of the ground on one side or the other, or on both sides. The scarps similarly can only be ascribed to a rupture of the earth with a relative vertical displacement along the rupture plane. Frequently small knolls or sharp little ridges are found to characterize this line and these are bounded on one side by a softened scarp and separated from the normal slope of the valley-side by a

In the Heart of the City.

line of depression. In many cases these features have been so modified and toned down by atmospheric attack that only the expert eye can recognize their abnormal character; but where their line traverses the more desert parts of the Coast Range, as for example in the Carissa plains, they are well known to the people of the country and the aggregate of the features is commonly referred to as the "earthquake crack."

This line begins on the north at the mouth of Alder creek near Point Arena and extends southeasterly nearly parallel with the coast line to a point about two miles below Fort Ross, a distance of 43 miles. Here it passes outside of the shore line and is again met with at the point where Bodega Head joins the mainland. Thence it appears to continue southward through Tomales bay and Bolinas lagoon. Beyond Bolinas lagoon it passes outside of the Golden Gate and enters the shore again at Mussel Rock, eight miles south of the Cliff House. From this point it is traceable continuously along the valley line occupied by San Andreas and Crystal Springs lakes, past Woodside and Portola, over a saddle back of Black mountain, thence along Stevens Creek canyon, passing to the southwest of Table mountain and Congress Springs to the vicinity of Wrights, on the narrow-gauge railway between San Jose and Santa Cruz. From Wrights it continues on in the same course through the Santa Cruz mountains to the point where the Southern Pacific railway crosses the Pajaro river near Chittenden. From the crossing of the Pajaro the line extends up the valley of the San Benito river, across the eastern portion of Monterey county, and thence follows the northeastern side of the valley of the San Juan river and the Carissa plains to the vicinity of Mt. Pinos, in Ventura county. The line thus traced from Point Arena to Mt. Pinos has a length of 375 miles, is remarkably straight, and cuts obliquely across the entire breadth of the Coast Ranges. To the south of Mt. Pinos the line either bends to the eastward following the general curvature of the ranges or is paralleled by a similar line offset from it en echelon; for similar features are reported at the Tejon pass and traceable thence though less continuously across the Mojave desert to

Cajon pass and beyond this to San Jacinto and the southeast border of the Colorado desert. The probability is that there are two such lines, and that the main line traced from Pt. Arena to Mt. Pinos is continued with the same general straight trend past San Fernando and along the base of the remarkably even fault-scarp at the foot of which lies Lake Elsinore. But, leaving the southern extension of the line out of consideration as somewhat debatable, we have a very remarkable physiographic line extending from Pt. Arena to Mt. Pinos which affords every evidence of having been in past time a rift, or line of dislocation, of the earth's crust and of recurrent differential movement along the plane of rupture. The movements which have taken place along this line extend far back into the Quaternary period, as indicated by the major, well-degraded fault-scarps and their associated valleys; but they have also occurred in quite recent times, as is indicated by the minor and still undegraded scarps. Probably every movement on this line produced an earthquake, the severity of which was proportionate to the amount of movement.

The cause of these movements in general terms is that stresses are generated in the earth's crust which accumulate till they exceed the strength of the rocks composing the crust and they find a relief in a sudden rupture. This establishes the plane of dislocation in the first instance, and in future movements the stresses have only to accumulate to the point of overcoming the friction on that plane and any cementation that may have effected in the intervals between movements.

The earthquake of April 18, 1906, was due to one of these movements. The extent of the rift upon which the movement of that date took place is at the time of writing not fully known. It is, however, known from direct field observations that it extends certainly from the mouth of Alder creek near Pt. Arena to the vicinity of San Juan in San Benito county, a distance of about 185 miles. The destruction at Petrolia and Ferndale in Humboldt county indicates that the movement on the rift extended at least as far as Cape Mendocino, though whether the line or rift lies inland or off shore in that region is still a matter of inquiry. Adding the inferred extension of the movement to its observed extent gives us a total length of about three hundred miles. The general trend of this line is about N 35° W, but in Sonoma and Mendocino counties it appears to have a slight concavity to the northeast, and if this curvature be maintained in its path beneath the waters of the Pacific it would pass very close to and possibly inside of capes Gordo and Mendocino. Along the 185 miles of this rift where movement has actually been observed the displacement has been chiefly horizontal on a nearly vertical plane, and the country to the southwest of the rift has moved northwesterly relatively to the country on the northeast of the rift. By this it is not intended to imply that the northeast side was passive and the southwest side active in the movement. Most probably the two sides moved in opposite directions. The evidence of the rupture and of the differential movement along the line of rift is very clear and unequivocal. The surface soil presents a continuous furrow generally several feet wide with transverse cracks which show very plainly the effort of tortion within the zone of the movement. All fences, roads, stream-courses, pipe-lines, dams, conduits, and property-lines which cross the rift are dislocated. The amount of dislocation varies. In several instances observed it does not exceed six feet. A more common measurement is eight to ten feet. In some cases as much as 15 or 16 feet of horizontal displacement has been observed, while in one case a roadway was found to have been differentially moved 20 feet. Probably the mean value for the amount of horizontal displacement along the rift line is about ten feet and the variations from this are due to local causes such as drag of the mantle of soil upon the rocks, or the excessive movement of soft incoherent deposits. Besides this general horizontal displacement of about 10 feet there is observable in Sonoma and Mendocino counties a differential vertical movement not exceeding four feet, so far as at present known, whereby the southwest side of the rift was raised relatively to the northeast side, so as to present a low scarp facing the northeast. This vertical movement diminishes to the south-

On Van Ness Avenue, Near Green Street.

east along the rift-line and in San Mateo county it is scarcely, if at all, observable. Still farther south there are suggestions that this movement may have been in the reverse direction, but this needs further field-study.

The great length of the rift upon which movement has occurred makes this earthquake unique. Such length implies great depth of rupture, and the study of the question of depth will, it is believed, contribute much to current geophysical conceptions.

The time of the beginning of the earthquake as recorded in the Observatory at Berkeley was 5 hr. 12 min. 6 sec. a. m., Pacific standard time. The end of the shock was 5 hr. 13 min. 11 sec. a. m., the duration being 1 min. 5 sec. Within an hour of the main shock twelve minor shocks were observed by S. Albrecht of the Observatory and their time accurately noted. Before 6 hr. 52 min. p. m. of the same day thirty-one shocks were noted in addition to the main disturbance. These minor shocks continued for many days after April 18, and in this respect the earthquake accords in behavior with other notable earthquakes in the past. The minor shocks which succeeded the main one are interpreted generally as due to subordinate adjustments of the earth's crust in the tendency to reach equilibrium after the chief movement.

The collection of time records necessarily proceeds slowly. The purpose of the co-seismal curves based upon these records is in general two-fold. In ordinary earthquakes it is one of the means of locating the seat of the disturbance when there is no surface manifestation of the rupture in the earth's crust. In the present instance, however, the rupture has declared itself in an unmistakable rift observable at the surface, and co-seismals are therefore unnecessary for the determination of this important factor in the general problem, so far at least as regards the main disturbance. It is probable, however, that so radical a change in the equilibrium of the stresses of the earth's crust would induce secondary ruptures and consequently secondary earthquakes closely associated with the chief shock. The careful plotting of the time records may, therefore, be useful in revealing the location of these secondary disturbances, such for example as the one which affected southern California on the afternoon of April 18. The second purpose of securing time records is the determination of the velocity of propagation of the earth wave; and the data for this which are likely to be most serviceable are the records obtained at various quite distant seismographic stations.

The destructive effects of the earthquake are in the main distributed with reference to the line of rift. The exact limits of the area of destruction have not yet been mapped, but it is known to extend out about twenty-five or possibly thirty miles on either side of the rift. On the southwest side the greater part of this area to the north of the Golden Gate lies in the Pacific. This area extends from Eureka in Humboldt county to the southern extremity of Fresno county, a distance of about four hundred miles.

