TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1900,-1901.

TOGETHER WITH THE PROCEEDINGS
FOR THE SAME YEAR.

VOLUME IV., ~~PART I~~.

AUSTIN, TEXAS:
PUBLISHED BY THE ACADEMY.
1901.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1900,

TOGETHER WITH THE PROCEEDINGS
FOR THE SAME YEAR.

VOLUME IV., PART I.

AUSTIN, TEXAS:
PUBLISHED BY THE ACADEMY.
1901.

COMMITTEE ON PUBLICATION.

FREDERIC W. SIMONDS,
R. A. THOMPSON,
H. L. HILGARTNER.

VON BOECKMANN, SCHUTZE & CO., PRINTERS, AUSTIN, TEXAS.

CONTENTS.

Some Advances Made in Our Knowledge of Immunity and Protective Inoculation.

[ANNUAL ADDRESS BY THE PRESIDENT.]

HENRY WINSTON HARPER,
AUSTIN, TEXAS.

THE TEXAS ACADEMY OF SCIENCE.

[ANNUAL ADDRESS BY THE PRESIDENT.]

SOME ADVANCES MADE IN OUR KNOWLEDGE OF IMMUNITY AND PROTECTIVE INOCULATION.

HENRY WINSTON HARPER,
University of Texas.

In grateful acknowledgment of the honor done me by the fellows and members of the Texas Academy of Science, it is my purpose this evening to bring before you "Some Advances Made in Our Knowledge of Immunity and Protective Inoculation."

"When we search the history of the development of scientific truth we learn that no new fact or achievement ever stands by itself, no new discovery ever leaps forth in perfect panoply, as Minerva did from the brow of Jove.

"Absolute originality does not exist, and a new discovery is largely the product of what has gone before.

" 'We may be confident that each forward step is not ordered by one individual alone, but is also the outcome in a large measure of the labors of others. The history of scientific effort tells us that the past is not something to look back upon with regret—something lost, never to be recalled—but rather as an abiding influence helping us to accomplish yet greater successes.'[1a]

"Again and again we may read in the words of some half-forgotten worthy the outlines of an idea which has shone forth in later days as an acknowledged truth."—*Sir William MacCormac.*[1]

The fact that persons once afflicted with smallpox rarely experienced a second attack of that disease when repeatedly exposed to it, was not only early observed, but made a matter of record by the Chinese long before the beginning of the Christian era. That the disease was contagious had long been a matter of common experience, and the means of protection against its ravages early became an interesting subject for investigation.

The Chinese observed that when the dried and pulverized material from smallpox pustules was blown into the nostrils of persons who had not experienced an attack of the disease, that the disease in persons thus infected underwent a milder course, was accompanied by a lower death rate, and conferred immunity against further attacks of smallpox. This early method of protection against the ravages of the disease became a common custom in China and India; but was later superseded by a more direct method of inoculation—that of introducing beneath the skin the scab of variolus pustules. The Chinese used the dried scab, the ordinary Hindoos the fluid pus, and the Brahmans pus that had been kept in wool for a period of twelve months. The latter is clearly an instance of using attenuated virus.

It should be remembered that smallpox extended westward to Europe during the sixth century, that it reached England toward the close of the ninth century, and at the time of the Crusades became widespread. In 1517 it was carried from Europe to Santo Domingo; reached Mexico in 1520, whence it spread throughout the New World. It was introduced into Iceland in 1707, and to Greenland in 1733.

It should be particularly noted, that in the invasion of new territory the virulence of smallpox at once became greatly intensified—in some instances nearly one-half the population being destroyed by it. Robertson records the death of three million and a half of people in Mexico alone as the result of the invasion of 1520. Again, the dark colored races seem to be more easily infected than Europeans.

The protective method of directly inoculating the pulverized variolus scab beneath the skin slowly traveled westward; so slowly, that it did not reach Western Europe until 1718, when Lady Mary Wortley Montagu introduced the process then in vogue in Constantinople. While the year 1718 marks the introduction of protective inoculation to the aristocracy of England, the practice had come into use among Scotch and Welch peasants at a much earlier date, which probably accounts for the next stage in the evolution of measures of protection against infectious diseases.

Herdsmen and milk-maids in both England and Schleswig-Holstein observed that occasionally on the udder of cows there appeared an eruption resembling smallpox; that this eruption could be communicated to persons in milking; and that persons infected with the cowpox were protected against an invasion of true smallpox. The fact that the notorious Mrs. Palmer, Duchess of Cleveland, was thus protected is evidence sufficient to show that such observations were common as early as 1663. In 1768 Fewster and Sutton in

London; 1774, Jesty, a Dorsetshire farmer; 1791, Pless, a Holstein teacher, and May 14, 1796, Jenner, confirmed these observations. It is true that the immortal work of Jenner began as early as the year 1769, for at that time, while a student under John Hunter, he heard a young country-woman, in whose presence the subject of smallpox was mentioned, say: "I can not take that disease, for I have had cowpox." Upon mentioning the subject to his master, Hunter replied: *"Do not think, but try; be patient, be accurate."* Jenner did try; was patient, was accurate; and on May 14, 1796, after years of patient labor, in his "Inquiry into the Causes and Effects of the Variolae Vaccinae,"[2] he experimentally established the following facts:

"(1) That this disease (cowpox) casually communicated to man has the power of rendering him unsusceptible of smallpox.

"(2) That the specific cowpox alone, and not other eruptions affecting the cow, which might be confounded with it, had this protective power.

"(3) That the cowpox might be communicated at will from the cow to man by the hand of the surgeon, whenever the requisite opportunity existed; and

"(4) That the cowpox once ingrafted on the human subject might be continued from individual to individual by successive transmissions, conferring on each the same immunity from smallpox as was enjoyed by the one first infected direct from the cow."

Thus it is seen that Jenner, by inoculating a cow with variolus matter produced in the cow an eruptive disease resembling smallpox, but of a milder type, and that the cultivation of this milder disease in the cow yielded a fixed virus (vaccine) which, transplanted to man gave rise to a still milder eruptive disease (vaccinia) possessing constant characteristics, and conferring upon persons who underwent it immunity against smallpox.

The older methods of inoculation against smallpox were quickly supplanted by the simpler and far safer method of vaccination; and since the introduction of the latter the appalling ravages of smallpox have been relegated to historical literature.

The subsequent development of vaccination is a matter of such general information there is no need of its further discussion here. It is sufficient to say that in the great majority (if not in all) of the cases of successful vaccination immunity against smallpox is conferred for an indefinite period, varying from three years to many years—averaging three to seven years—in some cases for life; and that compulsory vaccination and revaccination offers the safest and surest protection against this loathsome disease.

The pronounced success of vaccination gave great impetus to the investigation of the problem of immunity, and the annals of the nineteenth century contain a voluminous record of the prolonged and patient efforts of a host of brilliant workers whose contributions have at least laid the foundation upon which the solution of the problem may, in the future, be built. The building of this foundation can not be recounted here; but it will be necessary to mention some of the materials of which it is made that the latest progress may be intelligently discussed.

As in the case of smallpox, it had long been a matter of common observation that a number of the acute infectious diseases occur but once in the same individual. Whooping-cough, measles, scarlet fever and yellow fever are notable examples of acute infectious diseases, one attack of which usually confers immunity against subsequent attacks of the same disease. It was also observed that some infectious diseases confer a very evanescent type of immunity, and that others confer no immunity whatever.

From the standpoint of immunity the infectious diseases may be easily divided into three classes:

1. Diseases one attack of which confer immunity against subsequent attacks of the same disease.
2. Diseases one attack of which confer immunity against subsequent attacks of the same disease for only short periods of time.
3. Diseases an attack of which confer no immunity whatever.

It would seem that these facts, coupled with Jenner's discovery of a fundamental and practical method of producing artificial immunity, clearly outlined the path for future workers to follow; but, strange to say, the nineteenth century was well on its way before this important route found many followers.

The failure to fully appreciate Jenner's brilliant discovery, and to apply his method to the study of other infectious diseases, finds an explanation in the hazy theoretical conceptions of the cause and nature of infectious diseases which prevailed during the early part of the century. The investigations of fermentation by Astier, Sette, Franz Schulze, Cagnaird de Latour, Schwann, Fuchs, Remak, Mitscherlich, Helmholtz, and others, did much toward clearing the haziness of that period; but it was the monumental work of Pasteur that "finally established the truth of the view that all processes of fermentation and putrefaction alike are caused by living things, and that in each different fermentation different kinds of microbes are concerned."[3] In the light of newer knowledge this statement needs revision. The investigations of Koch on anthrax soon followed, and then came the growth of pure cultures of several pathogenic bacteria.

"The work of Pasteur and Koch afforded the first basis on which the study of artificial immunity could be again undertaken. The possibility of voluntarily producing a number of the most important infectious diseases of men and animals, and of modifying at will pure cultivations of bacteria, either, according to Jenner's precedent, by passage through the animal body, or otherwise in artificial culture media, laid the foundation on which advancement could proceed. Pasteur himself was the first, after Jenner, to produce an artificial immunity by using an attenuated virus; and he was also able to introduce the procedure to some extent into practice with most beneficial results. Still the theoretical explanation of all these facts lagged far behind their practical effect. The very able investigations of Metschnikoff and his theory of phagocytosis were, to many investigators, inconclusive."[4]

Numerous attempts were made to formulate adequate theoretical explanations of the accumulated facts concerning the phenomena of infectious diseases. The followers of Sydenham looked upon the specific disease itself as an *entity;* while Lotze and Virchow viewed it as a *process.* It was clear that a mechanical or dynamical process could not be a living entity. The physiologists Haller, Rail and Johannes Müller had established this principle for normal life processes, and its extension to abnormal life processes was simple enough. "Whatever be the outside forces that act, the eye perceives only light, and the ear only sound; the glands simply secrete and the muscles contract. It is, therefore, the internal condition of the organism, of its organs, tissues or cells, that alone determines the character of the effect. The impulse that must come from the outside to produce these effects is called the stimulus. Hence, there must exist a fundamental internal organization; that is to say, a predisposition to something external * * *. Disease, then may be regarded as the effect produced by quantitative changes in normal conditions, either when the physiological organization is too feeble or the stimulus too intense."[5] Disease may be viewed as a phenomenon of adaptation.

Against this conception, the parasitic or germ theory developed by Plenciz, Eisenmann, Henle, Davaine, Pasteur, Klebs, F. Cohn, J. Schroter, and Koch, appeared to introduce an entirely new qualitative element. It asserts: "That many diseases are due to the presence and propagation in the system of minute organisms having no part or share in its normal economy."[6]

Another conception is that of Pettenkofer, which holds that the determining cause is to be found in the external conditions which vary according to time and place.

It is not difficult to see that these theories are upholding entities as the cause of disease. While a kernal of truth is to be found in each, they all fail to realize the continuity of causes in the sense of modern exact science. "The true and sufficient cause of any effect is always something internal, something that follows from the kind and amount of initial energy, and from that quality and quantity alone and entirely. * * * It is the absolute thing 'that exists behind all change and remains primordially the same,' as Helmholtz expressed it."[7] Or as the modern physicist would put it: potential energy = cause, kinetic energy = effect; and as a liberating impulse will change potential energy into kinetic energy, so a liberating impulse will change cause into effect.

The cloudiness that characterizes many of the theories that have sought to explain the phenomena of infectious diseases is largely a legacy of Kantism, and is clearly out of place in these days of modern science. It is somewhat strange that "ontological toys" are still to be found in the workshop of some really brilliant investigators of natural phenomena. Nevertheless, they are there—which explains some explanations that do not explain.

The parallelism which subsists between the phenomena of fermentation, infection and immunity suggests the mental route to be traveled if an insight into our problem is to be gained; and for this reason it is necessary to first point out a few facts about

FERMENTATION.

If the phenomena of matter be defined as periodic functions of the atomic and molecular masses which constitute it and the rates of motion of these masses, and the chemical unit be viewed as a "center through which energy manifests itself," then the theories of modern chemistry should supply an explanation of the phenomena of fermentation.

The crucial test of every theory which seeks to explain fermentation is the satisfactory explanation of the following phenomena:

Enzymes appear to be capable of disrupting complex chemical bodies without undergoing any apparent chemical change themselves—that is, they bring about a chemical change in disproportionately large quantities of material. When the newly produced subtances attain a certain concentration the further action of the enzyme is inhibited, but its action is reasserted when the concentration of the zymolytic products is again lowered. Maximum, minimum and optimum temperature and pressure influence these changes. The introduction of certain chemical bodies also exert an accelerating or retarding influence; and phenomena of *selective* action are likewise to be found.

Many hypotheses have been submitted. Very ingenious explanations of some of the phases of fermentation are to be found in them; but under the searching light of completer knowledge their incompleteness is sooner or later developed. Many of the modern theories are little else than translations of the earlier hypotheses into terms of modern scientific terminology, so that the later literature is laden with modern extensions of the catalytic theory of Berzelius, Beal's bioplastic theory, Justus von Liebig's physical theory, the germ theory, etc.

Interesting and enlightening as some of these theories are their full consideration is not within the purpose of this address, the limits of which will permit only a brief and incomplete review of some of the more modern conceptions of fermentation, to which attention is now asked.

The more recent investigations of the organized and unorganized (soluble) ferments has dealt a severe blow to the vitalistic theory of fermentation. Hansen's admirable biological researches upon the yeasts, followed by the important investigations of Buchner, A. Croft Hill, Emil Fischer, and many others, brought to light many interesting hitherto hidden facts; and it now seems clear that all the phenomena of fermentation may be explained from a purely chemical basis. The so-called organized ferments appear to be "active proteids," and the unorganized ferments, or enzymes, are mostly proteid-like bodies presenting great differences in the complexity of their chemical structure.

Hueppe[8] looks upon "active proteid" as "a kind of intermediate stage between lifeless 'nutritional' proteid and living cells"; that it "appears like an anhydride of dead proteid," inasmuch as hydration converts it into an inactive form. Investigations of Bokorny and Loew[9] demonstrated the existence of active proteid in many plants. Loew[10] speaks of it as reserve protein matter of a highly labile nature, and that it differs from all other reserve proteins. He called it proto-protein, and suggested that it is the "material which, by being converted into organized nucleo-proteids, forms living matter." Protein comprises all kinds of albuminous matter, while proteid is used to designate complex compounds of proteins, such as nucleins, haemaglobin, etc. *Labile* chemical compounds are unstable bodies which easily undergo chemical change. Labile atoms or groups of atoms are atoms or groups of atoms which readily migrate from a center of instability to one of stability.

When the migration is intramolecular a stereoisomeric compound is the product of the change; when the migration is extra or intermolecular disruption of the molecule takes place. Loew[11] points out the necessity of distinguishing between "potentially labile and kinetically labile compounds; in other words, between static labile and dynamic labile"—using the potential chemical energy in the sense of intramolecular chemical energy. Nitroglycerole and certain other explosive organic compounds represent the potential type, while examples of the kinetic are found in the aldehydes and ketones.

The energy stored in a labile compound is beautifully illustrated in the explosion of the trinitrate of glyceryl — $CH_2(ONO_2).CH(ONO_2).CH_2(ONO_2)$, which, when heated to 257° C., or when struck, explodes with great violence. The products of the decomposition are represented by the equation:

$$4C_3H_5.(NO_3)_3 = 12CO_2 + 10H_2O + 6N_2 + O_2.$$

At the temperature of the explosion all these products are gases, and at atmospheric pressure will now occupy the space of about 10,400 litres, having expanded about 18,324 times its original volume.

Another instance is that of mercury fulminate $[(C{:}N.O)_2 Hg_2 + {}^1/_2H_2O]$, which develops a pressure of 43,000 atmospheres by detonating in its own volume.

Chemical changes partially or completely destroy the statically labile compounds, while the dynamically labile compounds readily pass into isomeric or polymeric compounds as a result of atomic migrations, or by polymerization. The classic illustration usually given of the production of an isomeric compound produced by atomic migration is Woehler's famous discovery: the transformation of ammonium cyanate into urea, which he accomplished in 1828, by evaporating an aqueous solution of ammonium isocyanate. The transformation is represented by the equation:

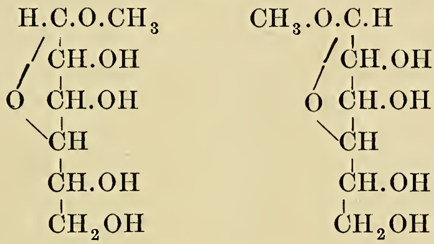
$$O{:}C{:}N.NH_4 \longrightarrow O{:}C\begin{matrix} \diagup NH_2 \\ \diagdown NH_2 \end{matrix}.$$

Many others can be cited.

Noting that labile compounds are more easily attacked by chemical agents than stable ones, Loew[12] has elucidated the action of many poisons. He says: "A systematic toxicological review shows us, among other things, that all compounds acting upon aldehydes and all that easily attack labile amido-groups are poisonous for all kinds of living protoplasm, which fact led me to infer that the lability of the plasma proteids is caused by the presence of aldehyde and amido-groups within the same molecules. * * * The *primum movens* in the living protoplasm must be defined as a mode of motion of labile atoms in the plasma proteins; that is, as a *special case of chemical energy.*" According to Loew, the enzymes belong to the dynamically labile compounds.

While the chemical structure of the enzymes is not yet known the researches of Emil Fischer go to show that a knowledge of their constitution is not far beyond our reach. In the fermentation of the sugars Fischer[13] has shown that the enzymes can only "attack those sugars which possess a molecular configuration corresponding to their own,"—that is, they must fit each other "as the key fits its lock." Viewing the enzymes as nucleo-proteid bodies, and as being optically active, he reasoned that *their molecules must have an asymmetric structure.* Their selective action toward α and β methyl-glucosides strongly supports this view.

According to Fischer, two methyl-glucosides are formed by the action of hydrochloric acid (HCl) on a solution of *d* glucose in methyl alcohol, and their configuration is given as follows:



One is called α, the other β, and their difference is found in the configuration of the one asymmetric carbon atom, yet the enzymes which attack the α will not attack the β, and *vice versa.* This important discovery sheds a world of light upon the vexed problem of fermentation, and will therefore help to explain many of the obscure phenomena of diseases and of immunity. It will also find a place in the investigation of many of the difficult problems of physiological chemistry. A very admirable feature of Fischer's hypothesis is its capacity to receive aid from, and give aid to, several other hypotheses—it possesses a wide range of applicability.

In 1892, our esteemed colleague, Professor J. W. McLaughlin,[14] in his book on "Fermentation, Infection and Immunity," elaborated a "Physical Theory," a quotation from which is here presented. After developing the modern conception of complex molecules, Dr. McLaughlin goes on to say: "When we add to this conception of atomic and molecular union, that of atomic vibrations in unvarying periods of time which are distinctive of each kind of atom, and that of etherial wave-motions vibrating in equal periods with the atoms that produce them, the law of 'interference' enables us to understand how atomic wave-motions may be supplemented or antagonized by other atomic wave-motions, and how molecular wave-motions may, likewise, be similarly influenced by other molecular waves; that, in fact, the molecular waves which give a substance its energy will vary with molecular grouping. Now it is in these principles of molecular dynamics, and in chemistry and biology, that, we believe, is to be found the explanation of cell metabolism—constructive and destructive—of fermentation, of infection and immunity." On page 66, he says: "It is only when the molecular vibrations of a ferment, whether this be a living, organized ferment, or a non-living, unorganized ferment, coincide with those of a fermentable substance, that the latter may be disrupted by the former, and fermentation ensue." While these two quotations do not adequately present Dr. McLaughlin's theory, they suggest a connecting link with the physical hypothesis of de Jager.

"Starting with Naegeli's view that fermenting yeast-cells emit vibrations which pass out of the cells and decompose the sugar in the solution surrounding them, de Jager suggests that the enzymes may be regarded not as substances at all, but as the vibrations themselves; that is, as properties of substances rather than material bodies."[15] He compares them to light, electricity, magnetism. That fermentation does not depend upon chemical action of a molecular substance, but that chemical transformations are brought about by physical forces. Maurice Arthus[16] has very ingeniously elaborated the theory of de Jager.