Beyond this area of destructive shock the earthquake was felt in its milder manifestations over a wide territory. Our reports to date show that it was felt in Oregon as far north as Coos bay and on the south as far as Los Angeles. To the east it was felt over the greater part of middle California and western Nevada, particularly along the eastern flank of the Sierra Nevada. It was felt at Lovelocks, and we have unconfirmed reports of its having been felt at Winnemucca. Far beyond the region within which it was apparent to the senses, however, the earth wave was propagated both through the earth and around its periphery; and some of the most valuable and most accurate records of the disturbance which we have are those which were registered at such distant seismographic stations as Washington, D. C.; Sitka, Alaska; Potsdam, Germany; and Tokio, Japan.

Within the area of destructive effects approximately 400 by 50 miles in extent the intensity varied greatly. There was a maximum immediately on the rift line. Water-pipes, conduits, and bridges crossing this line were rent asunder. Trees were uprooted and thrown to the ground in large numbers. Some trees were snapped off, leaving their stumps standing, and others were split from the roots up. Buildings and other structures were in general violently thrown and otherwise wrecked, though some escaped with but slight damage. Fissures opened in the earth and closed again, and in one case reported a cow was engulfed. A second line of maximum destruction lies along the floor of the valley system of which the bay of San Francisco is the most notable feature, and particularly in the Santa Rosa and Santa Clara valleys. Santa Rosa, situated twenty miles from the rift, was the most severely shaken town in the State and suffered the greatest disaster relatively to its population and extent. Healdsburg suffered to a nearly similar degree. San Jose, situated thirteen miles, and Agnews, about twelve miles from the rift, are next in order of severity. Stanford University, seven miles from the rift, is probably to be placed in the same category. All of these places are situated on the valley floor and are underlain to a considerable depth by loose or but slightly coherent geological formations, and their position strongly suggests that the earth waves as propagated by such formations are much more destructive than the waves which are propagated by the firmer and highly elastic rocks of the adjoining hill lands. This suggestion is supported by a consideration of the destructive effects exhibited by towns and single buildings along the same valley line which are situated wholly or partly on rock. Petaluma and San Rafael, though nearer the rift than Santa Rosa, suffered notably less, and they are for the most part on, or close to, the rocky surface. The portions of Berkeley and Oakland which are situated on the alluvial slope suffered more than the foothills, where the buildings are founded on rock. The same suggestion is further supported from a consideration of the zone of maximum destructive effect on the southwest side of the rift. This zone lies in the Salinas valley. The intensity of destructive action at Salinas was about the same as at San Jose, and the town is situated on the flood plain deposits of the Salinas river. Along the banks of the Salinas river and extending from Salinas to the vicinity of Gonzales, so far as our reports at present show, the bottom lands were more severely ruptured, fissured and otherwise deformed than in any other portion of the State. The Spreckels sugar mill, situated on the banks of the river, suffered more severely probably than any other steel structure in the State. Santa Cruz, on the other hand, which is on the same side of the rift, and at the same distance from it, but which is built on rock for the most part, suffered much less damage. In the northern counties along the coast the most severe effects were felt at Ferndale, on the south margin of the flood plain of the Eel river, and at Petrolia, on the bottom land of the Mattole. Ft. Bragg was severely shaken with very destructive effects, but our reports do not yet indicate the character of the ground upon which it is situated.

In the facts which have been cited we seem to have warrant for a generalization as to the excessively destructive effect of the earth wave as transmitted by the little coherent formations of the valley bottoms. But it must be borne in mind that by far the greater number of structures subject to destructive shock are situated in the valley lands, and that there has not yet been time for a detailed comparison of the effects in the valleys with those in the hills, where the buildings are founded on firm rock, except in a few notable instances.

The most destructive of these instances is the city of San Francisco, and the facts observed there are entirely in harmony with the generalization above outlined. In the city of San Francisco we may recognize for preliminary purposes four types of ground: (1) The rocky hill slopes; (2) the valleys between the spurs of the hills which have been filled in slowly by natural processes; (3) the sand dunes; (4) the artificially filled land on the fringe of the city. Throughout the city we have a graded scale of intensity of destructive effects which corresponds closely to the classification of the ground. The most violent destruction of buildings, as everybody knows, was on the made ground. This ground seems to have behaved during the earthquake very much in the same way as jelly in a bowl, or as a semi-liquid material in a tank. The earth waves which pass through the highly elastic rock swiftly with a small amplitude seem in this material to have been transformed into slow undulations of great amplitude which were excessively destructive. The filled-in material and the swampy foundation upon which it rests behaved, in other words, as a mass superimposed upon the earth's surface, rather than as a part of the elastic crust itself. In a less degree the same thing is true of the sand-dune areas, where the ground was frequently deformed and fissured. In still less degree the naturally filled valleys between the hill spurs were susceptible to this kind of movement, and the destruction of buildings was correspondingly less, but still severe, depending very largely on the character of the buildings, the integrity of their construction, etc. In portions of these valleys, however, the original surface of the ground has been modified by grading and filling, and on the filled areas the destruction was more thorough than elsewhere in the same valley tracts. On the rocky slopes and ridge tops, where, for the most part, the vibration communicated to buildings was that of the elastic underlying rocks, the destruction was at a minimum. On some of the hills chimneys fell very generally and walls were cracked; on others even the chimneys withstood the shock.

While this correlation of intensity of destructive effect appears to hold as a generalization, there are well known exceptions, which find their explanation in the strength of the structures. Modern class A steel structures with deep foundations appear to have been relatively passive, while the made ground in their immediate vicinity was profoundly disturbed. Thoroughly bonded and well cemented brick structures, on similarly deep and solid foundations, seem to have been equally competent to withstand the shock, except for occasional pier-like walls not well tied to the rest of the building. The weak points in wooden frame structures were in general the faulty underpinning and lack of bracing, and chimneys entirely unadapted to resist such shocks. With these faults corrected, frame buildings of honest construction would suffer little damage beyond cracking of plaster in such a shock as that of April 18, save on the made ground, where deep foundations and large mass appear to be essential for the necessary degree of passivity.

Pipe lines and bridges crossing the rift line present a peculiar, if not quite unique, engineering problem which will doubtless be solved in the near future. Pipe lines on low swampy ground or in made ground are in much greater danger of destruction from earthquake shocks than those on high ground underlaid by rock, except in the immediate vicinity of the rift, where nothing could be constructed which would withstand the violence of the earth movement.

One of the lessons of the earthquake which seems peculiarly impressive is the necessity for studying carefully the site of proposed costly public buildings where large numbers of people are likely to be congregated. In so far as possible, such sites should be selected on slopes upon which sound rock foundation can be reached. It is probably in large measure due to the fact of their having such a rock foundation that the buildings of the State University, at Berkeley, escaped practically uninjured. The construction of such buildings as our public schools demands the most earnest attention of the people and of the authorities charged with their construction. A great many of our schools proved to be of flimsy construction and ill adapted to meet the emergency of an earthquake shock of even less severity than that of April 18.

The Commission in presenting this brief report has had in mind the demand on the part of the people of the State and of the world at large for reliable information as to the essential facts of the earthquake. It has, therefore, not presumed to engage in any discussion of the more abstruse geological questions which the event naturally raises.

Relief Map of California.
The black lines indicate earthquake-faults.

THE EARTHQUAKE EXPLAINED.

By A. S. Cooper,

Formerly State Mineralogist of California.

The coast ranges of California consist of a number of broken anticlines, fissured by faults and step-faults, nearly all of which run in a northwest and southeast direction roughly parallel with each other, and with the valleys. Both sides of the fault are elevated but the northeast side is usually raised from one foot to several hundred feet higher than the southwest side.

The black line on the relief map, reproduced on the opposite page, shows the position of the master fault of the coast ranges. This fault extends from opposite Fort Bragg, in Mendocino county, to the Gulf of California, a distance of 700 miles. A wagon road follows 400 miles of its length. The movements of the earth which produced the earthquake of April 18, 1906, occurred almost simultaneously in this fault throughout its entire extent; consequently, there was no center of disturbance or seismic focus. The shock was of greater violence near Fort Bragg and San Juan, in San Benito county, than further south. Cracks and fissures can be seen from Tomales bay to San Juan. Two hundred miles of this fault broke into fissures of profound depth in about one minute, as is shown by the duration of the earthquake shock. The land on the northeast side of the cracks and fissures was elevated several feet higher than was the land on the southwest side. The fault marked by a white line on the relief map east of the master fault was also affected simultaneously, fissures opening for a long distance. All of the cities and towns lying within fifteen miles of this fault-line between Fort Bragg and Salinas City were badly damaged.

Fig. 1 is an ideal section from the Sierra Nevada through the San Joaquin valley and the coast ranges to the Pacific ocean in a northeast and southwest direction. As will be seen by reference to this section, all of the anticlines forming the coast ranges are faulted and fissured. The core of some of these anticlines is granitic while others have a core of metamorphic rock. The floor of the valley is also faulted, the fault being hidden by the debris deposited in the valley. These faults and fissures are formed by a mighty pressure coming

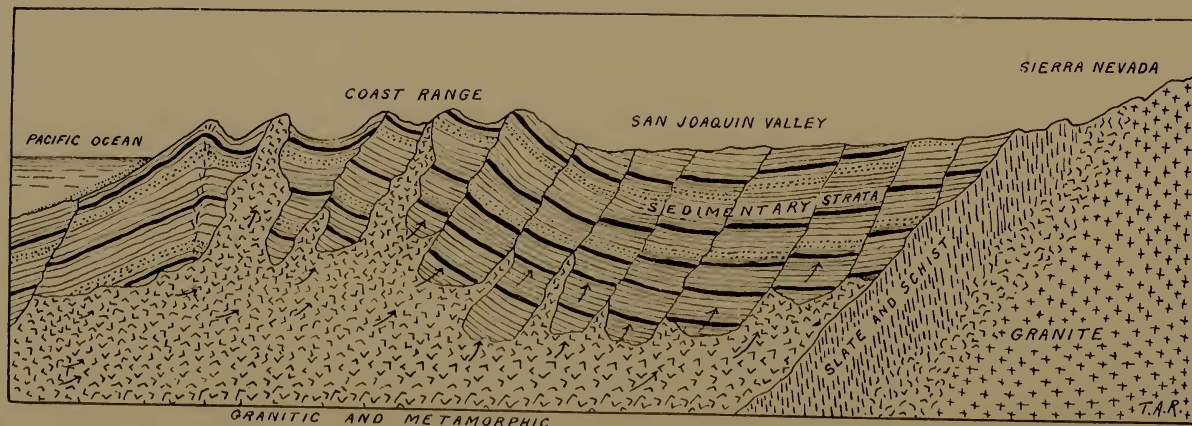


Fig. 1. Ideal Geological Section across California.

Fig. 2. A Broken Anticline.

Fig. 3. Intense Folding causes a Fault-fissure.

from the southwest, caused by shrinkage of the earth by secular cooling. The direction of this force is represented by the arrows. This force is deflected upward by the immobility of the base of the Sierra Nevada. The upward deflection of this force is shown by the curved arrows. That this pressure exists is shown by the fissility of the slates and the foliation of the schistose rocks at the foot of the Sierra Nevada. The slates split in a northwest and southeast direction and the foliation of the schistose rocks is also in the same direction. The splitting of the slates and the foliation of the schistose rocks are at right angles to those lines of pressure, such cleaveges occurring normally at right angles to the pressure.

Fig. 2, 3, and 4 represent the usual structure of the faulted and fissured anticlines of the coast ranges of California. Fig. 2 is an anticlinal structure which is bent so acutely that its apex is greatly fissured. Fig. 3 is an anticlinal structure faulted and fissured at F; both sides of the fault are elevated, but the side G has been raised from a few feet to several hundred feet higher than the side E. Fig. 4 is an anticline having a metamorphic core I. Both sides of the core are elevated, but the side J is generally elevated many hundred feet higher than the side H. There is a faulting at K, between the metamorphic rock I and the sedimentary strata H. The sedimentary strata next to the metamorphic rock are abruptly bent upward by the ascent of the metamorphic rock. The side J is elevated, but usually there is no faulting between the sedimentary rock J and the metamorphic rock. Gases and mineral waters ascend through the fissures and cracks in these anticlines.

The elevation of the strata has progressed several feet at a time. In the last fifty years in San Benito county the eastern side of the master fault was raised 14 feet, then two and one-half feet, then one foot and then two feet, higher than the western side.

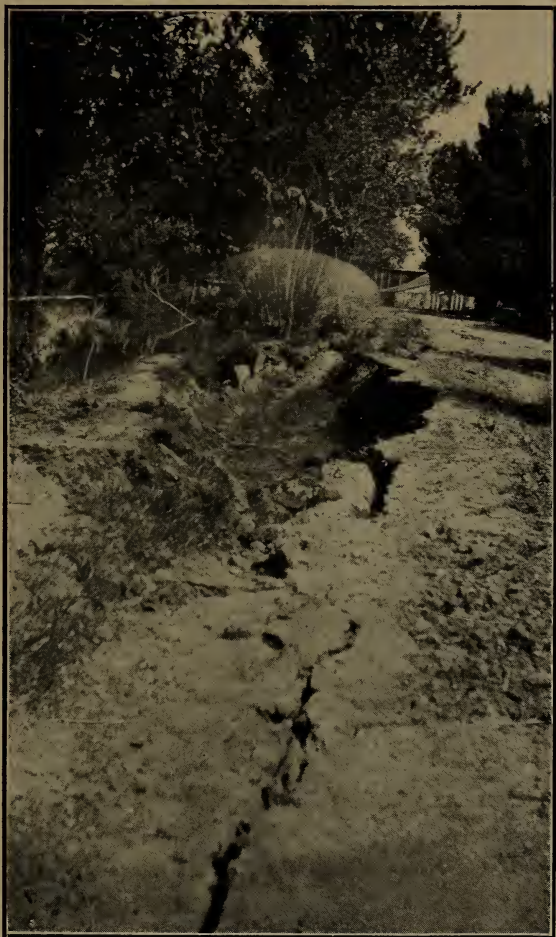
When the lateral pressure described above has increased sufficiently to overcome the weight of the overlying rocks and the friction, the rocks on the side of the fault away from the ocean are suddenly lifted, producing a jar or earthquake. There being a greater pressure when the first movement of the earth occurs, the first shock is always the most violent. This is followed by minor shocks as the earth adjusts itself. A number of years will generally elapse before the lateral pressure increases sufficiently to produce another movement of a similar kind.

Fig. 4. An Anticline with a Metamorphic Core.

EFFECTS OF THE EARTHQUAKE.

By D'Arcy Weatherbe.

For some time previous to the earthquake, John C. Branner, professor of geology in Stanford University, had been examining the topographic and geologic conditions through-



On the Line of the Fault.

out the Santa Clara valley and the adjacent mountains on either side. He came to the conclusion that there existed a zone of fracture or a line of faulting which intersects the Coyote river near the bridge on the road from Milpitas to Alviso. This fault is said to have a course approximately northwest and southeast and some rather remarkable demonstrations of the earthquake have occurred along the levee paths following the Coyote river north from the bridge mentioned. It should be stated in passing that the alluvial deposits of the Santa Clara valley are immensely deep—how deep is not known—although boreholes for artesian wells have been sunk over 1,000 feet in sand and gravel. At the locality mentioned large fissures, as much as eight feet wide and of nearly equal depth, have been opened and as partial filling ensued immediately, they must have been of much greater depth when first formed. In some places the road has been completely precipitated into the creek and at a point about half a mile below the bridge both the banks and the bed of the stream, including a heavy growth of willows, have been cut by a series of parallel cracks and the trees and banks thrown into the stream, thus forming a partial dam.