O'Sullivan and Tompson[17] have shown that invertase is capable of inverting more than 100,000 times its own weight of cane sugar without exhausting itself; and Tamman[18] proved that under proper conditions the enzyme is decomposed during its activity with extreme slowness. These reactions find their parallel in the action of nitric oxide in the manufacture of sulphuric acid, and in the action of sulphuric acid in the production of ethyl oxide; and Bredig and von Berneck[19] have recently shown that "one gram-atom (193 grams) of colloidal platinum diffused through seventy million litres of water shows a perceptible action on more than a million times the quantity of hydrogen peroxide."

In these four instances it will be observed that the invertase, nitric oxide, sulphuric acid, and colloidal platinum acted solely in the capacity of catalyzers; that is, they modified the time factor of the reaction—the positive cataylzers accelerating, and the negative catalyzers retarding the velocity of the reactions. Catalyzers, then, serve in the capacity of *liberating impulses.*

That zymohydrolysis is a chemical action finds further support in the recent work of A. Croft Hill[20] on "Reversible Zymohydrolysis." By varying the concentration of mixtures of glucose and maltose he found that the equilibrium point of these two sugars was reached when 85.5% of glucose and 14.5% of maltose were present. Increasing the glucose beyond 85.5% sent the hydrolysis one way, and the reaction reversed when the maltose was increased beyond 14.5%. This is in strict conformity with the law that *"every reaction proceeds to a state of equilibrium, with a definite reaction velocity."*

The phenomena of reversible reactions have been well worked out, and Konowalow's[21] reaction of acetic acid upon pentene:

$$CH_3CO.OH + C_5H_{10} \rightleftharpoons CH_3CO.O(C_5H_{11}),$$

has been shown to conform to the requirements of the law of mass-action by Nernst and Hohmann.[22]

Another very important observation made by Bredig and von Berneck[23] is that "relatively minute portions of certain substances are able to inhibit the catalytic action of platinum, and that these are substances which exert a markedly poisonous effect on the living cell and on enzymes. 1/345,000 gram-molecule per litre of hydrogen sulphide already exerts a strongly restraining action. 1/1000 gram-molecule per litre of hydrocyanic acid stops it entirely, and much less is able to retard it greatly. Carbon disulphide, and mercuric chloride show a similar behavior." This again parallels the action of ferments and antiferments.

Were it necessary, many other interesting parallels could be drawn to show the intimate connection between the phenomena of fermentation and the phenomena of chemical action; but this must suffice to authorize the statement that the complex phenomena of fermentation can be best understood when viewed from the pinacle of modern chemical theory:—the Avogadro-van't Hoff Rule, the Phase Rule, Electrolytic Dissociation, and the Doctrine of Energy.

Having shown that chemistry helps us to understand fermentation, let us see what light it is capable of sheding upon

INFECTION.

The fact that the poisonous action of the bacteria is due to the soluble products formed by the bacteria was established by Panum in 1874. Later, Koch, Chauveau and others succeeded in separating these poisons from the bacteria, and by inoculating animals with them proved that the proliferation of a number of pathogenic organisms in the body was less injurious to the body than the soluble poisons produced by them. Brieger viewed these poisons as organic bases, the so-called ptomaïns; but, subsequently some of them were shown to be either proteid or proteid-like bodies, and many of them acted not unlike digestive ferments. Brieger and Fränkel named the proteid-like bodies toxalbumins. Among the toxins are uncrystallizable poisons the complex chemical structure of which has not yet been made out. The ptomaïns are crystallizable products of bacterial activity somewhat analogous to the vegetable alkaloids. Some possess toxic properties, while others do not. The chemical structure of some of them is well known, but the structure of toxalbumins is a problem for future work.

In his work on "Ptomaines and Leucomaines," Vaughan[24] points out a very interesting chemical relationship between some of the non-poisonous and poisonous members of the cholin group. Starting with trimethyl-ethyl-ammonium hydroxide, by oxidation cholin, neurin, betaïn, and muscarin are derived as follows:

$$\begin{array}{l} CH_3 \\ | \\ CH_2 \\ | \\ N(CH_3)_3OH \end{array} + O = \begin{array}{l} CH_2.OH \\ | \\ CH_2 \\ | \\ N(CH_3)_3OH; \end{array} \begin{array}{l} CH_2.OH \\ | \\ CH_2 \\ | \\ N(CH_3)_3OH \end{array} - H_2O = \begin{array}{l} CH_2 \\ \| \\ CH \\ | \\ N(CH_3)_3OH; \end{array}$$

(Trimethyl-ethyl-ammonium hydroxide) (Cholin) (Cholin) (Oxyethyl-trimethyl-ammonium hydroxide) (Neurin: Vinyl-trimethyl-ammonium hydroxide)

$$\begin{array}{l} CH_2.OH \\ | \\ CH_2 \\ | \\ N(CH_3)_3OH \end{array} + O_2 = \begin{array}{l} CO.OH \\ | \\ CH_2 \\ | \\ N(CH_3)_3OH; \end{array} \begin{array}{l} CH_2.OH \\ | \\ CH_2 \\ | \\ N(CH_3)_3OH \end{array} + O = \begin{array}{l} CH_2.OH \\ | \\ CH.OH \\ | \\ N(CH_3)^3OH. \end{array}$$

Cholin) (Betaïn: (Trimethyl-glycocoll) (Muscarin: Dioxyethyl-trimethyl-ammonium-hydroxide)

The structural formulæ show the little change that is necessary to convert an innocuous substance into a very poisonous one, and vice versa. Cholin is only poisonous in large doses, while very small doses of neurin and muscarin are highly poisonous. Betaïn is not poisonous.

Methylguanidin $\left(NH : C \begin{array}{l} \diagup NH_2 \\ \diagdown NH. \end{array} (CH_3)\right)$, trimethylenediamin $\left(CH_2 \begin{array}{l} \diagup CH_2.NH_2 \\ \diagdown CH_2.NH_2 \end{array}\right)$, and tyrotoxicon (diazobenzene-potassoxide, $C_6H_5.N_2.OK$) are three other poisonous ptomaïns whose chemical structure is well known. Typhotoxin ($C_7H_{17}NO_2$) is said to be the toxin which gives rise to the typhoid intoxication, and Brieger has been able to separate from tetanus cultures four bases: tetanin ($C_{13}H_{30}N_2O_4$), tetanotoxin ($C_5H_{11}N$), spasmotoxin, and one other unnamed toxin. According to Brieger, each of these is capable of inducing tetanic intoxication. Against this last statement is opposed the further statement that tetanus toxin is a toxalbumin.

Roux, Yersin, and others, succeeded in isolating, seemingly in a state of purity, from the cultures of the Klebs-Loeffler bacillus a toxalbumin, soluble in water, which, when inoculated into a guinea-pig, produced the phenomena characteristic of diphtheria. Prosecuting this line of investigation, these and other investigators have isolated characteristic toxalbumins from cultures of other germs. These toxalbumins have been divided into two principle groups by Brieger and Fränkel, the classification being based upon their solubility. As previously stated, they are proteid-like bodies, highly complex and poisonous. Their further properties may be considered later; but in passing, an idea of their virulence should be given.

"A tetanus toxin has been prepared, of which 0.00005 milligrammes killed a mouse weighing 15 grammes; a man weighing 70 kilogrammes, with the same susceptibility, would be killed by 0.23 milligrammes. This would make the poison 300 times more potent than strychnine."[25]

Closely related to the toxins which arise as products of bacterial activity there is another group of toxic substances which arise in the living animal tissues as the products of either hyper or of retrograde metabolism of the protoplasm, or result from fermentative action. Some of these are proteid-like bodies (toxalbumins), while others are organic bases (leucomaïns) not unlike the vegetable alkaloids.

The chemical structure of many of the leucomaïns is well known; but the same cannot be said of the toxalbumins. The development of their structure must await the unraveling of the proteids—their chemistry seems to flow in channels parallel with the chemistry of the albumins, globulins, albuminates, proteoses and peptones. At least the poisonous principle clings to these products.

The venom of the snake belongs to this class. According to the researches of S. Weir Mitchell,[26] E. T. Reichert,[27] T. R. Fraser[28] and others, snake venom is a very complex mixture, containing, in addition to the poisonous substances, several bodies that are non-poisonous. The poisonous substances are not ferments. Fraser says: "They are substances that produce effects having a direct relationship to the quantity introduced into the body. This quantity in the case of each serpent varies with its size and bodily and mental condition; with the nature of the bite—whether both fangs or only one has been introduced, whether they have penetrated deeply or only scratched the surface; and with other circumstances related to the serpent, such as whether it had recently bitten an animal or not, and thus parted with a portion or retained the whole of the venom stored in the poison glands. * * * The quantity required to produce death being very exactly related to each pound or kilogramme of weight."[29] Fraser found the minimum-lethal dose per kilogramme to be: "For the guinea-pig (of dried venom), 0.00018 gm.; for the frog, 0.0002 gm.; for the rabbit, 0.000245 gm.; for the white rat, 0.00025 gm.; for the cat, somewhat less than 0.005 gm.; and for the grass snake *(Tropedonotus natrix)*, the relatively large dose of 0.03 gm."[30]

It is significant that the toxicity of cobra venom is not the same for all animals. Furthermore, it is exceedingly interesting to find that the experiments carried out by Fraser, *in vitro* and in the animal organism, leave practically no room for doubt that the poisonous action of snake venom and the antagonistic action of antivenin are both chemical. In the unprotected animal snake venom injected beneath the skin or into the blood stream gives immediate evidence of reactions of an endothermic character; but when in the same manner it is introduced into protected animals evidence of exothermic reactions is elicited. When introduced into the stomach of an animal snake venom not only fails to induce symptoms of poisoning, but exhibits a neutralizing action upon inoculated venom, and in the uninoculated animal confers immunity against snake venom. Moreover, the ratio between venom and antivenin is quantitatively brought out in the experiments of Fraser. All this can be shown to be in conformity with well known chemical laws.

Numerous examples which illustrate the chemical nature of the action of toxalbumins might be drawn from various intra- and intercellular protoplasmic bodies found in the vegetable and animal kingdom, but time will not permit their multiplication here. A bountiful supply is to be found in recent biochemical and medical literature, and interested persons are referred to that source.

The specific phenomena of these poisons as exhibited in the human body when toxic quantities are taken will be found in nearly every text-book of modern medicine, so there is no need to repeat them here.

What has been said of the chemistry of fermentation is equally applicable here. Specific illustrations and their enlargement just now would take us beyond the limits of this address; for that reason it is well to pass on to the consideration of the next phase of the subject:

IMMUNITY.

The problem of immunity is so closely entwined with that of protective inoculation it will be easier to discuss the two conjointly.

In its broadest sense, immunity represents that state of the living organism (animal or vegetable) which enables it to resist the toxic action of substances, whether such substances be introduced from an external source or are developed within the organism. Specific immunity is a state of immunity against a specific substance. This may be *natural,* as when the organism is normally *non-susceptible;* or it may be *artificial* (acquired), as in the case of protection against disease developed by a previous attack of the disease (as in smallpox), or by some other artificial means (vaccination, for instance).

Vexed as the problem is, much enlightenment is to be gained from an investigation of artificial immunity. Recalling the researches of Jenner, and the quotation from Ehrlich relative to the work of Pasteur, at that time it appeared as though artificial immunity was brought about by specific micro-organisms. Opposed to this view the investigations of Toussaint, Chauveau, Salmon and Smith, Roux, C. Fränkel, and others, brought forward evidence to show that artificial immunity could be induced by the "metabolic products" freed from bacteria—accustoming the organism to the specific poison seemed all sufficient. Later it was shown by Hueppe, Gamaleia, and Buchner that the specific toxins found in the culture fluid outside the bacterial cells were not identical with the protective substances found in the germs and their metabolic products.

At this point Hueppe[31] says: It has been "established that: 1, Undergoing the disease; 2, Inoculation with attenuated germs; 3, Inoculation with disease germs which have become wholly impotent; 4, Inoculation with saprophytes; and 5, Inoculation with the metabolic products of the parasite, can all confer immunity; while, 6, Inoculation with the specific poisons effects no immunization." Then followed the experimental proof that completely attenuated bacteria can no longer produce the specific poison. This effectually separates the protective substance and the poison.

The next important advance was the discovery of substances in the blood serum of animals immunized against diphtheria and tetanus that were able to specifically protect other animals against the toxines of these diseases. This discovery was made by Behring, and it at once opened an entirely new and promising field for investigation.

December 3, 1890, in No. 49 of the *Deutsche med. Wochenschrift,* Behring and Kitasato published an article, "Ueber das Zustandekommen der Diphtherie-Immunität und der Tetanus-Immunität bei Thieren," in which the statement is made that: "The blood of tetanus-immunized rabbits possesses the property of destroying tetanus toxin. This is possessed by the extravascular blood, and is the cell free serum." They showed that the blood serum of non-immunized animals did not possess this antagonizing action, and that the prepared serum was of therapeutic value. Ogata and Jasuhara[32] proved that blood serum from an animal naturally immune contained substances which, when injected into mice, conferred upon them the same type of immunity. Tizzoni and Cattani[33] (1891) found that the quantitative protective value of the blood serum of animals naturally immune to tetanus (the dog, for instance) could be greatly increased by repeated injections of gradually increasing amounts of tetanus-toxin; and that such serum possessed decided therapeutic value when inoculated into animals suffering from tetanus. This line of investigation has been greatly extended and enriched by Behring, Roux, Koch, Yersin, Haffkine, Pfeiffer, Buchner, Sanarelli, Ehrlich, and others, and as a result, there is to be found in the open market today a variety of antitoxin sera, such as antidiphtheritic, antitetanic, Marmoreck's antimycotic, antipneumococcic, antibubonic, antirhabic, yellow fever, etc.

March 20, 1896, Professor Thomas R. Fraser, M. D., at the Royal Institution of Great Britain, presented a very important contribution on "Immunisation Against Serpent's Venom, and the Treatment of Snake-bite with Antivenene," in which, for the first time, the quantitative relation between the "toxic" and the "anti" substance is shown. The contribution is rich in splendidly martialed experimental evidence which leads the author to the logical conclusion: that so far as snake venom is concerned, the antidotism of the "antivenene" is not the result of physiological reaction, is not due to phagocytic action, nor to the "resistance of tissues"; but "as I have already pointed out, a chemical theory, implying a reaction between antivenene and venom, which results in a neutralization of the toxic activities of the venom, is entirely compatible with the observed facts."[34]

Another significant fact of chemical importance observed by Fraser is, that in carrying out the immunizing process, "the saturation point of the blood for antivenene is reached before the possible maximum non-fatal dose of venom has been administered." The protective value of venom and "antivenene" when administered by the stomach has already been mentioned.

By this time the use of diphtheria antitoxin as a therapeutic agent in the treatment of diphtheria had become firmly established. The variation in the results obtained caused Ehrlich to search for a quantitative relation between the toxin of diphtheria and the antitoxin of diphtheritic serum. The result of Ehrlich's investigation is to be found in the Croonian lecture delivered by him before the Royal Society, London, March 22, 1900. "By means of test-tube experiments with suspended animal tissues" he brought out some very interesting facts. "The relations were simplest in the case of red blood corpuscles. On them, outside the body, the action of many blood poisons, and of their antitoxines, can be most accurately studied, *e. g.*, the action of ricin, eelserum, snake-poison, tetanus toxine, etc. * * * By means of these test-tube experiments, particularly in the case of ricin, I was able, in the first place, to determine that they yielded an exact quantitative representation of the course of the processes in the living body. * * * It was shown that the action of toxine and antitoxine took place quantitatively as in the animal body. * * * It was proved in the case of certain toxines—notably tetanus toxine —that the action of antitoxines is accentuated or diminished under the influence of the same factors which bring about similar modifications in chemical processes—warmth accelerates, cold retards the reaction, and this proceeds more rapidly in concentrated than in dilute solutions. * * * The knowledge thus gained led easily to the inference that to render toxine innocuous by means of antitoxine was a purely chemical process, in which biological processes had no share."[35]

The distribution of the toxins and the antitoxins in the system is a matter of prime importance, yet not more than a beginning has been made looking toward their localization. That they do possess a selective action has been established by Stokvis, Dönitz, Pfeiffer, Marx, Wasserman and Roux, and these facts throw a great deal of light upon the phenomena of incubation, time reactions, antitoxic action, protective action, serum therapy, etc.

The phenomena of agglutination and lysogenic action, the recent work of Buchner in Germany and Bordet in France on haemolysis, and some experimental work on ionic reactions done in my own laboratory deserve consideration here; but time presses for a summation, and they must be passed without further comment to a future occasion.

From accumulated facts, *acquired immunity* is separable into two distinct types: (The following classification is borrowed from Muir and Ritchie.)[36]

A. Active Immunity—*i. e.*, produced in an animal by an injection, or by a series of injections, of non-lethal doses of an organism or its toxines.

1. *By injection of the living organisms.*
   - (*a*) Attenuated in various ways. Examples:—
     - (1) By growing in the presence of oxygen, or in a current of air.
     - (2) By passing through the tissues of one species of animal (becomes attenuated for another species).
     - (3) By growing at abnormal temperatures, etc.
     - (4) By growing in the presence of weak antiseptics, or by injecting the latter along with the organism, etc.
   - (*b*) In a virulent condition, in non-lethal doses.
2. *By injection of the dead organisms.*
3. *By injection of filtered bacterial cultures, i. e., toxines; or of chemical substances derived from these.*

These methods may also be combined in various ways.

B. Passive Immunity, *i. e.*, produced in one animal by injection of the serum of another animal highly immunized by the methods of A.

1. *By antitoxic serum, i. e.*, the serum of an animal highly immunized against a particular toxine.
2. *By antimicrobic serum, i. e.*, the serum of an animal highly immunized against a particular organism in the living and virulent condition.[36]

The protective value of active immunity extends through a considerable period of time, while that of passive immunity is evanescent.

An adequate explanation of this vast array of facts is yet before us. The explanation in detail cannot be given tonight; that must await another time; but some generalizations must be made.

1. *Pasteur's Theory of Exhaustion* of the pabulum is disproved by the fact of passive immunity.

2. The *Theory of Retention* will have to be greatly modified before it can explain many facts with which it is now in opposition.

3. The *Theory of Acclimatisation or Habituation* has limited application, and like the theory of Adaptation, takes too little cognizance of details.

4. *Metschnikoff's Theory of Phagocytosis* falls before the facts of passive immunity; and

5. The *Humoral Theory* only presents another phase of its own evolution.

6. Buchner's hypothesis, which explains immunity as being due to the reactive changes in the integral cells of the body resulting from the action of chemical products absorbed from the seat of vaccination or inoculation, is strongly supported by experimental evidence; and

7. Ehrlich's[37] side-chain (Seitenkette) theory presents an exceedingly ingenious and interesting explanation of the phenomena of immunity adduced by experiments *in vitro* and *in vivo*..

By elimination the problem may be somewhat simplified. The facts themselves may be roughly divided into two groups: 1. Biological; and 2, Chemical; and the explanations will then be either biological or chemical. In the ultimate analysis: the Biological explanation will rapidly pass from the body as a whole to its respective organs and their respective cells, to the nucleated cells, and finally to the biogen of the nucleus; while the Chemical explanation will describe the cycle that begins with the minutest atomic reaction, passes onward through more and more complex intra- and intermolecular synthetic and analytic changes so long as chemical equilibrium is disturbed; but eventually finds its beginning and its end—cause and effect—in energy potential, energy kinetic, liberating impulse.

That the problem of immunity will be solved is only a question of time. The active research now in progress is rapidly dissipating the unknown; and when the chemical structure of the various animal proteids becomes a known quantity their interaction will be readily seen and the solution of the problem will be an accomplished fact.

The problem is a biochemical one, and biochemists will solve it. Many if not all the phenomena of fermentation, infection and immunity are explainable in terms of modern chemistry, and since modern chemistry is firmly founded on the doctrine of energy we have to consider merely the terms: ENERGY POTENTIAL, ENERGY KINETIC and LIBERATING IMPULSE.

I am conscious of having failed to bring before you a large mass of newly accumulated interesting facts which should be considered in this connection; but the largeness of the subject, together with the enormous accretions annually made to its literature, renders it impossible to present a complete survey of so immense a field of labor in the address of an evening. What has been said is little more than a beginning of what has been done in this line of biochemical research—the promise of its future remains to be told.

Beside the great intellectual gain must be placed the immense practical benefits such investigations have secured for man—as witnessed in the saving of millions of lives of human beings, many times more of the lower animals, and large areas of plant life. They have ever made for the betterment and happiness of man, and for the highest progress of civilization, and so will they continue.