All of these cracks are roughly parallel with the stream and approximately with the supposed course of the fracture zone in the rock far below the surface. Simultaneously with the above phenomena, dozens of small geysers or spouting craters were formed along the creek and in the adjacent fields. The mouths of these varied in diameter from three inches to about 15 inches, though the actual orifices probably do not exceed four or five inches in diameter. Mud and water were spouted to a height of over twenty feet, and continued to flow for several days. On some of the miniature craters incrustations of salt were deposited. The bridge above mentioned was shifted on its concrete supports, the two ends moving in opposite directions, and throughout the same locality rows of trees in the orchards are said to have been twisted and staggered out of shape. Above the valley to the east, in the solid rock of the mountains, practically no damage was sustained.

D. Rowan, who accompanied me on the above examinations, spent several days on the Marin side of the Golden Gate, along the Pacific coast, and reports the following effect of the earthquake in that locality: The road crossing the sand-spit at the mouth of Bolinas bay is fissured and in places disturbed, and the high cliffs—about 150 feet—at the end of the peninsula have crumbled and fallen down, carrying small trees with them. At the village of Bolinas, the soil has slipped down easterly toward the lagoon and on the east side of the road, which runs north and south, the buildings are entirely demolished, while those further up the hill on the west side are not so badly affected. From Bolinas to Olema the road is disturbed all the way. About half a mile west of Olema at Skinner's dairy a well-defined fissure passes north and south

Ruined Buildings at Stanford University.

under the barn, which is completely wrecked; the garden, lying between the two buildings, has slipped down the hill toward the lagoon in a northeast direction, following the slope of the land. It is said that higher up on the hills to the southwest of Olema the effect on the ground was worse and at a point about two miles in this direction an opening occurred in a yard where a cow was being milked, which swallowed up the animal so that its hind legs only were left out of the ground. From Skinner's the road runs north toward Inverness and for a distance of two miles it is so badly broken as to make vehicular traffic impracticable. The road from Inverness to Reyes Point station, running easterly and westerly and between one-half and three-quarters of a mile long, has broken about the center, the western portion being carried north 16 feet; a block 30 to 40 feet long has dropped down four feet. At Reyes Point station freight-cars, standing on the siding, were overturned to the west, following the slope of the ground. At Inverness, on the peninsula across Tomales Bay, the buildings along the low ground at the water-front were entirely demolished; in many cases they were thrown into the water and the wharves being apparently on short piles, were badly wrecked. Higher up on the hill, the motion was not felt to such an extent. Along the coast, the railway was greatly disturbed, invariably sinking in the low swampy land except where built on piling. At Tomales, about eight miles inland, the line for over 1,000 feet was carried down a gentle slope to the east for a distance of 50 feet. All these disturbances are exactly along the faulted line, now well defined, though the movement and action in each of the cases above noted has been entirely local and following the configuration of the ground. Little evidence, therefore, can be deduced pointing to a definite regional movement in any certain direction. Buildings on ground resting on long piles seem undisturbed and the worst effects are noted on or toward swampy ground.

At Stanford University.

FOLLOWING THE PAY-STREAK.

By R. B. Nickerson.

There are veins that seem to have been made to serve as illustrations for those who teach mining by books. They present ideal conditions. The veins are of a good size to work, say five or six feet and pitch at an angle of 50 or 60°. The walls are hard and firm and the vein pursues the even tenor of its way in a stately and dignified fashion in length, breadth and depth. Very little water is encountered in the development work, but there is an abundance at hand for power, with timber, etc., in the immediate vicinity. To complete this pen picture we will say that the ore is free-milling and goes $25 per ton. This is the kind of a mine that the honest miner had in his mind's eye when he remarked "Damn a mine that won't pay under any kind of management." Coming down to stern realities, it may be remarked that mines answering this description resemble the visits of angels in that they are few and far between. They are the good things, which like the buffalo seem to have long since disappeared from the face of the earth. They are the kind of mines that cause the fortunate investor to regard mining as a good thing and to assure his friends that "legitimate mining is no gamble, but an industrial proposition."

But how different from the foregoing description are the real conditions that usually confront the miner! All kinds of difficulties must be faced. The veins are uneven and irregular, often consisting of a system of streaks difficult to understand or follow. Separated by horses, displaced by dikes and faults, many feet apart, it is no wonder that orebodies are missed, overlooked or lost. Wet, heavy ground is encountered requiring large pumping plants, and a forest of timber is used to hold the ground up. The cream of the mines, the rich surface ore, further enriched by erosion and oxidation, is all gone. The miner must sink deep shafts or run long tunnels in order to open up bodies of lower grade ore—often so low-grade that, after equipment and months of development, the expense when subtracted from yield, leaves but a small margin of profit and that profit possible only when the closest and most rigid economy has been observed. The patient and long-suffering stockholder feels that mining is not all his fervid imagination had painted. Let us suppose that a mine has been worked for years at a profit, and while it may still be paying, the management deem it advisable to sink a new shaft or drive a new adit to tap the vein deeper than the present workings, in hopes of finding orebodies below. The work is done and the miner finds himself hundreds of feet below the old workings and in virgin ground. If a perpendicular shaft has been sunk, he starts his cross-cut to intersect the vein formation. The crucial moment has arrived. The development work has not been done without a great deal of deliberation and planning, in which expert opinion has been called in from the outside and paid for. The work has cost thousands of dollars. Obstinate and conservative members of the board of directors have been argued with and brought over to the new plan; and now the time has arrived when any stroke of the pick may uncover the much-coveted prize—a good orebody. The life of the mine depends upon what the development work will discover. To the superintendent who has faith in the mine and has recommended the work, it is a trying time. There is no rest for him now. The vein is struck with a rush of water; so far so good. The fissure is open, but what a disappointment! The gouge is there, but without ore; the formation is dull and dry looking. The quartz is glassy and brittle with no life in it; it contains some sulphides, but they are not the right kind. It is evident that there is no orebody here; it must be found elsewhere.

One way to prospect a mine in the condition just pictured, is to cross-cut the vein formation and drift on the foot-wall, making cross-cuts at intervals of every 50 or 100 feet so as to test the formation up to the hanging wall and a little beyond it. But in mines when the lode-channel is large, this is often a very expensive method, as the cross-cuts must be hundreds of feet in length to get to the hanging wall. Hard slips are met with, carrying gouge and quartz, resembling the vein and making it impossible to be certain that they are the main hanging wall, and that there may not be an orebody beyond. It is necessary to drive cross-cuts at comparatively short distances apart, for an orebody might lie between any two of them. But there are several ways to kill a cat, and the experienced miner knows that an orebody resembles a tree in that its feeders spread in all directions from the main mass. Whatever cause, whatever convulsion of nature opened the fissure so that a place was made for the ore deposit, it also made its pressure felt for hundreds of feet from the main ore deposit. It is an interesting study to examine the formation surrounding a worked-out orebody, and it is instructive also. There is generally, even in the same mine, something distinctive and characteristic about the formation of each individual orebody, peculiar to itself. Even the mineral constituting the separate orebodies will vary, and can be recognized by one familiar with the mine. It is interesting to follow, where possible, the drifts, raises, etc., leading to a worked out orebody. Test the filling of the fissure by panning, observe the formation and see just where the first indication of ore appeared. It will frequently be found hundreds of feet from the shoot. The pocket miner puts this knowledge to practical use in following the paystreak to the pocket. All quartz mines resemble each other in this respect, both gold and silver and some lead mines. The orebodies throw off their feeders just as the pocket does, and while it is often a difficult matter to follow them, if once a streak of gold quartz is found and followed it will sooner or later lead to ore, that is, in most mines. Some veins never were any good and never will yield an orebody. The feeders are there, but they do not bunch. These mines are strictly no good, but if a vein has made one good orebody it is a strong argument that it will make another. But it is often a delicate matter to follow these feeders. Many complications and difficulties are met with. One is literally groping in the dark. Much experience and judgment are required. It has often happened, especially in the old silver 'chloriding' days when men worked on the tribute system, that after a certain part of the mine had been considered thoroughly prospected by the company, a party of miners working on a lease of the ground and by following these little pay-streaks, would strike ore. Large and valuable orebodies have been found in this way, that probably would never have been found in any other way.

In the case cited, the cross-cut is being driven ahead and the old reliable gold pan is brought into play and everything thenceforth is panned and prospected. The development work goes ahead testing the vein, and every method known to modern mining is used to crowd the work ahead. Gasless powder is used. The steam-pipe to the pump and water-column are tapped, and a steam-jet and small water-pipe are run to the face. Extra men are put on to throw back the waste, to lay track, pipe, etc., so that a cross-bar can be set up at once and the back holes drilled while the waste is being shoveled. The best men, the pick of the mine, are put on the job and no expense is spared to rush the work in every way possible. The panning goes on, but not a color of gold is found and the assays yield nothing. A water-hose is run out to the end of the waste-dump and carloads of the muck are washed over to get a good look at the formation, but it looks dry and dead. The panning goes on, and finally one morning a tiny speck of gold is seen in the pan. Where did it come from? More pannings are made, but with no results. Finally a pan is washed with several little specks in it and in the washings is found a little piece of a bluish looking quartz, not a quarter of an inch cube, with a speck of galena in it. Down in the mine goes the superintendent and every inch of the last round blasted is gone over with painstaking care. Ah! Here it is! A tiny streak of gouge, not thicker than a knife-blade! He tries it with the point of his candlestick and finds a little grit. A handful is taken on top and carefully panned, and he sees something that sends a thrill of exultation through him. None of your little specks this time, but a good prospect! Plenty of fine gold and a few coarse colors! But he is suddenly chilled with the thought that it may be coming from the ore above; that it is nothing but the drizzle end of that ore giving out. Never mind, it must be followed, so down in the mine he goes and gives his orders, "When you set up again, boys, put your round in the cross-cut and drill another round here in the side from the same bar. We will start a drift here"; and the drift is started following the paystreak. These are anxious days for the superintendent and his foreman. The men share in the tension. They realize the importance of the work. They know why they were put there and what is expected of them and they bend their brawny muscles over the throbbing drill and work as men nowhere else do underground. The drift goes ahead, following that tiny thread of gold as it turns its tortuous way through the formation. Other seams and slips come in, but the right one must be picked out. The 5-foot rounds frequently leave it to one side or the other, but it must be found again. The "old man" has left word that he is to be called whenever they blast, day or night, and when the watchman raps lightly on his window and says, "You are wanted below, sir, they just blasted," he is up and down in the mine again to find that the last round lost the streak. A slip has cut it off, slick and clean. Now begins a hunt to find it. Which way did the slip cut it? From this way, of course. He gouges in on the slip and pans the gouge on a shovel-blade. There is the gold. He drills on the slip, several rounds, maybe, following the gold. Finally the slip does not pan any more and he looks for the pay-streak. There it is. He knows it at a glance this time. The same tiny streak of gritty gouge. Ahead again, and so on through all its erratic, winding course he traces and follows it with skill and patience; sometimes lost for days at a time, but always picked up again. Finally it begins to assume something of a definite shape. The walls become more regular and distinct; the gouge is thicker, more water follows the streak and there is more quartz showing up. It continues to improve. More water comes in. The quartz is soon a foot thick and prospects fine. A hay-maker could follow it now. The "old man" gives orders to blast the waste first, muck back, blast the ore and send it to the mill, and says, "Boys, I think we have made a strike here." He writes to the company that good ore is coming into the south drift and it looks favorable. It is all ore now and all going to the mill. The plates brighten up. The ore from the drift is sweetening the low-grade ore from the other stopes and the mill-boss says: "Can't you give us a little more of that rock from the bottom? That's good stuff."

When he goes to the bottom and stands in the drift running through the orebody, a feeling of pride and satisfaction comes over him. He was right. His judgment was correct. It is a strike, sure enough. There is no doubt of it. He feels "some proud" as he surveys the length and breadth of it. There is ore enough in sight to insure the prosperity of the mine for several years to come. He feels a personal interest in it. He found it and he knows how easy it would have been to have missed it many times, and that the ore might have lain undiscovered for years and might have never been found.

This is one way to find ore. It is going back to first principles. It has this advantage: It does not necessarily require a chemist, a geologist, or a mining engineer to do it.

THE RECOVERY OF COPPER FROM MINE DRAINAGE.

By Philip Argall.

The precipitation of copper from mine drainage is of comparatively recent introduction in the West, while in Europe it has been established as a profitable industry for at least 200 years. When and where the process of precipitating (on iron) the copper in mine drainage was first turned to practical account is difficult to determine. The phenomenon of cementation is mentioned by Agricola, who wrote in 1546. The process is said to have been in operation near Rio Tinto, Spain, in 1661. Dr. Edward Brown, in the Philosophical Transactions for the year 1670, describes the process of copper precipitation as practiced at the Ziment Springs, Herrengrund, while at Agorda in the Venetian Alps it was said to have been introduced in 1692. As far as I can find out, the first practical application in the British Isles of the process of precipitating the copper from mine drainage upon iron scrap, occurred at the Cronebane mines, in Wicklow county, Ireland, about the year 1750. Dr. Henry Kenroy, writing in the Philosophical Transactions for 1751, states that the process was discovered by reason of some workmen at the Cronebane mine having left a shovel in the mine water, which was found when taken out to be turned into copper. Whereupon Mr. Matthew Johnston, one of the proprietors of the mine, turned the discovery to account, in the following process, which is compiled from Dr. Kenroy's paper, previously cited.

The drainage of the mines was run into a chain of oblong pits, each ten feet long, four feet wide and eight feet deep, the bottoms of which were laid with smooth flagstones and the sides built up with stone and lime, with rude wooden beams across the pits to lay the iron bars upon. The copper replaced the iron, which passed off in solution; to hasten this reaction, the iron bars were frequently taken up and the copper rubbed off into the pit; in about twelve months the whole bar was dissolved if the iron was soft, but hard iron or steel was acted on less quickly and therefore was found not to answer so well. When the iron was dissolved, the water was turned off the pit and the copper shoveled out; this red copper mud was laid in heaps and when dry became reddish dust. One ton of iron produced 1 ton 19½ cwt. of this precipitate, each ton of which produced 16 cwt. pure copper; that is to say one ton of iron was sufficient to produce 1 ton 11½ cwt. copper which was worth £10 more per ton than the copper smelted from the ore.

It was subsequently found advantageous to run the drainage into settling pits, and to pass only the clear water over the irons. Evidently only a small quantity of the copper in solution was saved, as it appeared that the pits might be continued as far as the workers pleased; for the waters did not sensibly abate in quality by being subjected to the process. The quantity of copper running waste about this time must have been enormous as in one stream, 'the Sulphur brook,' it was calculated to be 129,600 grains per minute, or 124,100 ℔. per annum.