---

*Address at the annual meeting of the Texas Academy of Science, held in the Chemical Theatre of the University of Texas, Austin, Texas, October 26, 1900.

[1a] Presidential Address, British Association, Dover, 1899, by Sir Michael Foster, K. C. B.

[1] Address of welcome on the occasion of the centenary festival of the Royal College of Surgeons of England (July 25-27, 1900), delivered by Sir William MacCormac, Bart., K. C. V. O., etc. (President), and published in *The Lancet*, London, No. 4013, p. 281; also in *Science*, August 17, 1900.

[2] Jenner, Sir William: *Inquiry into the Causes and Effects of the Variolae Vaccinae;* London, May 14, 1796.

[3] Hueppe, Prof. Dr. Ferdinand: *The Principles of Bacteriology,* done into English by Dr. E. O. Jordan (1899), p. 446.

[4] Croonian Lecture: On Immunity with Special reference to Cell Life, by Professor Dr. Paul Ehrlich, Director of the Royal Prussian Institute of Experimental Therapeutics, Frankfort-on-the-Main, read March 22, 1900, before the Royal Society, London, and published in *Proceedings R. S.*, p. 425.

[5] Hueppe, F.: Loc. cit., pp. 225-226.

[6] Buck, A. H., M. D.: A Treatise on Hygiene and Public Health, Vol. I., p. 18.

[7] Hueppe, F.: Loc. cit., pp. 231-232.

[8] *Ibid*, p. 48.

[9] Bokorny and Loew: *Botan. Centralblatt,* 1889 and 1893.

[10] Loew, Oscar: *Science,* June 15, 1900, pp. 932-933; see also *Die Chemische Energie der lebenden Zellen,* von Prof. Dr. Oscar Loew; and *Ein natürliches System der Giftwirkungen,* by the same author, for a full discussion of this subject. (Both books are published by Dr. E. Wolff, Munich.)

[11] Loew: Loc. cit.

[12] *Ibid.*

[13] Fischer, Emil: Einfluss der Configuration auf die Wirkung der Enzyme. *Ber. d. deut. chem. Gesell.,* 1894, **27**, 2985, 3479 and 1895, **28**, 1429.

[14]McLaughlin, J. W., M. D.: *Fermentation, Infection and Immunity,* Austin, Texas, 1892.

[15]Green, J. Reynolds, D. Sc.: *The Soluble Ferments and Fermentation,* Cambridge, 1899, pp. 431-432.

[16]Arthus, Maurice: Natur des Enzymes; *Thèse pour le Doctorat en Médicine,* Paris, 1896.

[17]O'Sullivan and Tompson: Invertase: a Contribution to the History of an Enzyme or Unorganized Ferment. *Jour. Chem. Soc.,* London, 1890, **57,** p. 926.

[18]Tamman, Gustav: Zur Wirkung ungeformter Fermente. *Zeit. f. physik. Chem.,* 1895, **18**, 426-442.

[19]Stokes, H. N.: *Science,* October 12, 1900, p. 555; from Bredig and R. Müller von Berneck, *Zeit. f. physik. Chemic,* **31**, 275 (258-353).

[20]Hill, A. Croft: Reversible Zymohydrolysis, *Jour. Chem. Soc.,* London. 1898, **73**, 634-658.

[21]Konowalow: *Zeitschr. f. physik. Chem.,* 1887, **1**, 63.

[22]Nernst and Hohmann: *Zeitschr. f. physik. Chem.,* 1893, **11**, 352.

[23]Bredig and von Berneck: Loc. cit.

[24]Vaughan and Novy: *Ptomaines and Leucomaines,* 1888, pp. 179-199.

[25]Pearmain and Moore: *Applied Bacteriology,* London, 1898, p. 123.

[26]Mitchell, S. Weir, M. D.: Researches upon the Venoms of Poisonous Serpents. *Contributions to Knowledge,* Smithsonian Institution, 1886.

[27]Reichert, E. T., M. D.: *Ibid.*

[28]Fraser, Prof. Thos. R., M. D.: Immunisation against Serpents' Venom, and the Treatment of Snake-bite with Antivenene. Lecture, Royal Institution, Great Britain, March 20, 1896. *Proceedings* of same, pp. 1-2.

[29]*Ibid,* p. 2.

[30]*Ibid,* p. 8.

[31]Hueppe, F.: Loc. cit., p. 308.

[32]Ogata and Jasuhara: Ueber die Einflüsse einiger Thierblutarten auf Milzbrandbacillen. *Centralbl. für Bacteriol.,* Bd. ix., p. 25.

[33]Tizzoni and Cattani: Ueber die eigenschaften des Tetanus-Antitoxins. *Centralbl. für Bacteriol.,* 1891, Bd. ix., p. 685.

[34]Fraser, T. R.: Loc. cit., p. 18.

[35]Ehrlich: Loc. cit., pp. 428, 429, 431.

[36]Muir and Ritchie: *Manual of Bacteriology,* Edinburgh and London, 1899, p. 462.

[37]Ehrlich: *Klinsches Jahrbuch,* 1897, Bd. vi., Heft 2, S. 309; see also Zur Kenntniss der Antitoxinwirkung, *Fortschritte der Medicin,* 1897, Bd. xv., No. 2; also Croonian Lecture; Loc. cit.

Note:

$\rightarrow$ means: goes into.

$\rightleftarrows$ means: reversible—goes either way.

BIBLIOGRAPHY.

The following list contains only part of the publications on the important subject of immunity that have appeared since 1897. No attempt is here made to present an exhaustive list—many publications which appeared this year (1900) have been examined, but few of them are included. It was deemed unwise to print a bibliography of a living year, but in the face of this conclusion seventeen citations for the current year have been added—they do not by any means fairly represent the work of the year.

H. W. Harper.

Arloing, S.—Etude sur la sérothèrapie du charbon symptomatique. *Compt. rend. Acad. d. Sc.*, Paris, 1900, CXXX, 548-550.

Arloing, S.—De l'immunité contre le charbon symptomatique après l'injection du sérum préventif et du virus naturel isolés ou mélangés. *Compt. rend. Acad. d. Sc.*, Paris, 1900, CXXX, 991-994.

Arloing, S.—Nouveaux procédés de vaccination contre le charbon symptomatique du bœuf, par l'association de sérum immunisant et de vaccins. *Compt. rend. Acad. d. Sc.*, Paris, 1900, CXXXI, 319-323.

Aujeszky, A.—Zur Frage der Milzbrandimmunisation. *Centralbl. f. Bakteriol. u. Parasitenk.*, 1 Abt., Jena, 1898, XXIV, 325-327.

Aujeszky, A.—Ueber Immunisirung mit normalen Organ-theilen. *Pest. Med.-Chir. Presse*, Budapest, 1900, XXXVI, 49-55.

Baumgarten, P.—Beiträge zur Lehre von der natürlichen Immunität. *Berl. Klin. Wchnschr.*, 1899, XXXVI, 893-896.

Baumgarten, P.—Zur Lehre von der natürlichen Schutzmitteln des organismus gegenüber Infectionen. *Berl. Klin. Wchnschr.*, 1900, XXXVII, 136-138, 162, 192.

Béclère [*et al.*].—Transmission intra-uterine de l'immunité vaccinale et du pouvoir antivirulent du serum. *Compt. rend. Acad. d. Sc.*, Paris, 1899, CXXIX, 235-237.

Béclère, A., Chambon and Ménard.—Le pouvoir antivirulent du sérum de l'homme et des animaux immunisés contre l'infection vaccinale ou variolique.—*Ann. de l'Inst. Pasteur*, Paris, 1899, XIII, 81-125.

Beco, L.—Quelques travaux récents sur l'immunité. *Ann. Soc. Méd.-Chir. de Liège*, 1900, XXXIX, 47-76.

Bergey, D. H.—Susceptibility and immunity. *Phila. Medical Journal*, 1899, IV, 262-266.

Besredka.—Etude sur l'immunité vis-a-vis des composés arsénicaux; du rôle des leucocytes dans l'immunisation contre l'acide arsénieux soluble. *Ann. de l'Inst. Pasteur*, Paris, 1899, XIII, 465-479.

Bolton, B. M.—The theories which have been advanced to explain immunity from infectious diseases. *Tr. Path. Soc. Phila.*, 1898, XVIII, 437-449.

Boudesen, J.—Ueber Immunität nach erfolgter Vaccination. *Allg. Med. Centr.-Ztg., Berl.*, 1899, LXVIII, 331.

Bosc, F. J.—Considerations sur le mécanisme de l'immunité. *N. Montpél. Méd.*, 1898, VII, 181-189.

Bosc, F. J.—Considerations sur le mécanisme de l'immunité. *Arch. de physiol. norm. et path.*, Paris, 1898, 5.s., X, 72-84.

Bosc, F. J.—Considerations sur le mécanisme de l'immunité. *N. Montpél. Méd.*, 1898, VII, 181-189, 208-215.

Bouchard, C.—Immunité et specificité; réflexions à propos de la note précédente de MM. Charrin, Guillemonat et Levaditi. *Compt. rend. Acad. d. Sc.*, Paris, 1899, CXXIX, 308-311.

Brunner, G.—Beitrag zur Immunitäts-lehre. *Fortschr. d. Med.*, Berlin, 1899, XVII, 1-7.

Buch.—Der gegenwärtige Stand der Lehre von der Immunität. *Berl. thierärztl. Wchnschr.*, 1898, 385, 397, 409.

Buchner, H.—The way the body protects itself against the attacks of micro-organisms. *Indian M. Rec.*, Calcutta, 1899, XVII, 635-637, 657-662, 685-688.

Buchner, H.—Natürliche Schutzeinrichtungen des Organismus und deren Beeinflussung zum Zweck der Abwehr von Infectionsprocessen. *München Med. Wchnschr.*, 1899, XLVI, 1261-1265.

Buchner, H.—Zur Lehre von der natürlichen Immunität. (Zugleich als Antwort an Herrn Prof. P. Baumgarten.) *München. Med. Wchnschr.*, 1899, XLVI, 1418-1420.

Buchner, H.—Zur Kenntniss der Alexine, sowie der specifisch-bactericiden und specifisch-hæmolytischen Wirkungen. *München. Med. Wchnschr.*, 1900, XLVII, 277-283.

Buchner, H.—Natürliche Schutzeinrichtungen des Organismus und deren Beeinflussung zum Zweck der Abwehr von Infections-processen. *Therap. Monatsh.*, Berlin, 1899, XIII, 606-612.

Cabot, F.—Report of Experimental Work on the Dilution Method of Immunization from Rabies. *The Journal of Experimental Medicine*, New York, Vol. IV, 1899, pp. 181-188.

Calmette, A.—Sur le mécanisme de l'immunisation contre les venins. *Ann. de l'Inst. Pasteur*, Paris, 1898, XII, 343-347.

Camus, L., *et* Gley, E.—Sur le mécanisme de l'immunisation contre l'action globulicide du sérum d'anguille. *Compt. rend. Acad. d. Sc.*, Paris, 1898, CXXVII, 330-332.

Camus, L., *et* Gley, E.—Nouvelles recherches sur l'immunité contre le Sérum d'anguille; contribution à l'étude de l'immunité naturelle. *Ann. de l'Inst. Pasteur*, Paris, 1899, XIV, 779-787.

Camus, L., *et* Gley, E.—Expériences concernant l'état réfractaire au sérum d'anguille; immunité cytologique. *Compt. rend. Acad. d. Sc.*, Paris, 1899, CXXIX, 231-233.

Danysz, J.—Contribution a l'étude de l'immunité; propriétés des mélanges des toxines avec leurs antitoxines; constitution des toxines. *Ann. de l'Inst. Pasteur*, Paris, 1899, XIII, 581-595.

D'Avellar, M.—*Les théories de l'immunité revue critique. 8o. Paris, 1898, No. 502.

Davis, E. J.—Susceptibility to and immunity from disease. *Northwest. Lancet*, St. Paul, 1899, XIX, 107-110.

Davis, N. S.—Action by toxic agents; what are the physiologic processes or functions that impart to the living human body its vital resistance or immunity, and how can they be aided by therapeutic agents. *J. Am. M. Ass.*, Chicago, 1899, XXXIII, 3-6.

Dekker, H.—Die Schutz und Kampfmittel des Organismus gegen die Infektionskrankheiten. 8o. Hamburg, 1898.

DELEARDE, A.—A contribution to the study of experimental alcoholism and its influence upon immunity. *Bull. Pasteur Inst.*, Danbury, Conn., 1898, VI, 1-5.

DELEZENNE, C.—Sérum antihépatique. *Compt. rend. Acad. d. Sc.*, Paris, 1900, CXXXI, 427-429.

DEUTSCH, L.—Ueber den heutigen Stand der Immunitäts Lehre, theilweise auf Grund eigener Untersuchungen. *Pest.-Med.-Chir. Presse*, Budapest, 1899, XXXV, 253-254. [Discussion] 254-257, 272.

Dieudonné.—Experimentelle und Kritische Beiträge zur Kenntniss der agglutisnirenden (paralysirenden) Stoffe der Immunsera. Habilitations-Schrift. 8o. Würzburg, 1898.

Discussion (A) on the agglutinating or sedimenting properties of serums and their relation to immunity. *Brit. M. J.*, Lond., 1898, II, 588-593,

VON DUNGERN.—Globulicide Wirkungen des thierischen Organismus. *München. Med. Wchnschr.*, 1899, XLVI, 405-407, 449-452.

EHRLICH, P.—On Immunity, with Special Reference to Cell Life. *Proc. Royal Society*, London (Croonian Lecture), Vol. 66, 1900, pp. 424-449.

EMMERICH, R.—Bemerkungen zu dem Vortrage des Herrn Prof. Dr. H. Buchner: Natürliche Schutzeinrichtungen des Organismus, etc. (*Münch. Med. Wchn.*, 1899, s. 1261, etc.) *München. Med. Wchnschr.*, 1899, XLVI, 1342.

EMMERICH, R., AND LOEW.—Bakteriolytische Enzyme als Ursache der erworbenen Immunität und die Heilung von Infectionskrankheiten durch dieselben. *Ztschr. f. Hyg. u. Infectionskrankh.*, Leipz., 1899, XXXI, 1-65.

ERNST, H. C.—Infection and immunity. *Twentieth Cent. Pract.*, N. Y., 1898, XIII, 133-279.

FLEMMING, L.—Self-limitation and immunity. *Med. Rec.*, N. Y., 1898, LIII, 692-694.

FROEHLICH, J.—Zur Ehrlich'schen Theorie der Immunität. *Aerztl. Rundschau*, München, 1898, VIII, 145.

FROEHLICH, J.—Heilserum Immunität und Disposition. *Aerztl. Rundschau*, München, 1898, VIII, 273-278, 293-299.

GENGOU, O.—Sur l'immunité naturelle des organismes monocellulaires contre les toxines. *Ann. de l'Inst. Pasteur*, Paris, 1898, XII, 465-470.

GERHARDT, C.—Bemerkungen über Masern, Scharlach und Pocken; zur Immunitätsfrage. *Charité-Ann.*, Berl., 1898, XXIII, 224-228.

Ghéorghiewsky.—Du mécanisme de l'immunité vis-a-vis du bacille pyocyanique. *Ann. de l'Inst. Pasteur*, Paris, 1899, XIII, 298-318.

GRIPPER, W.—Immunisation by diphtheria antitoxin. *Brit. M. J.*, London, 1898, I, 816.

HAFFKINE, W. M.—Preventive Inoculation. *Popular Science Monthly*, New York, 1900, Vol. 57, pp. 115-125 and 240-247.

HAHN, M.—Immunisirungs- und Heilversuche mit den plasmatischen Zellsäften von Bacterien. *Situngsb. d. Gesellsch. f. Morph. u. Physiol. in München* (1897), 1898, xiii, 77-88.

HAHN, M.—Immunisirungs und Heilversuche mit den plasmatischen Zellsäften von Bacterien. *Situngsb. d. ärzlt. Ver., München* (1897), 1898, VII, 113-124.

Hiss, P. H., and Atkinson, J. P.—Serum-Globulin and Diphtheric Antitoxin. A Comparative Study of the Amount of Globulin in Normal and Antitoxic Sera, and the Relation of the Globulins to the Antitoxic Bodies. *The Journal of Experimental Medicine*, New York, 1900, Vol. V, pp. 47-66.

Kose, O.—Ueber die Immunisirung gegen den Staphylococcus pyog. Aureus. *Wien. Klin. Rundschau*, 1898, VII, 5.

Lemiere, G.—L'immunité. *J. d. sc. méd. de Lille*, 1899, I, 160-167; 205; 277; 372; 441; 496.

Lewin, L.—Beiträge zur Lehre von der natürlichen Immunität gegen Gifte. *Deutsche med. Wchnschr.*, Leipz. u. Berl., 1898, XXIV, 373-376.

Lewin, L.—Beiträge zur Lehre von der natürlichen Immunität. *Deutsche med. Wchnschr.*, Leipz., u. Berl., 1898, XXIV, 629-631.

Licorish, R. F.—Immunity and serum therapeutics; a new theory; the biophysical theory. *Med. Rec.*, N. Y., 1898, LIII, 620-624.

Liebreich.—Ueber die Wehrkraft des Organismus gegen Mikroorganismen. *Monatschr. f. prakt. Wasserh.*, München, 1899, VI, 198-202.

Liebreich.—Ueber die Wehrkraft des Organismus gegen Mikroorganismen. *Veröffentl. d. Hufeland. Gesellsch. in Berl. Balneol. Gesellsch.*, 1899, XX, 246-251.

Loeffler, F.—Erblichkeit, Disposition und Immunität. *Arch. f. Wissensch. u. prakt. Thierh.*, Berl., 1899, XXV, 427-442.

McClintock, C. T.—Immunity. *Columbus M. J.*, 1898, XXI, 441-448.

McClintock, C. T.—Enzymes and Immunity. *Medicine*, Detroit, 1900, VI, 272-276.

McFarland, J.—Immunity and the use of normal non-immunized serums; a refutation of certain erroneous views upon the subject. *Internat. M. Mag.*, N. Y., 1899, VIII, 566-570.

McSwain, I. A.—Immunity and susceptibility. *Memphis M. Month.*, 1899, XIX, 193-202.

Mann, C.—Beiträge zur Frage der specifischen Wirkung der Immunsera. *Arch. f. Hyg.*, München u. Leipz., 1898-9, XXXIV, 179-191.

Maxutow, A. M.—Ueber die Beziehungen zwischen natürlicher und künstlicher Immunität. *Deutsche Med. Ztg.*, Berl., 1898, XIX, 1003-1007.

Meltzer, S. J., and Norris, C.—The Bactericidal Action of Lymph taken from the Thoracic Duct of the Dog. *The Journal of Experimental Medicine*, New York, 1897, Vol. II, pp. 701-709.

Meltzer, S. J., and Norris, C.—On the Influence of Fasting upon the Bactericidal Action of the Blood. *The Journal of Experimental Medicine*, New York, 1899, Vol. IV, pp. 131-135.

Metschnikoff.—Le phagocytose. *Indépend. Méd.*, Paris, 1897, III, 49.

Myers, Walter.—On the Interaction of Toxine and Antitoxine: Illustrated by the Reaction between Cobralysin and its Antitoxine. *Journ. of Pathol. and Bacteriol.*, Edinburgh and London, 1900, Vol. VI, pp. 415-434.

de Nittis, J.—*La participation de l'organisme dans l'immunite. 8o. Paris, 1898, No. 225.

Nourney.—Zur Immunitätsfrage mit Berücksichtigung des Tuberculins. *Verhandl. d. Gesellsch. deutsch. Naturf. u. Aerzte*, Leipz. (1893), 1894, LXV, pt. II, 50-54.

PARK, W. H., AND ATKINSON, J. P.—The Relation of the Toxicity of Diphtheria Toxin to its Neutralizing Value upon Antitoxin at Different Stages in the Growth of Culture. *The Journal of Experimental Medicine,* New York, 1898, Vol. III, pp. 513-532.

PARKER, W. T.—Concerning immunity and the use of normal non-immunized, serums. 8o. Phila: 1899. *Repr. from Internat. M. Mag.,* Phila., 1899, June.

PARKER, W. T.—Concerning immunity and the use of normal non-immunized serums. *Internat. M. Mag.,* N. Y., 1899, VIII, 415-422.

PAWLOWSKY, A. D.—Zur Frage der Infection und der Immunität; das Schicksal einiger (hauptsächlich pyogener) Mikroben im Organismus empfänglicher und immuner Thiere. *Ztschr. f. Hyg. u. Infectionskrankh.,* Leipz., 1900, XXXIII, 261-312.

PELNAR, J.—Ueber Immunität. *Wien. Klin. Rundschau,* 1899, XIII, 460.

PETERSON.—Moderne Immunitätstheorien. *Verhandl. d. naturh. med. Ver. zu Heidelb.,* 1898, u. F., VI, 51-62.

PFEIFFER, R. AND MARX.—Ueber Schutzimpfungen gegen Cholera und Typhus mit conservirtem Impstoff. *Deutsche med. Wchnschr.,* Leipz. u. Berl., 1898, XXIV, 489-491.

PHILLIPS, O. P.—Immunity and the rationale of vaccination. *South. Calif. Pract.,* Los Angeles, 1899, XIV, 105-108.

PIERALLINI, G.—Ueber die baktericide Wirkung des Blutes bei Infectionen. *Sitzungsb. d. k. Akad. d. Wissensch. Math. naturw. Cl.,* Wien, 1899, CVIII, 42-54.

PODBELSKY.—Contribution à l'étude de l'immunité vis-a-vis du bacillus subtilis. *Ann. de l'Inst. Pasteur,* Paris, 1898, XII, 427-446.

RAINY, H.—On the Action of Diphtheria Toxine on the Spinal Stichochrome Cells. *Journ. Pathol. and Bacteriol.,* Edinburgh and London, 1900, Vol. VI, pp. 435-458.

RANSOM, F.—The conditions which influence the duration of passive immunity. *J. Path. and Bacteriol,* Edinb. and Lond., 1899, VI, 180-192.

REED, WALTER.—On the Appearance of certain Amœboid Bodies in the Blood of Vaccinated Monkeys (Rhocsus) and Children, and in the Blood from Cases of Variola. *The Journal of Experimental Medicine,* New York, 1897, Vol. II, pp. 515-527.

REICHENBACH, L.—Ueber Immunisierungsversuche gegen Staphylococcus pyogenes aureus. *Beitr. z. Klin. Chir.,* Tübing., 1897, XVIII, 92-102.

REID, A.—Acquired immunity. *Indian Lancet,* Calcutta, 1898, XI, 222-227; 259-262 cont'd.

REMLINGER, P.—Contribution experimentale a l'étude de la transmission héréditaire de l'immunité contre le bacille d'Eberth et du pouvoir agglutinant. *Ann. de l'Inst. Pasteur,* Paris, 1899, XIII, 129-135.

SALIMBENI, A. T.—La destruction des microbes dans le tissu sous-cutanée des animaux hypervaccines. *Ann. de l'Inst. Pasteur,* Paris, 1898, XII, 192-209.

SANGREE, E. B.—Immunity, natural and acquired. *South. Pract.,* Nashville, 1898, XX, 133-143.

SCHLEGEL, M.—Zur Lehre der Immunität. *Deutsche thierärztl. Wchnschr.,* Karlsruhe, 1898, VI, 89-93.

SHURLY, B. R.—Immunization with antitoxin. *Arch. Pediat.,* N. Y., 1897, XIV, 441-446.

Slawyk.—Ueber die Immunisirung kranker Kinder mit Behring's Heilserum. *Deutsche med. Wchnschr.*, Leipz. u. Berl., 1898, XXIV, 85-87.

Spiegel, L.—Die Ehrlich'schen Theorien über Giftwirkung und Immunität. *Therap. d. Gegenw.*, Berl.-Wien, 1899, u. F., I, 500-505.

Stewart, G. N.—The Changes Produced by the Growth of Bacteria in the Molecular Concentration and Electrical Conductivity of Culture Media. *The Journal of Experimental Medicine*, New York, 1899, Vol. IV, pp. 235-243.

Tchustovitch, T.—Etudes sur l'immunisation contre le sérum d'anguilles. *Ann. de l'Inst. Pasteur*, Paris, 1899, XIII, 406-425.

Thompson, W. G.—Immunity; recent theories viewed from the clinical standpoint. *Med. Rec.*, N. Y., 1898, LIII, 37-41.

Trumpp, J.—Das Phanomen der Agglutination und seine Beziehungen zur Immunität. *Arch. f. Hyg.*, München u. Leipz., 1898, XXXIII, 70-144.

Trumpp, J.—Die Beziehungen der Agglutination zur Immunität. *Verhandl. d. Cong. f. innere Med.*, Wiesb., 1898, XVI, 479-486.

Vallee, H.—Exaltation de la virulence dans les humeurs des animaux hyperimmunisis. *Compt. rend. Soc. de Biol.*, Paris, 1899, 11 s., I, 432.

Viollet, P.—Recherches sur les moyens de defense de l'organisme contre l'infection respiratoire au niveau des fosses nasales. *Arch. internat. de laryngol., etc.*, Paris, 1900, XIII, 1-11.

Viollet, P.—L'infection respiratoire; moyens de défense de l'organisme au niveau des fosses nasales; Leucocytose, phagocytose. 8o. Paris, 1900.

Wagner, H. L.—Natural immunity of the mucous membranes of the respiratory tract. *Tr. Am. Laryngol. Ass.*, 1898, N. Y., 1899, XX, 61-64.

Walz, K.—Erwiderung auf H, Buchner's Artikel: Natürliche Schutzeinrichtungen des Organismus und deren Beeinflussung zum zweck der Abwehr von Infectionsprocessen. *München. Med. Wchnschr.*, 1899, XLVI, 1342-1344.

Wassermann, A.—Ueber eine neue Art von künstlicher Immunität. *Berl. Klin. Wchschr.*, 1898, XXXV, 4.

Wassermann, A.—Weitere Mittheilungen über Seitenketten-Immunität. *Berl. Klin. Wchnschr.*, 1898, XXXV, 209-211.

Weigert, C.—Einige neuere Arbeiten zur Theorie der Antitoxinimmunität. *Ergebn d. allg. Path. u. path. Anat.* (*etc.*), 1897, Wiesb., 1899, IV, 107-146.

Welch, W. H.—Recent contributions to the theory of immunity. (Abstr.) *Maryland M. J.*, Balt., 1899, XLI, 228-230.

Welch, W. H.—Recent contributions to the theories of immunity. (Report of a lecture.) *Canad. Pract. and Rev.*, Toronto, 1899, XXIV, 311-318.

Weleminsky, F.—Ueber die mechanische Gewinnung bactericider Leucocytenstoffe. *Prag. med. Wchnschr.*, 1900, XXV, 97-99; 110.

Zeehuisen, H.—Beitrage zur Lehre der Immunität und Idiosynkrasie, Ueber den Einfluss der Körpertemperatur auf die Wirkung einiger Gifte an Tauben. *Arch. f. exper. Path. u. Pharmakol.*, Leipz., 1895, XXXV, 181-212; 375-400; 1899, XLIII, 259-273.

The Work of the Sanitary Engineer in Its Relation to the Public Health.

J. C. NAGLE,
COLLEGE STATION, TEXAS.

THE WORK OF THE SANITARY ENGINEER IN ITS RELATION TO THE PUBLIC HEALTH.

J. C. NAGLE,

Professor of Civil Engineering in the Agricultural and Mechanical College of Texas.

In the pursuit of pleasure and profit man often sets an immoderate value upon trivial things, but no matter how earnestly he may follow some special line of work he very naturally and properly places a higher value upon life than upon anything else in this world. It would therefore seem that the study of methods for the prolongation and preservation of life should be of most vital importance. Nevertheless, the masses have always been inclined to leave such matters to the physician, forgetting that it is the primary duty of the physician to cure disease, though he should also point out methods of prevention as well. The construction of appliances for the removal of the causes of disease and the execution of works that act as preventive measures come under the supervision of the sanitary engineer, and in the direct accomplishment of the prevention of diseases in populous communities, and the consequent prolongation and preservation of life, he has done as much, perhaps, as all other agencies combined. It is not usual nor necessary that the engineer be an investigator as to the methods of which disease agents accomplish their work, but he should know wherein the elements of danger lie and it should be his duty to provide measures for removing such elements before time is given for harm to be done.

Perfect health is the exception rather than the rule, and the mortuary reports of cities show that comparatively few of the deaths chronicled occur from old age, which should be the only normal cause of death. One would naturally think that a human mechanism weakened by the wear of many years should succumb to the attacks of disease more readily than would a younger and more vigorous one, but by far the larger percentage of deaths occur among infants and very young children.

The first essential of good health is a good constitution, but our capital in this respect comes to us at birth—a heritage from our ancestors. Afterwards education and experience must evolve the rules that are to govern our lives in the struggle with disease—a struggle that is never ceasing and which requires the maintenance of the greatest possible vigilance if we are to hope for anything like success. One hundred years ago Malthus made the assertion that "Diseases have been generally considered the inevitable inflictions of Providence," and Cruden, in his "Concordance" to the Bible, published near the middle of the 18th century, states that "Disease and death are the consequence and effect of sin." He further states that the scriptures go to show that sometimes the visitations of disease were ascribed to Divine vengeance and sometimes to the workings of the devil. These ideas were accepted in a general way until a comparatively few years ago, but in the light of modern investigations we know that disease is just as subject to natural law as are other natural phenomena, and that once having sought and found the cause of any specific disease it is possible to guard against infection and to treat more rationally the cases that actually occur.

Although Jenner, in 1796, was the first to provide, by vaccination, a measure for the prevention of smallpox it is obvious that general methods for the prevention of all manner of contagious or infectious diseases could not have been provided in advance of the discovery of the specific causes producing them. It was not until recent years that proof was found which showed that all such diseases were due to pathogenic bacteria which secure access to the human system by contact with a source of infection, or in the air we breathe, the food we eat, or the water we drink. Almost daily the list of infectious or contagious diseases is increased through the discovery of their specific bacteria, and many diseases—such as malaria and intermittent fever—that were not formerly supposed to belong to this class are now known to do so. Sanitary science has grown along with the science of bacteriology and the last ten or fifteen years have witnessed the discovery of the greater part of what is now known in this line. Sanitary engineering, however, existed at an earlier date, for experience having taught that certain diseases occurred in conjunction with certain other conditions, such as the presence of decaying organic matter, man learned to provide measures for the removal of the causes, or supposed causes, from proximity to his habitations.

The investigations of Pasteur led to the "germ" or zymotic theory of disease, while Koch's more recent work in bacteriology has converted the zymotic (or ferment) into the zymotoxic (or ferment poison) theory, which teaches that it is the poisonous products of the germs, rather than the germs themselves, that produce disease. But it matters little to the engineer how the germ does its deadly work, it is sufficient to know that the presence of certain germs leads to certain results, and that by excluding them form the media by means of which they gain access to the human system infection may be avoided.

The census reports of the United States show that about forty per cent. of the deaths in our Republic are due to such every day diseases as consumption, pneumonia, diarrheal diseases, diphtheria, typhoid fever, measles, whooping cough, scarlet fever and smallpox—all of which are preventable. Occasional visitations of cholera, yellow fever and plague epidemics would swell this percentage somewhat, but it is startling enough as it stands. Professor J. B. Johnson, in a paper read before the Engineers' Club of St. Louis, November 16, 1898, makes the following statement:

"The tracing of all these species of sickness to the ravages of micro-organisms which are not native to the human body, but which find, in weakened and diseased systems, conditions favorable for their propagation, has created a greater revolution in our lives and is likely to be of far more benefit to the race than Darwin's and Spencer's theory of evolution, or than all other discoveries of this century combined. Second only in importance to these discoveries of the causes of infectious diseases come the various means of prevention which have already been found, most of which it has been the business of the civil engineers to provide. Now, I hold that if the provision of the preventive means falls within the sphere of duties of the civil engineer, *then it becomes his further duty to thoroughly inform himself as to all these causes and remedies and to lead in the work of educating the public to the point of providing the necessary legislation and funds to carry out such measures, and to build such works as are required.*"

From the same paper I quote the following: "* * * Out of the 1400 active members of the American Public Health Association in 1894 there were listed but thirty-three engineers * * *. Practically all the rest were physicians. This is a ratio of forty-two physicians to one engineer who are struggling in America with the sanitary problems of the age. It may be that this is about the ratio of the total membership in these two professions in this country, but I should be surprised to find that the disproportion is so great." In the West the proportion of engineers upon boards of public health is away below that given above, while in the East—in New England particularly—the percentage is much higher, and it is a noteworthy fact that the East is doing much more effective work in this line than is being done in any other portion of the country. This is partly due to the fact that in the East the crowded condition of the population makes it imperative that effective measures be taken for the prevention of disease, but it is evidently due in part to the presence upon boards of public health of men whose professional training and experience have taught them how best to guard against the contamination of disease germs by eliminating them from the vehicles by means of which they are transmitted.

To give some idea of what has been done towards the prolongation of life in recent years the following figures, taken from a verbal statement made by Professor Mansfield Merriman at the Boston meeting of the Society for the Promotion of Engineering Education, in 1898, are given. These were since published in the Proceedings of the Society. Professor Merriman stated that from investigations he had made he had found that the median age of man in 1850 was 18.6 years; in 1860 it was 19.3 years; in 1870, 19.9 years; in 1880, 20.9 years; in 1890, 22 years; and in 1900 would probably be 23.1 years. By the median age is meant that the number of living persons younger than this age aquals the number living who are older. These figures strikingly exhibit the effect of education upon man's condition, for since 1850 the median age has increased at an accelerated rate from 18.6 to 23.1 years—a gain of 4.5 years for every person living, or practically twenty-five per cent. of the median age in 1850. This gain has been brought about in the comparatively short space of fifty years, and is without doubt chiefly due to the revelations of modern science in exhibiting to us the causes of disease and the measures to be taken for its prevention. Fifty years ago the engineering practices in sanitary science were crude in the extreme as compared to what they are now, and what was then done was largely by "rule of thumb" methods based upon very incomplete experience.

Disease germs secure access to the human system in various ways, but the chief vehicles by means of which they accomplish this are water, milk, ice, contaminated food, air, dust, dirt, etc. Neither chemical nor microscopical examinations can always tell with certainty whether or not disease-producing organisms are present, but large quantities of organic matter or excessive numbers of micro-organisms are always to be regarded with suspicion, for along with much organic matter come the conditions favorable for their transmission, and with a large number of bacteria present it is likely that pathogenic ones may exist—at any rate the conditions are favorable for their growth and transmission. The bacteriologist may point out the presence of these microscopic organisms, but it remains the duty of the engineer to remove them before they find lodgment in the bodies of persons having weakened constitutions or physical conditions favorable for their rapid multiplication. Obviously, then, the engineer sustains an important relation to the public health—a more important one than most of our smaller cities seem to appreciate, if one may judge by a comparison of the salaries paid to engineers and those received by other officials.

Water, more than any other medium, furnishes the readiest vehicle for the transmission of these disease-producing organisms, not only because the majority of such organisms are water borne, but also because it is most copiously taken. Surface water is more likely to be contaminated than that drawn from wells and other underground sources, but unfortunately most of our cities are forced to depend upon just such sources, either by impounding rain water in storage reservoirs, or by drawing their supply direct from some nearby stream. That which is caught in surface tanks is polluted by washings of the ground surface and by the absorption of dust, bacteria, etc., from the air during precipitation, and when allowed to stand in the reservoir the organic matter is subject to decay. River water is likely to be contaminated, not only from the surface washings during rain storms, but also by the discharge of domestic sewage by towns higher up the stream, and as the population of a district increases the danger from this source of infection grows greater. Rivers furnish such a convenient source of water supply that it is natural to turn to them for what is needed in large quantities. They also furnish an easy method of disposing of the wastes of a crowded city, both domestic and manufacturing, and the amount of dilution is rarely sufficient to render the water fit for domestic use. You would think that no city would be so foolish as to waste its sewage at a point above the intake of its own water supply, but such is not by any means on unknown circumstance. What wisdom would suggest should be done with regard to the relation between the discharge of sewage and the intakes for the water supply of a given city the rights of other communities lower down the stream should compel a city to do if their supplies are likely to be affected thereby. The old idea that running water purifies itself is now known to be a fallacy, and it is known that pathogenic bacteria will survive for days, weeks, even months, in water that may even be in motion, and that, too, under conditions of temperature that it would seem to be impossible for them to withstand.

The census reports tell us that at least one-seventh of the deaths in the United States are due to diarrheal diseases, to typhoid fever, malaria or intermittent fever—the germs of which are water borne. In 1890 there were 120,000 deaths from these diseases, all of which we may very properly charge to impure drinking water. In 1890 the deaths from typhoid fever amounted to fifty-six deaths in 100,000 persons population, the distribution being about the same for small as for large communities. In 1896 the deaths in the larger cities amounted to thirty per 100,000 from this disease, as an average, though there were many variations from the average. In Chicago, for example, typhoid fever carried off 83 in every 100,000 in 1890, 160 per 100,000 in 1891, 104 per 100,000 in 1892, while in 1894, 1895 and 1896 the deaths from this cause amounted to only 31, 32 and 48 for the respective years—the difference being directly traceable to the fact that in 1893 the city moved the intakes for the water suuply two miles further out into the lake, making the distance of these intakes four miles from shore instead of two miles. This was a purely engineering operation, and the reason for the drop in mortality consists in the fact that Chicago, as you know, formerly discharged practically all her sewage into the lake, from which she also drew her water supply. Since the opening of the Chicago Main Drainage Canal her sewage will go to the Mississippi river, and as a consequence St. Louis and other cities along the river are alarmed, and are considering methods of water supply purification as a means of providing against infection from the Chicago wastes. To give an idea of the saving of life accomplished by the change in the position of the intakes above referred to it will be sufficient to say that for the three years following the change the total number of deaths from typhoid fever alone were 1280 less per year than for the three years preceding the change.

During the year of 1899 the city of Philadelphia passed through a bitter experience in the matter of a typhoid epidemic. From January 1, 1899, to April 5, 1899, there were 4864 cases of typhoid fever and 485 deaths out of a population of 1,200,000, or an annual death rate of 160 per 100,000. During one week one ward of the city had one person in every 2000 ill of typhoid fever and another ward had one in every 3000 ill of the same disease. I have seen it stated, with how much truth I am unable to say, that investigation traced the origin of the disease to a single case that had occurred on the head waters of one of the tributaries of the stream that furnishes the water supply of the city, the wastes from the sick room having been carried into the stream. These appalling figures have finally forced the city to consider methods for purifying the city's water supply—which it may be noted the city's engineers had stenuously recommended for years previously, but which the press and the public had vigorously opposed because it involved the introduction of the (to them) odious water meters in order to reduce the wanton waste of water that now goes on. The daily water consumption is now 230 gallons for every man, woman and child in the city—an amount that it is manifestly impracticable to purify except at enormous cost. In a paper read before the American Waterworks Association, at Richmond, Va., meeting from May 15 to 18, 1900, John C. Trautwine, Jr., of Philadelphia, read a paper entitled "Water-works Management—Professional and Councilmanic," in which he showed, by means of a diagram, the rate of increase in the consumption from about 72 gallons per capita per day in 1885 to about 225 gallons per capita per day in 1898, and this has grown to the 230 gallons per capita per day since that time. Contrasted with this he shows on the same diagram how the daily consumption in Milwaukee has fallen off from about 225 gallons in 1882 to 80 gallons in 1898. In 1882 Milwaukee had less than two per cent of taps metered while in 1895 there were about sixty-two per cent. of them metered. This would seem to indicate that about sixty-five per cent. of the water used in 1882 was wasted, and that probably the same holds true in Philadelphia. Considering that more than one-third of the taps in Milwaukee were still unmetered, it is propable that even a higher percentage is wasted—probably seventy-five per cent. At the present time London, England, is considering the question of municipal ownership of the water works systems of the city, because the daily consumption of forty U. S. gallons is considered an outrageous waste, and it has been there shown by the use of meters and a house to house inspection, that a large portion of the population can get along with fifteen gallons or less. If London makes this purchase it will involve an enormous outlay, since the present value of all her water-works plants amounts to about $208,500,000 in our money.