Dr. Pryce, in his 'Mineralogia Cornubiesis,' published in 1778, page 291, gives credit for the introduction of copper precipitation at Cronebane to some Cornish miners who, having emigrated from Chacewater, settled at Cronebane; he adds, "Captain Thomas Butler, who was one of Redruth, and manager of that mine (Cronebane), persuaded the proprietors to adopt the scheme of precipitating copper." It is also related that the precipitation of copper on iron was noticed at the Chacewater mine, Redruth, Cromwell, in 1728; but I believe no practical use was made of the discovery till 1854. That a person named Butler was once at Cronebane is probably true, as there is a shaft on the property known as the Madam Butler. This, however, shows a leaning toward Irish gallantry; I do not recall that Cornishmen name shafts after their wives, and the name Butler is surely Irish. Then, as Dr. Kenroy wrote of what he had seen in 1751 and Dr. Pryce of what tradition had handed down to him, 27 years later, I am inclined to support the former and award to the Irish the first profitable application of the copper precipitation process in the British Isles. Furthermore the precipitation of copper from Cronebane mine drainage was an industry of considerable magnitude 150 years ago, the production of copper precipitates from 1753 to 1765 amounting to no less than $82,280; quite a respectable output considering the small amount of development on the veins, the appliances used in precipitation and the recent introduction of a mysterious and little understood process.

The pumping of acid waters in many Western mines is yet a matter of much experiment and considerable expense, on account of the corrosion of the pipes, plungers, etc. Many experiments have been made, with lead-lined pipes, special bronzes and subtle chemical compounds, in attempts to re-solve a problem that our forebears had satisfactorily elucidated before the foundations of modern chemistry were laid. Probably the first form of pump-column was the bored out and hooped log. These I have myself seen in the old workings of the Cronebane mine, abandoned before the time of the oldest miner thirty years ago, showing they are probably considerably over a century, and perhaps two centuries, old.

With the introduction of cast-iron pipes, it was but a short step forward to line them with wood, known at that time by previous experience, to be practically unaffected by the cuprous waters; nay more, it was found that the wood-lined pipe accumulated a deposit of ferric oxide which adhered tenaciously to the wood, and if not scraped off periodically it would in time choke the pipes.

I remember when a schoolboy seeing very acidulous water pumped from the Wicklow copper mines by means of Cornish pumps, the cast-iron water-columns of which were lined with quarter-inch soft-wood staves, the flange-joints of the pipes were made with gaskets composed of an iron ring 1½ by ¼ in., around which was wrapped a thickness of two inches of coarse flannel soaked in tar. In screwing up the pipe-joints this tarred flannel was pressed out over the wood lining, securely sealing the iron pipe from the acid waters, as well as making a tight joint between the pipes. Coarse tarred flannel was also wrapped around the pipes where exposed to falling water, and it was well painted with warm tar. The suction pipes for these pumps were made from logs of beech wood, bored out to size and the bottom drilled with suitable holes to form the straining orifice for the pump; the plungers and glands were made of bronze, the valves of copper and leather, but these metals corroded and were about the only parts of the pumps that required frequent attention and occasional renewal. I might add that in a wide and somewhat varied practice extending over thirty years I have never seen a case where the foregoing appliances would not satisfactorily handle the drainage of copper mines, no matter how corrosive.

The nature of the reaction between metallic iron and copper solution was of course not understood in 1751, twenty-three years before Priestley discovered oxygen; a quarter of a century before Lavoisier elucidated the theory of combustion and 53 years prior to the announcement of the atomic theory by Dalton. Therefore in the limited precipitation works existing at the time when Dr. Kenroy wrote, the operators might well be excused for considering the transmutation of iron into copper a continuous and unending reaction, for so far as their works extended "the water did not sensibly abate in quality by being subjected to the process." The mine drainage was evidently very rich in those early days; however, 47 years later (1798), the copper value of the Cronebane mine drainage had fallen off materially and we find the poor pyrites ore was heap-roasted and subsequently leached to enrich the copper salts in the drainage of the mines. As the active working of the mine fell off, the copper carried in solution gradually disappeared. I helped to re-open the Cronebane mine in 1874, at which time the effluent water carried but a slight trace of copper, though the mine had not been closed over twenty years. The drainage adits were, however, filled with ocher almost to the roof and the above-water stopes and vein exposures were almost completely sealed with ocherous deposits.

The Connorree mine, adjoining Cronebane to the east, was credited prior to 1872 with $75,000 worth of copper precipitate per annum, and was worked for a year or two almost entirely for the cement copper obtained from the mine drainage.

This, be it remembered, with coal at a high figure and all the water pumped from a depth of 90 fathoms. The mine closed down in 1880 and has not since been opened, but a published analysis of the stagnant mine-water taken in 1884, showed, it is claimed, 40 grains of copper to the gallon,—an excessive amount. The process of kernel roasting was carried out on the low-grade copper ores of the Connorree mine in the late sixties, and the oxidized envelopes of the sulphide kernels were leached in the mine-water, to remove the soluble sulphates, and enrich the waters on their way to the precipitation plant.

The Ballygahan mine on the same lode series, but west of the Avoca river, was not much of a copper mine, but a precipitation plant was added near the close of its active career, continued in daily profitable operation for five or six years after active mining had ended. The pumps, however, were operated by water power. Mr. G. A. Kinahan made the following analysis of Ballygahan mine waters about two years after the close of active mining: (The returns are in parts per 100,000.)

	Before Precipitation.	After.
Ferrous oxide	81.81	94.75
Ferric oxide	4.30	6.70
Cupric oxide	9.32	1.91
Sulphuric acid	634.26	642.34
Manganese oxide	2.30	2.50
Zinc oxide	1.20	1.80

Returning to the Cronebane mine, the re-opening of which, after twenty years' idleness I have previously referred to; it was found that as the stopes, drifts and working faces were cleaned, oxidation again proceeded; and the effluent waters of the mine became rich in copper. The portal of the principal adit, however, was well within the boundary of the adjoining property, the owners of which made big profits from the enriched drainage of the Cronebane mine. After repeated demands for a share of the profits derived from the precipitation works, which met with as many refusals, I was instructed by the manager of the Cronebane mine—whose assistant I then was—to proceed with the underground precipitation plant that we had worked out. The plant was a great success, as owing to the higher temperature of the water, its freedom from sediment and almost entire absence of ocher, we secured excellent precipitation. Our selfish neighbors were, however, almost driven out of business, as owing to the oxidation of the ferrous salts traveling through 2500 ft. of adit, the water carried much suspended hydrated ferric oxide on reaching the surface, and the precipitation plant of our neighbors acted mainly as catch pits for the ocher.

Immediately below the gossan of the Cronebane vein a rather soft clay filling occurred, carrying abundance of granular pyrite and various copper minerals, including sulphate; the leaching of these deposits in place by first opening them up with numerous small drifts and then turning down water through the loose gossan, soon formed a prominent portion of our mining work. These copper-bearing solutions were collected on the various levels between the outcrop and the lower adit, turned down through certain old stopes and fillings and were finally collected at the lower adit, the copper being precipitated from solution on pig iron. As we had no pay-ore on this adit at that time, our mining operations there consisted in lowering pig iron through the shafts, hoisting cement copper and attending to the underground precipitation plant.

As experience was gained in leaching copper ore in place, the following working cycle was evolved: (A) A period for oxidation; (B) A period for solution and (C) A period for the removal of the ferric oxide which had a tendency to seal up the sulphides and prevent further oxidation. The first two periods were obtained by dividing the ground into sections, some of which were oxidizing while others were leaching. The C period was obtained by running short drifts across the vein and allowing them to cave; stoping was in some cases resorted to, simply to give room for the settling of the vein matter,—while in bad cases the vein-matter in places was caved through to the gossan workings, and the material used to fill stopes below, in which the caved material was in due time again subjected to a leaching process. The method was entirely successful, but after my retirement it fell into disuse and the mine was eventually closed down.

I visited this property in the summer of 1901 after twenty-two years' absence, during twenty years of which the mine was idle. I found that the precipitation of copper from the mine drainage had long since been abandoned, because there was but little copper in the water, and that little could not be precipitated on account of the great quantity of ocher present. The ocher industry was, however, flourishing, large settling ponds having been constructed at the mouths of the adits, to collect this pigment, which commanded a ready sale. Some men were gophering through the softer and yellowish gossan on the back of the lode, in search of ocher of sufficient purity for pigment. One party had penetrated the gossan and reached the soft granular pyrites previously described; their picks and shovels, coated with metallic copper, excited no attention from the descendants of a keen and intelligent race of miners.