The dilution of sewage by a large volume of water into which it is discharged is usually considered sufficient to remove the danger of infection from the disease germs it may carry, and it has been proven that streams receiving only a limited amount of sewage become purer after flowing for some distance (see the 1899 Report of the Connecticut Sewage Commission), but this is due to several causes. Some of the contaminating matter is purified by the oxidizing effect of the air held by the river water and some is carried down by entanglement with the silt and heavier particles of matter carried in suspension, but the bacteria so carried down may live for months in the ooze at the bottom of the stream, to become active again when the bottom of the river is disturbed by any cause. They may even be frozen in ice, or may be transported hundreds of miles without losing their vitality. Again, the water in the stream may of sufficient volume to so far dilute the sewage as to render the conditions for multiplication unfavorable. Also biological exidation may take place through the activity of certain forms of bacterial life, for while air is inimical to that form of bacterial life producing putrefaction it is essential to that form of bacterial action which oxidizes the harmful elements of sewage without giving off offensive odors. Further causes for the self-purification (so-called) of streams is to be found in the agency of certain microscopic forms of vegetable and animal life, but all these causes combined are slow in their action and far from effective. From the Ninth Report of the Illinois State Board of Health we learn that below Bridgeport in the Illinois and Michigan Canal the amount of water pumped amounted to seven times the amount of sewage discharged from the South Branch. Between Bridgeport and Lockport, twenty-nine miles below, no other contaminated matter entered the canal, and the bottom was kept constantly stirred up by passing boats, so that the conditions for self-purification were almost ideal. Chemical examinations, 750 in number, showed, however, that by the best calculation only about twenty-three per cent. of the nitrogenous organic matter was removed, so that it would require a flow for 125 miles to remove ninety per cent of the organic matter.

As illustrating the vitality of disease germs, I quote the substance of a discussion by Mr. Gardener S. Williams published in the Transactions of the American Society of Civil Engineers, Vol. XLII, page 165: Port Huron, at the head of the St. Clair river, sixty miles above Detroit, discharges her sewage into Black river. On April 16, 1892, after a severe winter's freeze, dredgings were begun in this river—the excavated material being dumped from scows into St. Clair river. In some places the deposit below the mouths of the sewers amounted to over twelve feet. Now, the St. Clair river is eighteen miles long and after leaving the river the flow through St. Clair lake is very slow indeed, so that it forms an ideal settling basin. The outlet of this lake is the Detroit river, from which Detroit takes her water supply. It is estimated that it takes from six to ten days for the water to flow from Port Huron to the intake of the Detroit water-works. From May 11th to May 28th no deaths from typhoid fever occurred in Detroit, and only a very few cases earlier in the season. On May 28th there was one death, on June 5th there were four, and in the next twenty-five days there were thirty-seven deaths from typhoid fever in Detroit out of a population of 230,000. Allowing ten days for the water to come from Port Huron, fourteen days for the incubation of the disease germs, and twenty-five days more from the appearance of the disease until death occurred, we have a total of forty-nine days as against fifty days from April 16th until June 5th when four deaths occurred. After dredging in Black river was stopped by cold weather the epidemic of typhoid in Detroit also stopped, but began again next spring after dredging again began in Black river. Just how long these germs had lain dormant in the ooze at the bottom of Black river is not known, but it is possible that they were there for years, though I have no records of the epidemics of Port Huron at hand.

The death rate from typhoid fever is higher in the West than in the East, and higher still in the South. For the ten years previous to 1897 the death rate from this cause in Pittsburgh was 81.6 for every 100,000 population, while in Boston and New York the death rate for the same period from the same cause was 31.9 and 21 respectively. Examples of this kind might be multiplied indefinitely; the pages of our engineering journals are filled with them almost weekly, and they even creep sometimes into the columns of the daily press.

Since the ravages of even a single form of zymotic or zymotoxic disease may prove so deadly the necessity for the purification of drinking water supplies, and of the wastes that are likely to contaminate such supplies, is self-evident, and it remains for the engineer to accomplish this by constructing suitable plants for the purpose. The actual treatment of water that is to be used for drinking purposes is slightly different from the treatment given sewage, but most of the methods that are effective with one are also effective with the other. Many plans have been proposed and tried, but so far sand filtration has been found to be more effective than any other practical method. Chemical precipitation, alone or in connection with filtration, has been extensively tried, but when used alone it has not been found to be effective, while the sand filtration method has. In treating water for the use of cities it is often necessary to throw down the heavier particles of silt and other suspended matter before filtering, so as to avoid clogging the filters, and also to reduce the amount of work required of them. The coagulant usually employed is sulphate of alumina, though salts of iron and lime are also effective, but the lime salts are open to the objection that they make the water hard.

Two methods of filtration are in general use in purifying water supplies—the one known as the English, the other as the American system, the latter being often referred to as mechanical filtration. Omitting technicalities, it may be said that the difference lies chiefly in the rate of application to the filtering area, and the fact that coagulants are used with the process of mechanical filtration, though it is sometimes necessary to first effect clarification before applying the water to the filter in the slow sand filters also.

In the experiments recently ended at Pittsburg, which were carried on for nearly a year in order to determine the best method to be used there, the merits of the two systems were carefully studied for the particular sources of supply available—namely, the Allegheny and Monongahela rivers. It was stated that the slow sand filters would purify from two to five million gallons of water per acre per day, while the mechanical filters would purify at the rate of 104 million gallons per acre per day, though the cost of operating the latter was greater. In connection with Mr. Bouscaren's report on the matter of water purification for Cincinnati, it was stated that mechanical filters could be successfully worked at the rate of 125 million gallons per acre per day. It was found at Pittsburg that both methods clarified the water and reduced the number of bacteria within the limits of what is required for a potable water. For example, the sand filters reduced the number of bacteria from 16,340 to 153 per cubic centimeter—an average of two sets of tests—while the mechanical filters reduced the number from 11,427 to 262 per cubic centimeter. The sand filters, therefore, had an efficiency of over 99 per cent., while the mechanical filters had an efficiency of 97.7 per cent. These tests were made on water from the Allegheny river from which, if I remember correctly, the water supply was drawn in 1892, when I was in Pittsburg.

Regarding the methods by means of which the filters remove the organic matter and bacteria the two systems differ materially. With the slow sand (or English) filters purification is brought about by bacterial action within the filter bed itself, the full efficiency of the beds not being developed until the particular bacteria that effect this purification have had time to grow and coat the grains of sand composing the filter. The mechanical filters, on the other hand, act more as strainers and remove the organic matter and bacteria by entanglement within the body of the filter. They require to be frequently washed, and for this purpose filtered water must be used. This accounts in some measure for the greater cost of operation when this method is used. The slow sand filtration may be either continuous or intermittent, it being still somewhat of an open question as to which effects the better results. With the slow sand filters the organic matter is decomposed by bacterial action, as has been stated, and converted from unstable into stable compounds, and it is probable that some, at least, of the bacteria that are found in the effluent are of a harmless kind that have grown near the bottom of the filter bed. With either method 100 bacteria per cubic centimeter in the effluent is not considered high for a first class drinking water.

Quite recently the sanitary journals have contained notices of a new method proposed for the purification of water supplies by the use of ozone. The *Engineering Record* for February 3, 1900, contains the translation of a paper read some months ago before the German Association of Gas and Water Engineers, in which Dr. Th. Weyl, of Charlottenburg, Germany, describes the methods used by him. The *Record* also gives the discussion by engineers present at the meeting. One set of experiments was made on a scale of considerable magnitude in which water containing varying number of bacteria were treated. One test showed a reduction of the bacteria from 84,400 to 371 per cubic centimeter, while the average of fourteen tests given show that less than 1.5 per cent. of the bacteria remain after ozonation. The water was first passed through a species of rough filter to remove the larger pieces of suspended organic matter, such as paper, decayed vegetable and animal matter, as it was found that the ozone attacked these first and only burned up the bacteria after the larger particles of organic matter had been destroyed. The water used was taken from the river Spree, and contained from 80,000 to 100,000 bacteria per cubic centimeter, and as this is far beyond the limit allowable in water from which a drinking water supply should be drawn it was mixed with water from the city mains before the ozone was added. On February 14, 1900, Dr. George A. Soper, of New York City, read a paper before the New England Water-works Association upon this subject—the first of the kind to be presented in America, though the paper had been printed, in substance, in the *Engineering News* of October 19, 1899, over Dr. Soper's signature. He described his experiments upon the Croton water supply and mentioned some of the plants now in operation in Europe, the largest of which is at Blankensberg, Belgium, where 3,000,000 gallons are treated daily. There is also an experimental plant at Paris which visitors to the Exposition may have the opportunity to see in operation. Many of the engineers who were present at the reading of Dr. Weyl's paper took exception to his implied statement that sand filters are not effective, and showed that in such cases the cause lay in improper handling. It may be here noted that practically all of the European water supplies are filtered—a condition that is the exception in this country.

The chief obstacle to the installation of filters in this country lies in the outrageous waste of water that goes on in all unmetered cities—a condition that engineers fully recognize but are unable to improve because of the foolish popular prejudice to the use of any kind of meter. As well had people object to the merchant weighing out the groceries that he sells to them. What man would say to such a merchant, "Because I choose to pay you so much for the groceries I shall need, you must throw open your store to me and let me take what I wish without let or hindrance." Many think that certain charges should be made for certain sized fixtures. As well charge for supplies by the size of the door through which they are taken out. To show to what length water waste may be carried I may mention the case of Saratoga Springs, N. Y., described recently in the *Engineering News*. Actual measurements show that from 400 to 500 gallons are pumped daily for each actual consumer, and the actual daily consumption is exceeded by few municipalities in the world. On the continent of Europe twenty gallons per capita per day is considered sufficient, and the use of meters keeps the consumption close to this limit. In London, as was stated above, forty U. S. gallons per capita is considered on outrageous waste, and the use of meters has shown that consumers will cut this down to nearly one-third of this amount when they find that they must pay for just what they use. In one district the consumption fell from 47.2 imperial gallons per capita in September, 1896, to 10.8 imperial gallons in October of the same year as the result of the introduction of meters. In this country most cities consider themselves fortunate if they can restrict the consumption to 100 gallons per capita per day. The waste that takes place is chiefly due to the negligence of consumers. Last summer I saw a bath tub faucet run for weeks in Houston, and when I asked the householder why it was not stopped I was told that a payment of such and such fixed charge was required, and that if the water company wanted the leak stopped they could come and remedy it. I then asked if the water company had been notified and was told that they had not—and this simply because it was too much trouble, notwithstanding the people had a telephone in the house. Between January 2nd and February 13th, inclusive, of this year, there were discovered, in Hartford, Connecticut, 3231 leaking and running fixtures, 190 being running wide open. This probably heads the list of reckless wasters of water, and it is safe to say that if these houses had been metered the instances of waste would have been greatly reduced, and in any case the reckless wasters of water would have been compelled to pay for their negligence instead of making every other consumer contribute to the payment for water they had wasted. If the water consumption records for many of our cities be plotted there will be found a general resemblance in the curves for unmetered cities—nearly all of the unmetered ones showing a rapid increase in the per capita consumption of late years. In Philadelphia the increase has been such that instead of something less than 75 gallons per capita consumed in 1885 the amount has now reached the alarming figure of about 230 gallons, while Pittsburg exceeds this slightly—the amount being put at 233 gallons per capita. Of the other cities in which meters have been introduced there is shown a fairly uniform falling off in the consumption in proportion to the number of taps metered, Milwaukee representing one of the most pronounced of this type.

But, passing on to the matter of sewage purification, let us consider how the sanitary engineer may influence the public health. Upon him devolves the duty of designing and constructing systems for this very important purpose, and it should also be his duty to inform the public how best to dispose of this character of waste matter. It is not uncommon to find communities so lacking in information regarding the dangers from this source that they even allow their own wastes to pollute the source from which they draw their water supply, and so inconsiderate of the rights of others lower down stream that sewage is discharged directly into streams from which other communities are obliged to secure their supplies of water. Houston discharges her sewage directly into Buffalo Bayou, the stagnating waters of which flow very slowly through the heart of the city. Sometimes lack of water in the artesian wells, or the call for a higher fire pressure than the supply from the wells will afford, make it necessary for the water from the bayou to be pumped directly into the mains, where its appearance or odor bears testimony to its unfitness for domestic use. Fresh sewage, which ordinarily contains less than two parts of organic matter per 1000, has never been known to injure any one by reason of its proximity, but when allowed to stand and concentrate by reason of daily augmentation, and the growth of bacterial life causing putrefaction, it does become a menace, especially if it find its way into the mains from which the supply of domestic water is drawn, and this it sometimes does in Houston. During the coldest spell of weather that we had last winter the daily paper stated that, owing to the excessive demand made upon the water supply, due to the fact that faucets were kept open to prevent freezing, the wells were unable to furnish sufficient water to keep up the required pressure, and bayou water was pumped directly into the mains, the color and odor for days afterwards bearing evidence to the fact. However, it is probable that Houston will remedy this condition in the comparatively near future, as surveys have been made and plans adopted for the purification of the city's sewage, though some of the local engineers seem to doubt the effectiveness of the methods adopted because of local conditions. Indeed, I believe that work has been begun upon the construction of the trunk sewers that will be needed in collecting the sewage and bringing it to the pumping station. This very commendable determination on Houston's part was brought about, not so much by the desire to improve the health condition of the city, as by the fact that some such sewage treatment was made a condition of the passing of a congressional appropriation for the improvement of Buffalo Bayou. People are quick to make expenditures when they see commercial gains in consequence, but strangely slow when it is only a matter of health—particularly if it happen to be some one else's health that is in danger.

Now, since the conditions are fast becoming such that a city may not discharge its sewage into the nearest stream without menacing the rights of its own residents, or interfering with riparian rights further down, the purification of sewage is a vital matter, and much study has been done and many methods proposed and tried in the effort to secure the best and most economic results. Chemical precipitation has been extensively tried and is still used to some extent in connection with other methods, but alone it has not been found to be effective. True, clarification can be secured, and much of the organic matter precipitated, but enough remains to afford feeding ground for bacteria when the effluent happens to again become seeded with them. Moreover, it is not economical. Natural methods are now preferred, among which may be mentioned purification by irrigation—a process in which the sewage flows over land occupied by growing plants which assimilate a part of the plant food carried in the sewage, while another part is purified by nitrification in the upper layers of the soil. This method requires extensive area—one acre being now regarded as sufficient to purify the sewage of from 50 to 100 persons, and in the case of a very porous soil of 200, or possibly 300 persons. That is to say, that the 998 or 999 parts of water carried are sufficient to drown the soil and stop purification of the other one or two parts whenever greater quantities are applied to the sewage farm. Another objection to the method lies in the fact that in winter no crops grow, besides which the land may become frozen over and incapable of having any purifying effect. The method that has so far been most used with success is known as intermitten downward filtration. This requires either a very porous natural soil or else the construction of artificial beds. These beds are usually from four to seven feet in depth, and should be underdrained, and if material of varying coarseness is used the larger particles should be below in order to prevent clogging. By applying the sewage in intermittent doses the beds become aerated, air being drawn down as the sewage flows out through the underdrains, and the oxidizing action of the bacteria in the beds converts the unstable organic matter into harmless stable compounds. With the proper amount of rest between doses the effluent may be made as clear and limpid as spring water, and in many cases just as fit for drinking purposes, for neither chemical nor bacteriological examinations show sufficient foreign matter present to endanger the consumer. The bacteria that produce the effect in this case are aerobic—that is, they require the presence of air before they become effective. Usually it requires some little time for the filter bed to attain its maximum purifying power, and examinations show that the sand grains—particularly those near the surface—are then covered with colonies of these oxidizing bacteria. Occasionally the surfaces of the filter beds—of which there should be several in order to allow for the period of rest above referred to—have to be raked to prevent clogging by larger particles in the sewage, but the body of the filter does not become clogged, for most of the insoluble matter is converted into stable compounds that are soluble in water and which pass out with the effluent. Many modifications of the sand filter have been tried, but the process of intermittent filtration has so far been found most effective. One of the modifications that still retains some of the characteristics of this method is to force large quantities of air through the filters, and thus accelerate their action. Col. George E. Waring, Jr., who died of yellow fever contracted in Havana while investigating the sanitary conditions there last year, devised a method that is said to give no offence when used in close proximity to dwellings. Some months ago I wrote to the company in regard to the cost of a plant for purifying the sewage from a village of 1000 inhabitants and they said that the wastes could be easily purified in a space 80x80 feet square. Their method of cleansing the beds is somewhat similar to that used in the mechanical filtration of water.

In the sand filtration method the action of the bacteria is aerobic, but within the last two or three years it has been discovered that another class of bacteria exist that are active in the absence of air and light, though I have recently seen it stated that it is not absolutely necessary to exclude either. These are the kind of bacteria that produce putrefaction, and it has been found that they do their work with amazing rapidity under favorable circumstances. In this process—known as the septic tank method—the sewage usually passes slowly through a tank, occupying several hours in the journey—rarely more than from twenty-four to thirty-six—and is drawn off at the further end without disturbing the portion that remains, after which the effluent is passed rapidly through coarse filters, generally of coke or coke breeze, and issues from the underdrains in a remarkably pure condition. The sewage in the tank becomes covered with a scum-like coating from one to three or four inches thick, in which the bacteria are very active. Heavier particles in the sewage are precipitated to the bottom and are there acted on by the bacteria which break up the organic compounds rendering many of them soluble in water, and which pass out with the contents of the tank, so that the accumulation of sludge in the bottom of the tank is comparatively slow. Whenever it becomes necessary to draw this off it is passed to coarse filters, or sludge beds, where most of the water is drained off. The action of the anaerobic bacteria in the tank not only destroys much of the organic wastes, but renders those that remain susceptible of purification by thin, coarse filters at a very rapid rate, besides avoiding the great quantities of sludge that are so troublesome in the chemical methods, and which, despite the fertilizing qualities that it possesses to some considerable degree, it has been found almost impossible to dispose of to farmers, except in some portions of Europe, even for the cost of carting away. The first of these septic tanks to be constructed on a scale of considerable magnitude was, as far as I could learn, at Exeter, England, where it has been in successful operation since 1897. Many such tanks have since been constructed, however, and have been found to greatly facilitate the process of filtration.

The State College of Iowa, at Ames, built a purification plant in 1898, which combines the principle of the septic tank with direct filtration and which treats the sewage of about 600 persons in a very efficient manner. The tank holds sewage for only about six or seven hours and is automatically emptied by means of a Miller 8-inch siphon—all of the contents except the sludge being emptied each time the siphon operates. Under these conditions the tank acts more as a settling basin than as a septic tank, but, nevertheless, it has been found that the effect upon the sewage is highly beneficial, a partial purification taking place within the tank, and the tank effluent being left in a condition to be readily acted upon by the bacteria in the filter bed. Professor Marston, who designed the plant, has kept valuable temperature and discharge records, and finds that the effluent from the filter beds can not be told from ordinary spring water, either by appearance or odor, it being a clear, limpid looking water. The plant is situated within 1000 feet of the nearest college building, and while some odor can be detected in the immediate vicinity of the plant it is not discernible at a little distance therefrom. The filter beds are screened gravel and sand and vary in depth from 3½ to 4½ feet and are two in number, each having an area of two-tenths of an acre. It required some time for the beds to attain their full purifying capacity, but after the bacterial life had had time to grow within them the work has been very effective. Valuable chemical and bacteriological analyses have been made by Professors Weems and Pammell, and show conclusively how effective the plant has been. To illustrate, I quote some of the figures for its bacterial efficiency, as given in the *Engineering Record* for February 24, 1900. Professor Pammell found that on January 11, 1899, the manhole above the settling tank had 345,864, the tank 31,200, and the effluent 8600 bacteria per cubic centimeter. On May 3rd the number of bacteria were 194,956 in manhole, 168,600 in tank, and 11,520 per cubic centimeter in the effluent. On June 28th the tank contained 1,108,000 bacteria, and the effluent only 2640 per cubic centimeter. On July 5th the manhole had 708,000, the tank 814,000, and the effluent 1280 per cubic centimeter. The highest number of bacteria occurred on September 27th, the manhole having 9,600,000 and the effluent 8160. On September 5th the manhole had 9,000,000 and the west filter bed only 600 per cubic centimeter. The average number of bacteria in the effluent for eleven months was 5127, while the sewage before flowing into the tank had an average running away up into the hundreds of thousands. Nine millions per cubic centimeter means something like 144,000,000 per cubic inch—a number that the human mind fails to grasp the meaning of. It was noticeable that when the temperatures in the manhole were highest the number of bacteria were greatest, thus showing that temperature has a marked effect upon the growth of this low form of vegetable life. Indeed, investigations seem to show that in the arctic regions bacteria are nearly or wholly wanting, which would indicate that they were not essential to the life of higher organisms, as has been repeatedly stated.

Of course in any method of sewage purification a separate system of sewers is required, because it is manifestly impossible to provide, at a reasonable cost, facilities for treating the great amount of rain water that occurs at times in connection with the ordinary sewage.

Now, it has been customary to say all manner of hard things about sewer air, or sewer gas, as it is frequently, though incorrectly, called, and certainly such odors as a badly ventilated system sometimes exhales are neither agreeable nor good for the general tone of the system. However, neither chemical nor bacteriological examinations show any evidence of disease-producing matter in sewer air, and, indeed, it is often purer than outside air in the number of bacteria carried, and those that are usually present are of a harmless kind, for in no recorded cases were pathogenic varieties present, while those that were found were not at all similar to those in sewage, being all air borne varieties instead of water borne. The chemical analyses showed, however, a considerable amount of free carbonic acid gas, for the oxygen of the air in the sewers had been largely consumed in the transformation of the organic matter present. Certain examinations showed that there was a little more of this carbonic acid present than in a crowded Boston theatre, the latter in one case amounting to a little more than one-half of one per cent. It is doubtless due to this gas, as well as some others, not considered as poisonous, that the continued breathing of sewer air may lower the tone of the constitution and thus make one an easier prey to disease. Fish die in water much polluted with sewage, but it has been conclusively shown that it is the absence of air that kills them, not the nature of the sewage itself. Laborers who work in sewers have been found to enjoy rather better health than the average, and in England many of them have worked for thirty or forty years at this business. At the Barking Creek outlet of the old London Main Drainage System the houses of the operatives were built over the 9½ acre reservoir that held the sewage for twenty-four hours, the reservoir being arched over and sodded. Notwithstanding they were directly over a lake of sewage, the people who lived there were healthier than those who dwelt in the crowded portions of the city. I am not advocating the liberation of sewer air in the vicinity of one's living or sleeping apartments, but merely wish to show that the danger is not nearly so great as people usually think. Moreover, it can be effectually excluded by a proper system of plumbing and care in the use of fixtures.

The work of the sanitary engineer includes the collection and disposal of garbage, which by putrefaction is likely to contaminate the air in cities. If it be not permissible to dump the garbage into tide water, and this should only be done at a sufficient distance from land to prevent the currents from returning it to the shore, the organic matter in garbage has either to be destroyed by cremation or by digestion. It was not until 1880 that furnaces for cremation purposes came into use. Their introduction into America having occurred in 1885 at army posts. The digestion method is of even later date. With the cremation method the organic matter is entirely wasted, its destruction being the end sought, but the digestion method furnishes commercial products in the form of products condensed from the vapors, grease and a solid product called tankage that has a commercial value as a fertilizer. The dark colored liquid that is drawn from the digestors contains much organic matter, but no bacteria, these having been killed by the heat. It may become seeded with them again, however, and for this reason should not be discharged directly into streams, but should be run into the sewers or separately purified.

While not usually considered a part of the work of the sanitary engineer the matter of good street surfaces has an important bearing upon the health of a community. Good, smooth surfaces that will shed water readily and that will not absorb and retain moisture and organic matter subject to decay are matters that affect the health of every passer by, the construction of which comes directly under the supervision of the civil engineer. So also the proper heating and ventilation of buildings constitute a branch of engineering that lies on the border land that separates civil from mechanical engineering, and which are important factors as regards the health of a community. It is certain that the crowding of many school children into poorly heated, poorly lighted, poorly ventilated rooms for several hours each day often results in weakened constitutions, ending finally in disease which is charged to overstudy. In this case, as in many others, we are prone to accept the first explanation that occurs to us, instead of looking for the real cause of the trouble.

It is no easy matter to compute the money value of a proper saintary condition in a community, but if we return to the figures given for the saving of life from typhoid fever alone in Chicago, for the years 1894, 1895 and 1896, due to the change in the water supply, we shall have enough to set us thinking. As I told you an average of 1280 lives per annum was probably saved to that city during those three years. Now, place the money value of each life at $5000, this being the amount that courts of justice have several times allowed in cases where some of our cities have been sued for negligence leading to loss of life, and we shall have the surprising figures of $6,400,000. Taking the death rate at Philadelphia, as given a while ago, as probably showing the same proportion of deaths to total cases—namely, one-tenth of the cases fatal—we should probably have 11,500 cases in Chicago annually that would have survived for the 1280 that would probably have died, and if the expense of doctors' bills and the financial loss due to illness be placed at $300 per case we should have an additional sum of $3,450,000, making a grand total of $9,850,000 annually saved to the residents of the city, as regards this one disease, which was effected by the change in the water supply. Now capitalize this at the very high rate of ten per cent. per annum to allow for a sinking fund for repairs and you get $98,500,000 that Chicago would have been justified in expending for the change, when as a matter of fact the actual cost was probably only a small fraction of this amount.

While the foregoing does not by any means cover the field of the work of the sanitary engineer in its relation to the health of the public, the matters mentioned will suffice to show that the relation is an important one. In addition to the execution of projects entrusted to him the engineer should do his part towards convincing the public that certain processes are necessary in certain cases. He should be a leader in such cases, not a follower. As a class engineers are slow to force their opinions upon the public, and there are several reasons for this. For one thing, they are, if they are really competent, very busy men and have little time to spare from their professional duties in order to bring their views before the public. Then, too, as a class, they are modest in their claims and are governed by a strict, though unwritten, code of ethics. Moreover, the public has no right to expect of them professional advice involving considerable study and research without compensation, any more than they would expect professional advice from a lawyer without a fee. In our state there is, apparently, an inherent dislike to expend a few dollars for professional services in this line when some practical workman is ready to give his advice or opinion for nothing. I do not mean to undervalue any knowledge derived from practice, for I believe that theory and practice should go hand in hand, but I do mean that a practical knowledge in a single line of work, however valuable it may be in that line, will not justify a man in drawing general conclusions about an entirely different line of work. There are times when an engineer is just as much needed as a physician is in a critical case, but while one would not think of dickering with a physician about his probable charges the majority of men entrusted with our public works will hunt around for the lowest priced man they can get—and if he is not an engineer of established reputation so much the better—and in the end they usually pay many times more than the right kind of professional advice would have cost them. In our sanitary works, particularly, has this pernicious habit been followed in Texas, with the result that many inefficient systems have been constructed and an unknowable loss and damage done to many communities in consequence.

The Development of the Present Texas Railway System.

R. A. THOMPSON, Assoc. M. Am. Soc. C. E.,
AUSTIN, TEXAS.

THE DEVELOPMENT OF THE PRESENT TEXAS RAILWAY SYSTEM.

R. A. THOMPSON, Assoc. M. Am. Soc. C. E.,
Expert Engineer, Railroad Commission of Texas.

INCEPTION AND EVOLUTION OF THE RAILWAY.

The history of the evolution of the modern railway properly begins with the roadbed and track, and we have records that tracks were built of stone blocks to facilitate the passage of vehicles by the early Romans. At the end of the sixteenth century miners in the Hartz mountains used wooden tracks to convey the products of their mines in rude cars to the highways. Queen Elizabeth imported some of these miners to develop the English coal mines and they built the first tracks in England. Here began also the development of the steam railway and the honor of bringing it to its present high state of efficiency is shared with the English by the Americans.

At first wooden rails were used to which, later, iron straps were spiked. Cast iron rails were used as early as 1768 and wrought iron rails were patented in 1820. The discovery of the Bessemer process in 1856 for making steel cheapened the manufacture and made possible the use of the more durable and efficient steel rail.

With the development of the track the development of the motive power kept pace—in fact has outrun it of late years. Steam, as a locomotive power was experimented with in the eighteenth century, but not until the nineteenth century was it successfully applied to the locomotion of vehicles. On October 6, 1829, Stephenson's engine "Rocket" won a prize of 500 pounds for the best steam propelled vehicle, offered by the Liverpool and Manchester Railway Company. Though this was not the first engine successfully propelled by its own power, this contest brought steam into general notice as a propelling power and marks the beginning of the era of steam locomotive construction in the world. The problem of the locomotion of vehicles being apparently so successfully solved, an impetus was given to the construction of track and the use of the railway for the transportation of freight and passengers in general.

In the United States the first tramroad was built in 1826 from the granite quarries at Quincy, N. H., to the Neponset river, horse power being used. In the same year the Maunch Chunk Railway in Pennsylvania was opened for the transportation of coal and stationary engines were used to pull cars up inclines which they descended by gravity. An English engine was used on the Carbonsdale and Homesdale Tramroad in 1828, but not successfully. The first American locomotive that was successfully operated was built at West Point and placed on the South Carolina Railroad in 1830. This line was then ten miles long and was increased to 136 miles by 1833.

The Baltimore and Ohio Railroad was perhaps the first railway in the United States to put into successful operation a system of transportation for freight and passengers. This line was begun in 1828 and 15 miles were open for traffic in 1830. It was operated by horse power till 1831 when the use of steam power was inaugurated. This line reached a length of 67 miles in 1832.

From 1830 dates the remarkable growth of railway building in the United States. At first short lines were chartered and built to promote the welfare of some special city or enterprise. For a time they were regarded as properly feeders for canal systems. Gradually the length of the lines increased, and as their number multiplied, consolidations were effected and the foundations of our present gigantic railway systems laid. The discovery of gold in California and subsequent rapid growth and development of the western portion of our continent and the necessity for the establishment of some means of rapid communication and transportation with the same, led to the conception of our immense transcontinental systems which with liberal government aid were projected and carried to successful completion.

The following table will indicate the rapid and remarkable growth of our railway systems in the United States after the successful inauguration of locomotion by steam power in 1830.

At End of Year.	Miles in Operation.	Increase Over Previous Year
1830	23	....
1835	1,098	1,075
1840	2,818	1,720
1845	4,633	1,815
1850	9,021	4,388
1855	18,374	9,353
1860	30,626	12,252
1865	35,085	4,459
1870	52,922	17,837
1875	74,096	21,174
1880	93,296	19,200
1885	128,296	35,000
1890	166,817	38,521
1899	192,398 (approximate)	11,,486
1895	180,912	11,486

The following table gives the approximate railway mileage in the world at the end of same periods:

At End of Year	Miles in Operation.	Increase Over Previous Year.
1830	206	....
1835	1,502	1,296
1840	5,335	3,833
1845	10,825	5,490
1850	23,625	12,800
1855	42,340	18,715
1860	66,413	24,073
1865	90,280	23,867
1870	131,638	41,358
1875	182,927	51,289
1880	231,190	48,263
1885	303,172	71,982
1890	385,000	81,828
1896	426,465	41,465
1900	500,000 (estimated)	73,535

RAILWAY LEGISLATION IN TEXAS.

The legislators of the State of Texas early recognized the advantages of the railway in solving the important question of cheap transportation without which it was evident that the magnificent agricultural and industrial resources of the state could not be successfully developed and they inaugurated a policy of liberality toward railway companies that stands without a parallel in the history of the world. With great prodigality, large areas of the fertile and valuable public domain were generously donated to encourage the building of railways. In addition to these, moneys were loaned from the public school fund at a low rate of interest to aid these enterprises in their infancy. The donations of land by the state to the railways in Texas amount to the enormous sum of 34,179,055 acres or about 53,405 spuare miles. This area which is equivalent to about one-fifth of the total area of the state, would form a territory as large as the state of Arkansas and is larger than the states of Pennsylvania and New Jersey combined.

It is with great regret that we have seen such generosity as was displayed to the railways unappreciated by their promoters and builders. In many cases the gifts of land and money were appropriated by them and in addition, the railways were loaded with fictitious issues of stocks and bonds, which were disposed of at almost any figure for cash. The proceeds of such sales were as a rule pocketed by the promoters and the properties permitted to lapse into a state of hopeless ruin and bankruptcy. The past history of our railways in Texas is not a bright one and it has taken a generation to undo the ruin wrought by the unreliable and unresponsible builders, to restore confidence in the money centers with regard to the security of our railway investments and to develop the railways themselves to their present high state of efficiency.

The early acts of incorporation of railways in the state, from 1836 to 1854, granted a bonus of eight sections of public land per mile of railway constructed. It soon became apparent that this amount, on account of the undeveloped and consequent unsalable condition of the land, did not appeal to the promoter, and the 5th Legislature, on January 20, 1854, passed an act "to encourage the construction of railroads by donations of land." The provisions of this act entitled any railway that had constructed or might hereafter construct lines within the limits of the state to a bonus of sixteen sections of public land or 10,240 acres, per mile of constructed road. To secure this donation, however, 25 miles of railway must be completed and 25 more graded in advance. Those railways that had already received eight sections per mile for road constructed were to receive eight sections per mile additional. Rails weighing not less than 54 pounds per yard must be laid. The Act was to remain in effect ten years after passage. Although a great many lines were projected and chartered under the provisions of this act, and a fe wbegan construction, little was actually done before the civil war came on, which paralyzed railway construction and caused a suspension for some years of development of all kinds.

On November 13, 1866, the terms of this act were renewed, and as public lands had become more valuable, under more favorable conditions railway building began again in earnest, and several thousand miles were built in the state under this act. From the beginning of railway construction in the state few of the special acts incorporating the lines were carried out as provided and succeeding legislatures passed acts of relief, extension of time, etc. Every possible favor was granted in order to aid and stimulate the construction of railways. In addition to the public lands donated, liberal grants of money, right of way, depot ground, etc.,. were offered by each community and city through which the railways passed. Often concessions and gifts of land and money were extorted by the promoters from cities and they were required to bid against each other for the privilege of being the favored one in securing some particular line of railway. Even to this day it is the exception when any projected road must provide for the purchase of its right of way, depot and terminal grounds; all such property—often with money in addition—being required by the railway and donated by the communities and cities through which the line is projected.

In 1856, at the session of the 6th Legislature, a law was passed entitling any railway company to a loan of $6,000 per mile of constructed line from the public school fund. Interest at the rate of 6 per cent. per annum was charged on these loans and the railway companies besides paying the interest were required to provide for a sinking fund. At the time this legislation was regarded as being wise, for in addition to materially assisting in the development of the country by aiding the railways, it offered a fair and apparently secure means of investing the dormant permanent public school fund. Under the provisions of this act $1,816,000 were loaned to several railways of the state as follows:

Houston Tap and Brazoria, (I. and G. N.)	$ 300,000
Houston and Texas Central	450,000
Washington County, (H. & T. C.)	66,000
Buffalo Bayou, Brazos and Colorado, (G. H. & S. A.)	420,000
Texas and New Orleans	430,500
Southern Pacific, (T. & P.)	150,000
Total	$1,816,500

A considerable amount of this loan with interest was paid back into the school fund, but in several instances the lines upon which money had been loaned, failed to pay their interest and when foreclosure was made and the roads sold, the proceeds rarely sufficed to pay the amounts originally loaned. This method of investing the school fund, after these experiences, was regarded by both the people and the legislature as being unsafe and unsatisfactory and the privilege was withdrawn. Suits are now pending in the Supreme Court of the United States involving $1,120,677, principal and accrued interest, for the recovery of part of this fund loaned to the railways.

RAILWAY BUILDING IN TEXAS.

Rivalry between cities situated at or near the coast for the rich and valuable trade of the interior, early determined the loci for railway projection. These cities were seats of political influence and could in a measure control legislation in favor of certain railways, which were projected in territory favorable to them. The interior towns were rivals in securing for themselves the favor of being made the objective points of these lines.

The first railway charter in Texas was granted by Congress on December 16, 1836, to the Texas Railroad and Navigation Company, who proposed to connect the Sabine river with the Rio Grande and construct branch lines to different parts of the state. The charter of the Galveston and Brazos Railroad was approved May 24, 1838. A number of other lines were chartered up to 1848, all of which were forfeited, including the first two. On March 11, 1848, the charter of the Galveston and Red River Railroad was approved permitting the construction of a line from Galveston to Red River. This was the first line chartered in Texas that was actually built although it was not the first to begin construction.

The Buffalo Bayou, Brazos and Colorado Railway was incorporated by act approved February 11, 1850, and was projected from a point on Buffalo Bayou between Lynchburg and Houston, west to the Colorado River, thence north to Austin, developing the very fertile valleys of the Brazos and Colorado rivers. This is the pioneer of Texas railways and though chartered subsequent to the Galveston and Red River Railroad, was the first to construct and operate a line of railway in Texas territory. Work began on this road just 22 years after the first railway was in operation in the United States.

The above charters were followed by a large number of others for lines in different parts of the state, but all were forfeited except those given in the following statement, which shows the number and mileage of lines in operation in Texas on October 1, 1859:

Name of Railway.	When Chartered.	Date work began.	Miles.
Galveston & Red River, (H. & T. C.)	Mch. 11, 1848	1853	75
Buffalo Bayou, Brazoria & Colorado, (G. H. S. A.)	Feb. 11, 1850	1852	65
San Antonio & Mexican Gulf, (G.W.T. & P.)	Sept. 5, 1850	1856	5
Galveston, Houston & Henderson	Feb. 7, 1853	Mch. 1, 1854	42.5
Memphis, El Paso & Pacific, (T. & P.)	Feb. 7, 1853	Feb. 1, 1857	....
Southern Pacific, (T. & P.)	Aug. 16, 1856	1856	27.5
Washington County, (H. &. T. C.)	Feb. 2, 1856	1857	11
Sabine & Galveston Bay, (T. & N. O.)	Sept. 1, 1856	1858	10
Houston Tap, (see H. T. & B.)	....	1856	....
Houston Tap & Brazoria, (I. & G. N.)	Sept. 1, 1856	1858	36.5
Indianola, (G. W. T. & P.)	Jan. 21, 1858	1858	....
Total mileage October 1, 1859			272.5

In addition to track in operation as noted, the above railways had between 130 and 140 miles of line graded in advance and ready for track.

To arrive at a clear idea of the development of the several railway systems of the state in detail, a brief history will be given of each in the order of their construction.

Galveston, Harrisburg and San Antonio Railway.—The Buffalo Bayou, Brazos and Colorado Railway, as before stated, was chartered by act approved February 11, 1850, and was the first company to begin construction in the state. Work began near Harrisburg in 1851 when the first locomotive ever brought into Texas, weighing twelve tons, was put on. Twenty miles of this line were completed by August 1, 1853, and by

December, 1855, the road was in operation to Richmond, 32 miles. Here the problem of bridging the Brazos river confronted the engineers and the first bridge was a pontoon or floating bridge, which was operated with great difficulty, especially during the flood seasons. By December, 1859, the line had reached Eagle Lake, 67 miles, and in 1860 was completed to Alleyton, within two miles of the Colorado river, opposite Columbus. It had early been the intention of the company to extend the line up the Colorado valley to Austin, but it was seen that the natural course was in the direction of San Antonio and an extension was chartered February 16, 1858, under title of the Columbus, San Antonio and Rio Grande Railroad from the Colorado river near Columbus west via. Gonzales and San Antonio to the Rio Grande river near Eagle Pass. To connect the B. B. B. & C. Ry. with the C. S. A. & R. G. R. R., the Columbus Tap Railway was incorporated by act approved February 2, 1860.

No further construction was done on any of these lines until after the civil war. In accordance with an act passed at the called session of the 12th Legislature, approved July 27, 1870, the Galveston, Harrisburg and San Antonio Railway was chartered to succeed the B. B. B. & C. Ry.; also to acquire and succeed to the corporate rights of the Columbus Tap Railway and extend same west, via San Antonio, to El Paso with branch lines to Austin and Eagle Pass. Construction began again in 1874 and in 1875 the line had reached Luling, 109 miles from Harrisburg. On March 1, 1877, the road was in operation to San Antonio, 207 miles. In 1880 the branch from Stella to Houston was opened and also the Austin branch as far as LaGrange. On September 1, 1881, the company was reported to have 100 miles in operation east of El Paso. Construction proceeded as rapidly as possible and the gap between San Antonio and El Paso was closed in 1883. The Eagle Pass branch was opened from Spofford to Eagle Pass about same time.