Here the shovel episode of 1750 is repeated, a century and a half later, in a slightly different manner. The copper sulphate in the moist pyritic sand and clay underlying the gossan attacked the iron of the tools, plating them with copper. The mining spirit and even tradition had, however, taken their departure, and the husbandman gophering between seedtime and harvest in the surface workings of a great vein, failed to realize the importance of the treasure that not only surrounded him, but actually plated the instruments of his toil.

PERSPECTIVE IN MINING.

By J. Parke Channing.

An Address to the Engineering Society of Columbia University.

The melancholy Jacques in 'As You Like It' says, "Call me not fool till Heaven hath sent me fortune." Call me not fool till Fortune hath sent me the opening up and equipment of a mine; for in mining there is so much that is not teachable, nevertheless learnable, that unless a man has this instinct, inherent in all capable persons, he can never hope to achieve success as an engineer. Each mine is, so to speak, a law unto itself, and not until the engineer recognizes this can he get true perspective in mining.

When you leave school and start out in practical life there are certain things that you have heard in your studies which have impressed themselves upon you. The reason for that impression would be hard for you to say. It may be that some particular thing had interested you because of some previous experience of yours. As a result you are really not able to define the proper relations between things, and that is one of the reasons why a man, after he graduates, should not start immediately on consulting work, or take entire charge of any enterprise.

It should be remembered that your course in the school is simply one of preparation; in other words, if you want to learn the mining business you have got to go into the mines and study it, just as if you were going to learn the dry-goods business you would have to go to a dry-goods store; to learn banking you would begin as a messenger or clerk and work your way up. The only advantage of going to a school of mines is that you get a technical education; you have a certain ground-work, which helps you out, and you also have gained a very important thing in knowing how to study, and knowing how to put two and two together so as to make four, and not three or five.

When a man goes out I would advise him to get a position at some mine or metallurgical works; it is not always desirable that it should be a particularly large mine or works; often he gets a better knowledge of what is going on by working in a smaller mine. When you take your first position in a mine I would advise you to work underground. This gives you an opportunity of watching mining work—sinking, drifting, stoping, timbering, tramming,—and it particularly gives you your first idea of the proper relation of things.

About fifteen years ago I was running the East New York mine at Ishpeming, Mich., and Mr. T. F. Cole, who is now manager of all the iron mines of the United States Steel Corporation, was running the Queen group of mines at Negaunee, Mich. We used to compare cost sheets, and his cost of development amounted to 2.5 cents per ton and mine amounted to 25 cents per ton. The reason for this was that his orebody was in area ten times as large as mine, and, although my shafts and cross-cuts were of the same length as his, the decreased tonnage was against me. This simply shows how the cost of development has got to be watched in its reference to the size of the ore deposit.

Take for example the opening of an iron mine at Lake Superior; after first striking the ore, the proper thing to do is to sink a small one-compartment shaft, one big enough for a good size bucket and ladder. With a shaft of this size you can get down to the ore and you can get out a good deal of ore. After you have gone down a hundred feet and have your drift, and have some idea of the size and shape of the orebody, you can, if you find the conditions warrant it, put in a larger shaft.

I have seen prospecting or development schemes wrecked by the man in charge spending a lot of money and time in sinking what he called a "working shaft," and when he got down found that there was nothing to work, or at least it could have been worked through a small shaft. In prospecting or small mine work you don't want to put in any brick set or water-tube boilers, and you don't want too large an engine. You want to get a cheap portable locomotive or upright boiler. It won't hurt to burn a few extra cords of wood.

On the other hand, you also want to try to get the idea of how far you should go on equipment without going to the point of over-equipment. Suppose, for example, that you finally take hold of a mine that is developed and is producing ore for shipment, and you find the mine is fairly well equipped when you get there. You may find a great many things that do not satisfy you or do not come up to your ideas. You may find a shaft-house that was badly arranged; you may find that the hoisting engine is one that uses too much steam, and the compressor is not the right thing; that the shaft is crooked, and there is no skip only a bucket. Now, don't be in too much of a hurry to tear all of these out; go ahead and see what you can do with them, until you get to the point that you can definitely see and figure it out in dollars and cents, just how much you will save if you were to sink a new shaft or straighten out the old one; or if you were to build a new engine house or put in a new engine.

Some of the men who were at Copperhill, Tenn., last summer remember the excellent plant we had at the Burra Burra mine; there was a brick house containing water-tube boilers; there was a big power-house which contained a first-motion hoisting engine, together with a cross-compound, two-stage, air compressor, with room to put in another one. There was also a shaft crusher house with its paraphernalia. When I equipped that mine I had at the same time the idea of later putting in a similar equipment at the London mine, and I had the plans drawn and everything arranged for it. But, after carefully thinking the matter over and seeing the tonnage that came from the latter mine, I finally came to the conclusion that I would make a great mistake to take this mine, which was only 500 ft. long and 30 ft. wide, as compared with the Burra Burra, which was 1,600 ft. long and 80 ft. wide, and give it the same equipment, notwithstanding the fact that it would be very nice to have two or three mines all provided with exactly the same type of equipment. So, instead of putting in a duplicate of the plant we had at the Burra Burra, I simply bought a cheap geared hoist and put it back of the London shaft in a small building covered with corrugated iron, and we used the same boilers that had been used there since the beginning of the development work.

The more you work the more you will find out that there is absolutely nothing that cuts down cost as much as tonnage. Another suggestion is this: When you start up a new mine don't be in too much of a hurry to build a nice house for the manager or superintendent, or too grand an office building. That is one of the things that an English engineer at a new mine looks after before anything else. The first thing he does is to build himself a house, and then he goes ahead and develops the mine. If your mine happens to turn out all right it is very good to have lived well while developing it; but if it does not turn out all right, then the house that you built will be a monument to your folly. While I don't advise you to open up a mine and live in a hut or tent all winter, you must use proper judgment as to the kind of a house you do build.

Take, for example, the cost of underground haulage; you know that the tendency nowadays is to do underground haulage, wherever possible, with electric locomotives. It figures out as very economical, and the electrical people will be only too glad to estimate on the cost of installation and operation, but you must remember that it is the opinion of most mining men that for medium distances, say 500 or 600 ft., you can do nothing better than to use man power, for the reason that you have to give the man loading the cars a rest and he gets this rest, if the grades are properly made, by pushing his car out and waiting a minute or two at the shaft until it is dumped, and then pushing the car back again. This is a change from loading the ore, and so he trams really for nothing.

At one of the mines in Bingham Canyon, Utah, they mine about 1,000 tons per day, and it comes out from one adit, where it is handled by four horses—two on each shift. At one of the adjoining mines they put in an electric tramming plant, and yet the tonnage they have could readily be handled by two horses. It does not take much figuring to see that two horses are cheaper in first cost and up-keep than an electric installation. So, therefore, in adopting any particular apparatus, or any particular method, you must take into consideration the tonnage and conditions under which it is operated.

When you come to metallurgical work this factor will be strongly emphasized. Remember that you do not want to get things too automatic. I remember when I was talking with the late Richard P. Rothwell, of 'The Engineering & Mining Journal,' about Mr. Edison's iron-ore plant out in New Jersey; he said that the plant was too automatic, and that once in a while there should have been an Italian with a shovel. You will notice that at some concentrating mills they may have a certain product that has to be handled or moved to some other part of the plant for re-treatment. In a small mill that amount is so slight that one man could shovel it as it accumulates, so that under these circumstances it is no use putting in an elevator or some other apparatus to handle this small amount of material. In a large mill, however, it may be really necessary to have something to carry your concentrate and middling from various points where they are produced to a central point.