The G. H. & S. A. Ry. is one of the best constructed and most efficiently operated railways in the state and constitutes an important link in the great Southern Pacific Transcontinental Railway System, one of the most powerful and successful railway systems in the world. The B. B. B. & C. Ry. borrowed $420,000 from the public school fund to aid in its construction and with its successor, the G. H. & S. A. Ry., received from the state 1,460,104 acres of public land as a donation. Its present mileage in the state, main line and branches, is 918.16 miles.

Houston and Texas Central Railroad.—The H. & T. C. R. R. was chartered by act approved March 11, 1848, under the name of the Galveston and Red River Railroad, to construct from Galveston to the Red river. Work did not begin on this line within the time specified and the charter was forfeited, but was renewed by act of the legislature February 14, 1852. Work began at Houston in 1853, and by act approved February

7, 1853, the legislature confirmed this action, instead of requiring Galveston to be made the southern terminus. The first locomotive was not put on till January 22, 1856, when two miles had been constructed. A reorganization of the company was effected and the name changed to the Houston and Texas Central Railway by act approved September 1, 1856. The line was completed to Cypress, 25 miles, by July 27, 1856; to Hockley, 35 miles, by May 11, 1857; to Hempstead, 50 miles, in 1858 and by October 1, 1859, 75 miles were in operation. In 1860 the road was extended to Millican, 80 miles from Houston, when construction was suspended on account of the civil war. After the war the work was taken up and pushed with energy. Was completed to Bryan, 100 miles, in 1867; to Calvert, 130 miles, in 1868; to Corsicana, 210 miles, in 1871; to McKinney, 296 miles, in 1872, and to the present terminus at Denison, by January 1, 1873.

By an act approved August 30, 1870, the H. & T. C. Ry. Co. was granted authority to purchase and consolidate with the Washington County Railroad from Hempstead to Brenham, and extend the same to Austin. Also by an act approved May 24, 1873, it was granted authority to acquire the property and franchises of the Waco and Northwestern Railroad from Bremond to Waco and extend same northwest in accordance with provisions of the W. & N. W. R. R. charter. The H. & T. C. Ry. passed into the hands of a receiver and was sold September 8, 1888. Was reorganized August 1, 1889, under title of the H. & T. C. R. R., which included only the main line from Houston to Denison and the Austin Branch. The W. & N. W. R. R. (Waco Branch) remained in hands of its receiver until by act of the legislature passed in May, 1897, the H. & T. C. R. R. was permitted to purchase and consolidate with same.

TheAustin Branch of the H. & T. C. R. R. was chartered by act approved February 2, 1856, from Hempstead to Brenham under name of the Washington County Railroad. Work began on this line in 1857, and 11 miles were in operation in 1858. The road was open to Brenham, 25 miles, by October 1, 1860. The Air Line Railroad was chartered January 30, 1860, to construct from Brenham to Austin but nothing was done. After acquiring the W. C. R. R. in 1870, the H. &. T. C. R. R. extended and completed the same to Austin in 1872.

The Waco Tap Railroad was chartered by act approved November 5, 1866. Was rechartered under the title of the Waco and Northwestern Railroad by act of August 6, 1870, and completed from Bremond to Waco in 1872. Was operated as a part of the H. & T. C. Ry. till 1884, when the latter passed into the receiver's hands. A seperate receiver was accorded the W. & N. W. R. R., which was purchased by the H. & T. C. R. R., as above stated, in 1897, and is at present a part of that system.

The Austin and Northwestern Railroad was chartered April 29, 1881, from Austin to Abilene. Was opened as a narrow-gauge line to Burnet, 60 miles, by January 1, 1882, and was completed to Marble Falls by May, 1889

The Central Texas and Northwestern Railway was chartered as the Waxahachie Tap Railway by act approved January 25, 1875, to construct a line from a connection with the H. & T. C. Ry. to Waxahachie. Was rechartered under its present name September 28, 1881, and built to Waxahachie from Garrett, 12 miles.

The Fort Worth and New Orleans Railway was chartered from Fort Worth to New Orleans on June 13, 1885. This line was in operation from Waxahachie to Fort Worth, 41 wiles, by May, 1886.

The A. & N. W. R. R., C. T. & N. W. Ry. and F. W. & N. O. Ry., though operated as separate and distinct lines, are considered as part of the H. & T. C. R. R. system. An act of the 26th Legislature, approved May 20, 1899, granted authority to the H. & T. C. R. R. to purchase and consolidate with these lines upon the fulfilment of certain conditions, but to date the company has not taken advantage of the terms of this act.

The present mileage of the H. & T. C. R. R. system, included allied lines is as follows:

H. & T. C. R. R., including Austin and Waco Branches,	507.75 miles
A. & N. W. R. R.	107.75 miles
C. T. & N. W. Ry.	11.40 miles
F. W. & N. O. Ry.	41.97 miles
Lancaster Tap R. R.	4.76 miles
Total	673.74 miles

This system received land donations from the state as follows:

H. & T. C. Ry.	4,612,980 acres
Washington County R. R.	236,160 acres
W. & N. W. R. R.	481,280 acres
Waxahachie Tap Ry.	113,920 acres
A. & N. W. R. R.	109,440 acres
Totol	5,553,780 acres

The H. & T. C. was the first railway constructed across the state from north to south and it opened up a vast and very fertile territory. It is one of the most valuable pieces of railway property in the state and its gross earnings for the year ending June 30, 1899, were $7500 per mile.

Galveston, Houston and Henderson Railroad.—This road was chartered in accordance with an act passed by the legislature and approved

February 7, 1853. Construction began at Virginia Point March 1, 1854, and in three years the line was in operation to Harrisburg, 40 miles. The construction of the Galveston Bay bridge delayed the company and to aid in its building the city of Galveston on May 19, 1857, authorized the issuance of $100,000 in bonds. These were to be given to the railroad company, who were to pay interest on and provide a sinking fund for same. After retirement of the bonds the bridge was to become the property of the railroad company. The bridge was constructed and the line opened up from Houston to Galveston in 1860.

The G. H. & H. R. R. leases joint track privileges to the International and. Great Northern Railroad and to the Missouri, Kansas and Texas Railway from Houston to Galveston. Its gross earnings per mile for year ending June 30, 1899, were $8,379 per mile and it is regarded as the most valuable railroad property in the state. It received from the state 610,560 acres of land as donation.

Houston Tap and Brazoria Railroad.—The Houston Tap Railroad was built by the city of Houston, from Houston to Pierce Junction, in 1856, to connect Houston with the B. B. B. & C. Ry. It was sold to the Houston Tap and Brazoria Railroad Company, which was organized under act approved September 1, 1856, and extended to Columbia on the Brazos river, 50 miles from Houston, by 1861. The H. T. & B. R. R. was sold under foreclosure by the state on February 15, 1871, for non-payment of interest on money lonaed it from the public school fund and was purchased by the Houston and Great Northern Railroad Company and consolidated with the same by act of May 8, 1873. At present it forms a part of the International and Great Northern Railroad system, the successor of the H. & G. N. R. R.

Gulf, Western Texas and Pacific Railway.—This line is the result of the consolidation of the San Antonio and Mexican Gulf Railroad and the Indianola Railroad.

The S. A. & M. G. R. R. was chartered under provisions of an act approved September 5, 1850, from Port Lavaca to San Antonio. Grading began at Port Lavaca in 1856 and by January 1, 1858, 5 miles were reported as completed.

The Indianola Railroad was chartered under act approved January 21, 1858, from the rival port of Indianola, a few miles south of Port Lavaca, north via Gonzales and Austin, to intersect with the Southern Pacific Railway (now the T. & P. Ry.). It was graded a few miles and in 1860 was taken over by the S. .A& M. G. Ry. Co.

The S. A. & M. G. Ry. was open for traffic in April, 1861, from Port Lavaca to Victoria, 28 miles. It was destroyed by order of General Magruder in December, 1863, and falling into the hands of the Federals was rebuilt by them in 1865-66. Was sold by the Federal government in 1870. On August 4, 1870, an act was passed by the legislature authorizing the consolidation of the S. A. & M. G. R. R. with the I. R. R. and reorganization of both under the name of the Gulf, Western Texas and Pacific Railway. This line was open for traffic to Cuero on May 31, 1874. The extension was completed from Victoria to Beeville, 55 miles, in.....

This line received land donations from the state as follows:

S. A. & M. G. R. R.	264,898 acres
Indianola R. R.	171,520 acres
G. W. T. & P. Ry.	299,520 acres
Total	735,938 acres

Its present mileage is 111.2.

Texas and Pacific Railway.—The T. & P. Ry. was formed by the consolidation of the Memphis, El Paso and Pacific Railway, the Southern Pacific Railway and the Southern Transcontinental Railway.

The M. E. P. & P. Ry. was chartered by act approved February 7, 1853. This charter, which was forfeited, was renewed by act approved February 4, 1856. The railway was projected from the state line near Texarkana west to El Paso. Construction began on February 1, 1857, near Texarkana. It was proposed to bring the rails and track material up the Red River by boat to Texarkana, but on account of the forming of an immense raft in the river below about this time, a branch line was projected to Caddo Lake, near Jefferson, to bring material over for the main line. Five miles of this branch were built and 57 miles of the main line graded before operations were suspended by the war. Construction was renewed in 1869 and by March 1, 1870, 50 miles were in operation; by June 15, 1870, 100 miles were complete.

The Southern Pacific Railway was chartered as the Vicksburg and El Paso Railroad or the Texas Western Railroad by act approved February 16, 1852. An act approved August 16, 1856, amended the above act and changed the name to the Southern Pacific Railway. This line was projected from a connection with the Vicksburg, Shreveport and Texas Railroad at the state line west, via Marshall, to Dallas. Work began in 1856 on a branch line to Caddo Lake, over which track material could be brought for the main line. By February 10, 1858, 20 miles were in operation, and by October 1, 1859, 27.5 miles. In 1866 connection was made between Shreveport and Marshall and the Caddo Lake Branch was abandoned. By 1871 the line was in operation to Longview, 23 miles from Marshall.

The Southern Transcontinental Railway was incorporated in accordance with terms of act approved July 27, 1870, which also granted it authority to purchase the M. E. P. & P. Ry. and Jefferson Branch of same.

An act "to encourage the speedy construction of a railway from Texas to the Pacific Ocean" was approved May 24, 1871, which granted to the the S. P. Ry. Co. and the S. T.-C. Ry. Co. each $3,000,000 in state bonde on condition that said railways would extend their lines west to a junction not east of the eastern line of Shackelford county. Also said act authorized the consolidation of the S. P. Ry. and the S. T.-C. Ry. under name of the Texas and Pacific Railway, a company incorporated by act of congress, March 3, 1871, provided the stipulated conditions above mentioned were complied with. An act of November 11, 1871, amended above act to provide that the S. P. Ry. and the S. T.-C. Ry. might form a junction near the junction of the West and Clear Fork of the Brazos river; also that they should complete the branch line between Texarkana and Marshall; also that the State should have the right to substitute 24 sections of land per mile in lieu of the bonds authorized. Construction was rapidly pushed on both of these lines and by May 31, 1874, 300 miles were in operation. In 1878 the Texas and Pacific Railway operated mileage as follows

Shreveport to Fort Worth	222 miles
Texarkana to Sherman	154 miles
Texarkana to Marshall	68 miles
Total	444 miles

The northern line was extended west from Sherman, via Whitesboro, to a connection with the southern line at Fort Worth. On September 1, 1880, the T. & P. Ry. had 504 miles in operation and by September 1, 1881, 922 miles. By January 1, 1882, connection was made with the G. H. & S. A. Ry. at Sierra Blanca, making a through line from east to west across the northern part of the State. At present the T. & P. Ry. operates about 1040.31 miles of railway in Texas. This system received land donations from the State as follows:

M. E. P. & P. Ry	258,399 acres
Southern Pacific	562,560 acres
Texas and Pacific	4,911,314 acres
Total	5,732,237 acres

Texas and New Orleans Railroad.—This line was chartered by act approved September 1, 1856, under name of the Sabine and Galveston Bay Railroad and Lumber Company, from the Sabine river in Orange county, via Beaumont, to Galveston Bay. An act approved December 24, 1859, changed the name to the T. & N. O. R. R. Work began on this line in Houston in 1858 and by August, 1860, it was completed to Liberty, 40 miles. By January 1, 1861 it was in operation to the Sabine river at Orange. It was partially destroyed by the Confederates in 1865 and was not entirely rebuilt and operated again until 1876. On August 1, 1876, it was reopened for traffic from Houston to Orange.

The charter for the T. & N. O. R. R. was amended May 23, 1882, to provide for a line from Sabine Pass north to Marshall. The Sabine and East Texas Railway was acquired, which was in operation from Sabine Pass to Rockland, 103 miles. This road was originally chartered under the name of the East Texas Railroad on April 29, 1880, which was amended to S. & E. T. Railway on August 3, 1881. By an act approved May 22, 1899, the T. & N. O. R. R. was authorized to purchase and consolidate with the Texas Trunk Railroad from Dallas to Cedar, about 50 miles, and extend same to connect with former S. & E. T. Ry. at Rockland. The T. & N. O. R. R. operates at present about 216 miles. The system received land donations from the State amounting to 1,226,880 acres.

International and Great Northern Railroad.—This line was formed by the consolidation of the Houston and Great Northern Railroad with the International Railroad, which it succeeded.

The Houston and Great Northern R. R. was chartered October 22, 1866, from Houston north to Red River, intersecting the line of the Texas and Pacific Railway at Clarksville. By 1871 50 miles were in operation north of Houston, and by January 1, 1872, the road was completed to Trinity, 88 miles. The line was opened to Palestine, 150 miles, in November, 1872. The Huntsville Branch Railroad, which was chartered April 4, 1871 and built in 1872, and the Houston Tap and Brazoria Railroad, which, as before stated, was purchased in 1872, were consolidated with the H. & G. N. R. R. by act approved May 8, 1873.

The International Railroad was chartered August 5, 1870, from the Red River opposite Fulton, Arkansas, via Austin and San Antonio, to the Rio Grande at Laredo. Work began at Hearne in 1870 and the line was built to Jewett, 50 miles, in 1871. It was completed to Palestine, 90 miles, by February 1, 1872, and was in operation to Longview by December of same year. The state at first granted the company bonds to the amount of $10,000 per mile, for which were afterwards substituted the usual land grant of 16 sections per mile. In addition to this the road was exempted from taxation for a period of 25 years.

Under the provisions of an act approved September 23, 1873, the International and Great Northern Railroad was incorporated with authority to purchase and consolidate the H. & G. N. R. R. and the I. R. R. under this title, and extend latter, etc. The branch from Troupe to Mineola, 44 miles, was opened in April, 1874. In 1876 the main line was extended to Austin. The Henderson and Overton Railroad was chartered April 29, 1874, and opened for traffic May 8, 1877. The Georgetown Railroad was chartered May 31, 1878, and built that year. Both of these lines were absorbed by the I. & G. N. R. R.

The main line was extended from Austin west, via San Antonio to Laredo and was opened for traffic in 1881. The system comprises at present about 775 miles. It received land donations from the State as follows:

Houston Tap & Brazoria R. R.	500,480 acres
Houston & Great Northern R. R.	2,307,200 acres
International & Great Northern R. R.	3,331,200 acres
Henderson & Overton R. R.	143,360 acres
Georgetown Railroad	98,560 acres
Total	6,380,800 acres

Missouri, Kansas and Texas Railway.—By an act approved August 2, 1870, the M. K. & T. Ry. Co., which was incorporated by act of congress, was authorized to construct a line from Red River south, via Waco and Austin, to the Rio Grande. Right was granted it to acquire and consolidate with any other railway in the state. The main line of this railway reached Denison by January 1, 1873.

By act approved April 16, 1891, the M. K. & T. Ry. of Texas was organized and authorized to purchase and absorb the following existing lines of railway:

Denison & Pacific, from Denison to Whitesboro	25 miles
Gainesville, Henrietta & Western, Whitesboro to Henrietta	86 miles
Denison & Southeastern, Denison to Mineola	103 miles
Dallas & Greenville, Greenville to Dallas	52 miles
Sherman, Denison & Dallas, Denison to Sherman	11 miles
Dallas & Wichita, Dallas to Denton	39 miles
Dallas & Waco, Dallas to Hillsboro	66 miles
Taylor Bastrop & Houston, Ft. Worth to Boggy Tank	250 miles
Taylor, Bastrop & Houston, Echo to Belton	7 miles
Taylor, Bastrop & Houston, San Marcos to Lockhart	15 miles
Trinity & Sabine, Trinity to Colmesneil	67 miles
Total mileage purchased	721 miles

In addition the M. K. & T. Ry. of Texas constructed line as folloows:

Boggy Tank to Houston	77 miles
Lockhart to Smithville	37 miles
Red River to Denison	5 miles
Grand Total	840 miles

The actual mileage in Texas as reported by the M. K. & T. Ry. of Texas Company for year ending June 30, 1899, is 841.98 miles.

The system received land donations from the state as follows:

Dallas & Wichita Railway	411,520 acres
Denison & Southeastern Railway	214,400 acres
Denison & Pacific Railway	426,240 miles
M. K. & T. Ry. Extension	272,000 miles
Total	1,324,160 acres

Rio Grande Railroad.—This line was chartered by act approved August 23, 1870, and was open for traffic from Point Isabel to Brownsville on July 4, 1872.

Sherman, Shreveport and Southern Railway.—This line was chartered March 22, 1871, under the name of the East Line and Red River Railroad and was open for traffic from Jefferson to Greenville, 124 miles, December 5, 1876. The line was extended to McKinney from Greenville, 32 miles in ..... On February 28, 1893, it was re-incorporated under the present name. It is operated as a branch line of the M. K. & T. Ry. of Texas and by act of the legislature, passed and approved May 16, 1899, authority was granted to consolidate with same under certain conditions, which are being complied with by the M. K. & T. Ry. of Texas Company. The extension from Jefferson east to the state line near Waskom was recently completed, making about 181 miles of operated line in Texas. The E. L. & R. R. R. R. Co. received 1,164,160 acres of land as donation from the state.

St. Louis Southwestern Railway of Texas.—This line was originally chartered under the name of the Tyler Tap Railway by act approved December 1, 1871, from Tyler northeast 40 miles to an intersection with Southern Pacific (T. & P.) Railway. The Texas and St. Louis Railway was organized April 14, 1879, and succeeded to the Tyler Tap Railway in accordance with its charter filed May 17, 1879, which provided for an extension northeast to Texarkana and west through McLennan county. The line was opened up from Texarkana to the Trinity river, 181 miles, at close of 1880. Its extension reached Corsicana, 203 miles, by April 1, 1881. Was completed to Waco, 260 miles, by September 1, 1881. The road was placed in the hands of a receiver on January 16, 1884, and sold under foreclosure on December 1, 1885. Was reorganized January 29, 1886, under name of the St. Louis, Arkansas and Texas Railway, the charter for which was filed May 8, 1886. An amendment to same, filed September 15, 1886, provided for the construction of the branch from Mt. Pleasant to Sherman; also an amendment filed March 15, 1887, provided for the construction of the Ft. Worth and Hillsboro branches, which were constructed in 1888.

The St. L., A. & T. Ry. was sold under foreclosure on October 23, 1890, and on January 12, 1891, the St. Louis Southwestern Railway of Texas was chartered to succeed the same.

The Kansas and Gulf Short Line Railroad was chartered February 18, 1880, from Tyler to Sabine Pass. The first section was opened December 18, 1882, and the line completed to Lufkin, 90 miles, by July 1, 1885. Was placed in the hands of a receiver and sold by order of the court on October 23, 1885. Was reorganized and rechartered under the title of the Tyler Southeastern Railway on January 12, 1891. By act of the legislature, passed in May, 1899, the St. L. S. W. Ry. of Texas was granted authority to purchase and consolidate with theT. S. E. Ry.

The total operated mileage of the St. L. S. W. Ry. of Texas, including the T. S. E. Ry., at present is 640.3 miles. This system received land donations from the state as follows:

Tyler Tap Railway..................	458,240 acres
Texas & St. Louis Railway...........	942,080 acres
Total..................	1,400,320 acres

Gulf, Colorado and Santa Fe Railway.—This line was chartered by an act approved May 28, 1873, to construct from Galveston to Red River. Construction began at Virginia Point in 1875 and the line was built to Arcola, 43 miles, in 1877; to Richmond, 64 miles, in 1878; to Brenham, 126 miles, by August 1, 1880; to Belton by February, 1881; to Lampasas by May 15, 1882; to Ft. Worth by December 8, 1881. By act approved April 14, 1882, the G., C. & S. F. Ry. was authorized to purchase the Central Montgomery Railroad from Navasota to Montgomery and extend same to Somerville and to Conroe. An act approved July 7, 1882, provided for the purchase of the Chicago, Texas and Mexican Central Railway from Dallas to Cleburne and extend same to Paris. By 1885 the extensions were completed from Lampasas to Brownwood and from Montgomery to Conroe. In 1886 extensions were completed to Ballinger and Honey Grove ; in 1887 to Paris, Weatherford and San Angelo.