In metallurgical work, modern practice is along the line of labor-saving devices, but in a small blast-furnace plant, where you have but one furnace, it is a question whether it would pay you to put in a so-called automatic charging apparatus. This is the method in use at large plants, where the ore is run into cars and pulled by an electric locomotive to the furnaces. I believe that there is no doubt that one could get better metallurgical results in copper-blast furnaces by hand-charging than by dumping the charge from cars, but the cost would over-balance the metallurgical saving.

In places like Mexico, where wages are only 75 cents to one dollar per day, it is sometimes impossible to get enough men to do the work, which, of course, necessitates your putting in labor-saving devices, not to save money, but to run at all. When we started in Tennessee labor was a dollar per day, and we seriously considered whether it would be advisable to put in a charging apparatus for the furnaces. But I felt that in the South it would be difficult at times to get labor, and so, fortunately, I put in electric charging cars, and they have been a great success. This question of shortage of labor is important in an agricultural country. Take for example in Mexico: In the springtime the men go off to plant their corn, and when it comes autumn they go off to harvest it. You notice the same thing in Tennessee. In the spring the men go to plant their crops, and when the time comes to harvest, off they go; they do this regardless of whether it would pay them better to attend to their farms or not. For instance, in Central Mexico, where laborers receive two or three dollars a day, a man will leave his position and go to harvest a $30 crop and lose $60 in wages.

A man can frequently be penny wise and pound foolish in refusing to advance the wages of good men. So do not always be looking at your payroll with the idea that the best way to economize is to cut down wages. The first thing that an untrained man does when he goes to a mine is to try to find some way to save money. He looks at the payroll and finds that it amounts to $10,000 per month and that the supplies are $5,000, and that the mine is running behind. He concludes that the only way to remedy the matter is to cut wages. He does this; his men loaf, or the best leave him, and he runs still worse behind.

You want to be careful to see what work per man per day you get, so therefore it is essential to remember when you are engaging labor to pay about the same wages that are being paid by others in the district, and be slow about reducing wages, but see that the men work. Try rather to keep your wages a little bit higher than anybody else, so that you can get the best men; let the other fellows keep the poor men. If you get a good man and pay him 25 cents more per day, he will probably do a great deal more work.

Perhaps the young men who were down in Tennessee remember the two big trammers we had at the Burra Burra mine. One of the men has been with us at least four years. He is a stout, husky fellow, and would load just as many cars as two ordinary men would do. Two ordinary men would load ore at 18 cents per car and perhaps get out 20 cars per day, while this one man would get out 16 or 18 cars himself.

Now, then, think of the money we would save if all our men were of that kind. It would mean that, if we wished to, we could practically double the output of our mines.

Another thing you want to bear in mind is this: Never be afraid to engage a man who knows more than you do; that is just the kind of a man you are looking for and just the one you want. A young man, as a rule, never wants to engage a man, or have any man under him, who knows more than he does. If you engage a foreman, get one that knows all about the handling of men. If you get an engineer, get an engineer that knows something that you do not know, one who has had lots of experience at other mines; his experience will be of great benefit to you in solving new problems that will arise.

While I have referred more to the economical details of operating, there is another perspective view which takes a long time to get, and that is a comparative idea as to value of mines—whether there is really a mine or not—or whether it is going to be a small mine or a large mine; and the only way you get that is by looking at as many different mines as you possibly can. Never lose a chance when you are traveling or looking for a job to go into a mine and through its workings. If you visit a mine of any importance, try to get a position in the underground workings, because that is one of the things they cannot teach a man and which can only be acquired by long experience and by looking at different properties.

I might say that your college experience has enabled you to make a quick decision. Really the main thing in mining is the capacity to see a property in a partially developed stage and from that inspection be able to determine whether it is going to be a mine. You find that it has 50,000 or 60,000 tons of ore in sight, and that it seems to have the earmarks of a large deposit, and you will advise your people to take it. If you have the courage of your convictions, if you think that it is good, stick to it and do not let the property go by. It is a great deal better for a man to make a mistake once in a while in getting hold of a property that does not turn out well than it is to let a good one go by. Still, however, if a young man makes two or three of these mistakes, it is likely to go against him in the long run; so I say to you, that when you start out, keep away from making these examinations, or, at least, from consulting work. It is very nice for you to go in as assistant to some engineer and help him in sampling and making determinations as to the value of mines, but do not get yourself into a position where you are called upon to pass judgment upon mines, because you may get yourself into some bad predicament, which will take a long time to live down.

I do not want you to understand that I would recommend a man starting out to begin as an assistant for an examining engineer. It is pleasant work, but I think that if one starts out in it he is liable to get rather a bad habit. Remember that the really successful consulting engineer is that man who has the capacity to size up a mine and to determine its value, and who thoroughly understands the cost of operating it. The whole tendency today is toward the mining of low-grade ore-bodies, and the question of operating expense is one of vastly more importance than the question of sampling and assaying the ore. For example, take the large porphyry orebody in Bingham Canyon, Utah; a man who examined it stated that it averaged less than 2%, yet his samples checked those of the mine manager within 0.01 per cent.

I recently examined a concentrating property in Nevada and the ore ran slightly under 3%, my samples checked on one of the mines within 0.03% and on the other mine within 0.02% of the results of the management. So you see that sampling, to a certain extent, is mechanical. In a large concentrating proposition of this kind the main thing is, what is it going to cost to mine and treat the ore. The original report on this mine by the manager had been taken over to Paris by the senior member of a large banking house and the figures as to the grade of the ore and the cost of treatment submitted to several French engineers, who simply laughed at the thing, and said it was impossible to treat ore of that grade. My examination showed that the conditions were exactly right for a big property—one that could be handled and show a large profit.

The trouble with the French engineers was that they had not kept up with the latest practice in concentrating or the latest methods in reverberatory smelting, and, while they were only two or three years behind, they might just as well have been twenty years behind the times. Therefore, I say to you that one of the most important things for a successful consulting engineer to have is a good knowledge of operating; the only way to get a true idea of operating is to work your way up from the bottom.

There is also one other important thing in mine examination and mine operation, and that you have to study and pay particular attention to, and that is the geology. If it is copper, you must keep yourself posted thoroughly on secondary enrichment; if you do not, you will have difficulty in getting along. It was about eight years ago that I examined the Highland Boy mine in Utah; the fourth and fifth levels were then opened up and showed an average of about 7.3% copper and considerable gold and silver, but I could see plainly that a good deal of that copper was in the form of chalcocite, which I knew was secondary. Another engineer, who came out about the same time, looked the property over, and, although he agreed with my sampling and assaying, he predicted that the sixth level would only go one per cent; he gave too great a weight to secondary enrichment; later developments showed that the lower levels went four per cent, and the result was that his people lost a fine property. This simply shows the necessity for keeping thoroughly up on the literature of ore deposits, because it is being added to day after day with great rapidity. Of course, this is not as absolutely essential to you as a knowledge of operating, because there are certain geologists who make a specialty of studying ore deposits. In case of necessity, you can get a man of this kind to help you out, and you perhaps may be able to make certain economic conclusions which he was not able to see. Some of the big mining companies keep an economic geologist at work all the time. In a small mining company that is impossible, and the geologic work devolves upon the mining engineer.

When you get a mining engineer you want to get a man that has been well schooled, one who understands geological conditions and is able to lay out future work. This has been done in the Butte mines in the last three or four years, and I believe there is not a single cross-cut in the mines of the Amalgamated that is not laid out on paper in the office before a stroke of work is done underground. Of course, you get a much better training now in geology than I ever got, not because your professors are any better, but simply because the subject is more thoroughly understood than it was twenty years ago.

Therefore, I say to you to study economic geology just as much as possible, because the question of ore deposition is one of such vital importance that you must forever have it before you. Whenever you see an orebody, and it is a particularly rich one, you want to look at it carefully and study the conditions and try to determine whether these conditions exist a hundred or a thousand feet down, or whether they are only local conditions. This capacity to see is one of the things that you can only learn by going around and seeing, and remembering what you see.