Land donations were received from the state as follows:

Central Montgomery...............	263,040 acres
Chicago, Texas & Mexican Central....	225,280 acres
Gulf, Colorado and Santa Fe.........	3,259,520 acres
Total	3,747,840 acres

The G. C. & S. F. Ry. Co. operates today 989.11 miles of main line within the limits of the state.

Ft. Worth and Denver City Railway.—This line was chartered May 26, 1873. Was completed to Decatur, 36 miles, May 1, 1882; to Bowie, 64 miles, July 1, 1882; to Wichita Falls, 110 miles, Sept. 24, 1883; to Harrold, 144 miles, May 12, 1885; to Vernon, 163 miles, Octoer 15, 1886; to Quanah, 192 miles, February 1, 1887; to Clarendon, 276 miles, October 1, 1887; to State Line, 453 miles, January 26, 1888. In connection with the Denver, Texas and Ft. Worth Railway, was opened from Ft. Worth to Denver on March 1, 1888. The total mileage in the state, including the Ft. Worth and Denver Terminal Railway, is 453.57 miles.

Houston East and West Texas Railway.—This line was chartered March 11, 1875. Was opened to Goodrich, 62 miles, in 1879; to Moscow, 87 miles, in 1880; to Burke, 110 miles in 1881; to Nacogdoches, 138 miles, in 1882; to Sabine River, 192 miles, by December 1, 1885.

This line received from the state 787,840 acres of land donation.

Texas Mexican Railway.—This line was chartered from Corpus Christi to the Rio Grande River on March 13, 1875, under title of the Corpus Christi, San Diego and Rio Grande Railroad. Present name was adopted by amendment dated June 30, 1881. Length of main line is 162.24 miles and received from the state land donations as follows:

Corpus Christi, San Diego and Rio Grande,	855,680 acres
Texas Mexican, ...	556,800 acres
Total...............	1,412,480 acres

Texas Central Railroad.—This line was chartered May 28, 1879, from a point in McLennan county northwest to state line; also northeast to state line. The northwest branch was built from Ross to Albany, 176 miles in 1882 and in 1889 extended to Stamford, 214 miles. The eastern branch was built from Garrett to Roberts, about 52 miles, and when sold under foreclosure on March 25, 1891, was reorganized under title of the Texas Midland Railroad, which was extended south to Ennis and north to Greenville, 72 miles from Ennis. Was built from Commerce to Paris, 38 miles. It operates over the St. L. S. W. Ry. track from Greenville to Commerce. The Texas Central R. R. Co. received 1,471,360 acres of land from the state.

New York, Texas and Mexican Railway.—This line was chartered from Rosenberg to Brownsville on November 17, 1880. Was completed to Victoria, 91 miles, on January 15, 1882. It is at present under the control of the Southern Pacific Railway Company and operated in connection with the G. W. T. & P. Ry.

San Antonio and Aransas Pass Railway.—This line was chartered August 28, 1884, from San Antonio to Aransas Pass. Construction began in August, 1885. The charter was amended on March 29, 1886, and on May 24, 1888, to extend northwest from San Antonio; to build Corpus Christi Branch; to extend from Kennedy east to Houston and west to Laredo and to build the Waco Branch. On December 31, 1890, the system had 630 miles in operation. Its present mileage is 687.4 miles.

Ft. Worth and Rio Grande Railway.—This line was chartered from Ft. Worth to Kerrville in May, 1885. Construction began in November, 1886, and the line was completed to Granbury, 40 miles, by June 1, 1887. Was extended to Dublin in 1889 and completed to Brownwood in 1891. Operates at present 146.16 miles.

There are a number of small lines in Texas which are operated as a rule in connection with and controlled by the larger systems, and their history in detail is not of sufficient importance to be commented upon here.

The railways of Texas can be grouped in systems, showing by whom they are dominated and controlled and under what outside influences they are operated. They are however all operated in the state as separate and distinct lines in accordance with the laws of the state which provide in such instances. The following statement shows the dominating or controlling systems and the lines operated in the state in connection therewith. The mileage given is for June 30, 1899, as reported by the Railroad Commission of Texas:

SOUTHERN PACIFIC SYSTEM.

Sunset Division:

Texas and New Orleans Railroad	216.26 miles.
Galveston, Harrisburg & San Antonio Railway	918.16 miles.
Galveston, Houston & Northern Railway	56.18 miles.
Gulf, Western Texas & Pacific Railway	111.20 miles.
New York, Texas & Mexican Railway	91.00 miles.
Louisiana Western Extension Railway	6.70 miles.
Texas Trunk Railroad	51.68 miles.

Central Division:

Houston & Texas Central Railroad	507.75 miles.
Austin & Northwestern Railroad	107.86 miles.
Central Texas & Northwestern Railway	11.40 miles.
Ft. Worth & New Orleans Railway	41.97 miles.
Lancaster Tap Railway	4.76 miles.
Hearne & Brazos Valley Railroad	16.42 miles.
San Antonio and Aransas Pass Railway	687.40 miles.
Houston East & West Texas Railway	192.00 miles.
Texas Central Railroad	177.00 miles.
San Antonio & Gulf Railroad	37.95 miles.
Total	3235.69 miles.

GOULD SYSTEM.

International & Great Northern Railroad	775.40 miles.
Galveston, Houston & Henderson Railroad	50.00 miles.
*Velasco Terminal Railway	20.00 miles.
†Calvert, Waco & Brazos Valley Railway	15.00 miles.
Texas & Pacific Railway	1040.31 miles.
Denison & Pacific Suburban Railway	7.63 miles.
St. Louis Southwestern Railway, of Texas	551.70 miles.
Tyler Southwestern Railway	88.60 miles.
Total	2548.64 miles.

SANTA FE SYSTEM.

Gulf, Colorado & Santa Fe Railway	989.11 miles.
Southern Kansas Railway	100.41 miles.
Panhandle Railway	14.72 miles.
Paris & Great Northern Railroad	16.94 miles.
Pecos & Northern Texas Railway	94.48 miles.
Pecos River Railroad	54.13 miles.
Rio Grande & El Paso Railroad	20.15 miles.
Total	1289.94 miles.

*In hands of receiver.

†January 1, 1900.

KATY SYSTEM.

Missouri, Kansas & Texas Railway, of Texas......	841.98 miles.
Wichita Falls Railway..........................	17.96 miles.
Denison & Washita Valley Railway..............	6.40 miles.
Sherman, Shreveport & Southern Railway.........	153.04 miles.
Cane Belt Railroad............................	11.00 miles.
Total..........................	1030.38 miles.

DENVER SYSTEM.

Ft. Worth & Denver City Railway...............	448.57 miles.
Wichita Valley Railway.........................	51.00 miles.
Fort Worth & Denver Terminal Railway..........	5.00 miles.
Total..........................	504.57 miles.
Other systems	1107.85 miles.
Grand Total	9717.07 miles.

The following statement shows the number of miles of railway in operation in Texas at the end of each year, beginning with 1854, and increase in mileage for each year. The table has been prepared from the most authentic sources and is believed to be quite correct:

End of year.	Miles in Operation.	Increase.	End of Year.	Miles in Operation.	Increase.
1854	32	....	1878	2,428	228
1855	40	8	1879	2,591	163
1856	71	31	1880	3,244	653
1857	157	86	1881	4,913	1,669
1858	205	48	1882	6,009	1,096
1859	284	79	1883	6,075	66
1860	307	23	1884	6,198	123
1861	392	85	1885	6,687	489
1862	451	59	1886	6,925	238
1863	451	....	1887	7,889	964
1864	451	....	1888	8,205	316
1865	465	14	1889	8,486	281
1866	471	6	1890	8,710	224
1867	513	42	1891	8,801	92
1868	513	....	1892	9,028	226
1869	583	79	1893	9,154	126
1870	511	128	1894	9,231	77
1871	865	154	1895	9,422	191
1872	1078	213	1896	9,485	63
1873	1578	500	1897	9,589	104
1874	1650	72	1898	9,778	189
1875	1685	35	1899	9,869	91
1876	2031	346	1900	*10,124 est.	255
1877	2210	179			

* This estimate does not consider about 78 miles that have been abandoned and rails taken up within past year.

By referring to the above columns marked "Increase," one can readily note the periods of greatest activity and depression in railway construction in Texas, which can be easily traced to good times on the one hand and panics on the other in the money centers of the world. During the civil war and years immediately following, railway construction was practically at a standstill. Later business revived and under favorable conditions in way of magnificent land donations offered to any railway company that might construct in the state, several thousand miles were built. 1881 is the "banner year" in railway construction in Texas when 1669 miles were added to its mileage.

The year 1900 will see more miles of railway constructed in Texas than any year since 1889. More than two hundred miles of line are under construction, chiefly extensions and feeders of the larger systems. It is probable that this activity will continue for several years. As the territory becomes more developed the necessity for railway extensions will increase. In former years while land and other donations invited the expenditures of capital for railway construction, at present the prospective business in a territory must guarantee such investment.

Texas has a land area of approximately 260,900 square miles and a population of about 3,000,000. Placing its railway at 10,000 miles we note that it has about 3.833 miles of railway for every 100 square miles and about 33.333 miles for every 10,000 inhabitants. The following comparative statement, taken from a table given in the statistical report of the Interstate Commerce Commission for the year ending June 30, 1898, in which comparisons are made between the ten states leading in railway mileage, may be of interest. It will be noted, however, that the population of Texas was estimated at about 2,591,000.

State.	Miles of Railway.	Miles of Railway per 100 sq. miles.	Miles of railway per 10,000 inhabitants.
Illinois	10,852	19.38	24.27
Pennsylvania	9,910	22.02	16.25
Texas	9,650	3.68	37.24
Kansas	8,790	10.76	53.14
Ohio	8,736	21.43	20.52
Iowa	8,518	15.35	38.44
New York	8,300	17.43	11.94
Michigan	7,975	13.89	32.86
Missouri	6,793	9.84	21.77
Wisconsin	6,398	11.75	32.72

From the above table it is seen that, though Texas is well supplied with railway in proportion to population, being exceeded by only two of the states mentioned, in point of railway in proportion to territory it is far below the lowest. If it were as well supplied with railway in proportion to its territory as Illinois, it would have 50,759 miles; as Pennsylvania, 57,900 miles; as Kansas, 28,178 miles; as Ohio, 56,163 miles; as Iowa, 40,240 miles; as New York, 45,644 miles; as Michigan, 36,380 miles; as Missouri, 25,766 miles and as Wisconsin, 30,784 miles. The wonderful possibilities of Texas as a railway state becomes apparent upon consideration of these figures.

A glance at the map of Texas will show a large area of comparatively undeveloped territory particularly west of the 21st meridian. A line drawn from the Red River to the coast through the towns of Wichita Falls and Corpus Christi, approximately divides the state into what we might consider the developed and undeveloped portions and with regard to this line the following statistics are approximately true on the basis of a total land area of 260,900 square miles, a population of 3,000,000 and a railway mileage of 10,000.

	West.	East.
Land area in square miles	173,750	87,150
Population	640,235	2,359,765
Population per square mile	3.68	27.08
Miles of railway	3097	6903
Miles of railway per 1000 square miles	17.82	79.21
Miles of railway per 1000 inhabitants	4.84	2.90

It is seen that while the area west of the line is about twice as large as the area east, the eastern part has more than twice the railway mileage and almost four times the population.

Of the states in the Union in 1870 Texas was 25th in railway mileage; in 1880 it was 9th; in 1890 it was 3rd and holds that rank today. In view of the increased activity in railway building in the state at present over recent years, it is probable that by the end of 1900 Texas will take 2nd place from Pennsylvania. By 1905 it should be first and ever thereafter hold the lead in point of railway mileage of all the states in the Union.

The records in the office of the Secretary of State show that for the period of ten years ending June 30, 1899, approximately 14,390 miles of railway were chartered in Texas. Of this amount 1136 miles were built, or about 8 per cent of the line chartered. As the present and prospective conditions for railway construction are more flattering, we are safe in assuming that for the next decade the ratio of constructed line to the chartered mileage will be considerably in advance of the above figure.

I. Cretaceous of Obispo Canyon, Sonora, Mexico.

E. T. DUMBLE,
Houston, Texas.

The trail between La Barranca and La Dura, Sonora, after crossing Obispo Pass, follows the Obispo canyon southward for three or four miles. In this canyon, about ten miles from La Dura, there is an exposure of thin to medium bedded limestones of light color, streaked with gray or black, which rest upon a purple volcanic agglomerate and are, in turn, overlain by the "greenstone" of the region.

An examination of the beds show that they form the sides of a range of rounded hills which extend along the west bank of the canyon for nearly a mile, and that they carry fossils of Cretaceous age. The fossils are all, or nearly all, siliceous pseudomorphs and badly preserved, and it required considerable search to find forms that could be positively identified. Many oysters were found, a few gasteropods, a fair specimen of the form formerly known as Cypremaria, part of the plates of a large echinoid of the Cidaridæ class and small Gryphæa—enough to prove its Cretaceous age. The thickness of the beds is not more than seventy-five feet. They rest, as has been stated, on a purple agglomerate. I was not able to ascertain positively whether the contact showed an unconformity or not, but I think it did. Just below the first limestone there is in the thin bedded agglomerate a bed of flint, then agglomerate and then lime, the base of which was mixed with the agglomerate. At other places it seemed to me that the limestone rested directly on the bed of flint.

This agglomerate is here the uppermost bed of the Triassic volcanic complex—the Lista Blanca, and the andesitic greenstone which immediately succeeds the Cretaceous limestone is here the base of the Trincheras complex and of supposedly Tertiary age.

The nearest Cretaceous known is that at Arivechi, sixty miles or more to the east, and that near Casita, more than that distance west of this locality.

Besides being of importance as a new and hitherto unnoticed occurrence of the Cretaceous, this place is still more important as showing most clearly the actual demarkation of these two systems of igneous rocks, and as the only place so far found where both occur in such a position and connection as to be definitely and accurately limited and determined.

II. Occurrence of Oyster Shells in Volcanic Deposits in Sonora, Mexico.

E. T. DUMBLE,
Houston, Texas.

The Mesozoic and Neozoic deposits of Sonora contain three great complexes of igneous rock. The older of these, which comes in connection with clastic sediments of the Triassic and underlying the Cretaceous, we have called the Lista Blanca. The second, which overlies the Cretaceous, has been named the Trincheras, while the latest has received the designation from the town where it is so well exposed—Nogales. These complexes comprise massive igneous rocks, both andesites and rhyolites, with agglomerates and tufaceous agglomerates, volcanic conglomerates, tuffs and scoriaceous lavas, interbedded with sedimentary deposits of sand, clay and lime. The details of these formations were given in "Notes on the Geology of Sonora," Transactions American Institute of Mining Engineers, January, 1899.

It is not always possible to determine to just which one of these series any given outcrop belongs, unless there is present sedimentary rock of either Triassic or Createceous age. The rocks at Guaymas are of this class. In character they seem to correspond fairly well with the Trincheras, but we are inclined, on account of their position, to place them with the Nogales. These rocks form considerable hills around the city of Guaymas, and also rise from the waters of the bay as islands, and on one of these there is, in a pinkish feldspathic material, a bed of oyster shells. The material is rhyolitic and the shells, which are entirely silicified, are completely imbedded in and covered by the matrix as though it had flowed around and over them as volcanic mud. The oysters are of the same general shape as those growing in the bay today, but so completely covered and altered as to be unidentifiable.

At La Barranca the Coal Series of the Triassic is capped by a gray andesitic agglomerate belonging, we believe, to the Lista Blanca. In cutting a road through the material we uncovered the remains of a large oyster shell completely imbedded in this agglomerate. Such parts of the shell itself as remain are altered to calcite and not silicified, as the Guaymas specimens were.

Both localities were found by Mr. J. Owen.

Note on the Mart and Bluff Meteorites.

O. C. CHARLTON,
Professor of Science. Baylor University, Waco, Texas.

In January, 1888, the meteorite now known as the Fayette County, or Bluff Meteorite, was purchased by the Ward Natural History establishment of Rochester, New York, from Mr. H. Hensoldt, who had been teaching near Bluff, Fayette county, Texas. It had been found some ten years previously on a farm then owned by Mr. Frank Rainocet, who now lives on another farm near Bluff. When secured by the Wards the stone weighed about 280 pounds. It is listed in their catalogue as a Siderolite.

It was described by Mr. J. E. Whitfield and Mr. Geo. P. Merrill in the *American Journal of Science*, August, 1888. They found it to "consist essentially of enstatite and olivine with a good deal of nickel, iron and some pyrrhotite." The iron contained over fifteen per cent. of nickel and two per cent. of cobalt. A large part of the original mass has been cut into slices and quite widely distributed, though the Wards still have over fifty pounds of the stone.

Early this year (1900) Mr. C. L. Melcher, of Swiss Alp, near Bluff, sent me two stones which he supposed to be meteorites. Fragments from them were examined by Mr. George P. Merrill, of the United States National Museum, who concluded that the two stones were parts of the fall which had furnished the large Bluff meteorite of twelve years ago. The total weight of these two stones, and a third small stone recently found, is 31½ pounds. The largest one of these is now owned by Mr. Henry A. Ward, of Rochester, the other two by Baylor University.

The Mart Iron Meteorite was found by Mr. Watts Vaughan while ploughing on a farm south of Mart, Texas, in 1895. It lay about eight inches beneath the surface of the ground, and its presence was made known by the plow scraping against it. During the summer of 1899 it was sent to the United States National Museum, where it was examined by Mr. George P. Merrill. In September, 1899, the ownership of the iron was transferred to Baylor University, after which Mr. Merrill photographed it, prepared a cast of it, cut a slice from it and polished and etched the exposed surface of the principal mass. The slice was retained for use in the preparation of a full report, which report is, perhaps, now ready for publication.

Recently Mr. Henry A. Ward cut off about four pounds for himself and one slice for me. The slice and principal mass are retained by Baylor University. The Widmanstätten figures are shown quite well on all etched surfaces.

The weight of the Mart iron when found was 15 pounds 9 ounces.

Baylor University, Waco, Texas, June 16, 1900.

On the Fossils of the Texas Cretaceous, Especially Those Collected at Austin and Waco.

JOHN K. PRATHER, B. S.,
Waco, Texas.

(An extract from a paper entitled "The Cretaceous as the Kindergarten of Paleontology," presented at the Baylor-Waco meeting, December 29, 1900.)

The greatest development of the Cretaceous in the United States is found in Texas around Austin and Waco, where, owing to the softness of the rock and the lack of metamorphism, fossils are easily obtained. Here are found examples of almost all of the main divisions of the animal kingdom.

1. Commencing with the PROTOZOA, the *Foraminifera* are quite common and are represented by a number of species, as are also the *Radiolaria*.

2. The COELENTERATA, too, are well represented. In some divisions of the Cretaceous sponges are very numerous, while in others they are rare. The *Cnidaria* are represented by such forms as:

Pleuracora texana (Roemer), Edwards Limestone, Deep Eddy Bluff, Austin.

Turbinolia texana (Conrad), Denison Beds, near El Paso.

And many new corals from the Edwards, Shoal Creek, Fort Worth, and other divisions of the Cretaceous. Most of these forms have been very little studied. They are also represented by some new species of *Leptophyllia* from the Edwards Limestone recently described by Mr. T. W. Stanton.

3. The ECHINODERMATA are especially well represented both as to number of forms and beauty of the specimens. Some of the most common are:

Enallaster texanus (Roemer), Fort Worth, Edwards, and Comanche Peak Limestones.

Epiaster elegans (Shumard), Fort Worth Limestone.

Epiaster whitei (Clark), Fort Worth Limestone.

Hemiaster texanus (Roemer), Austin Chalk.

Holaster simplex (Shumard), Fort Worth.

Holectypus planatus (Roemer), Edwards Limestone.

Pseudodiadema texanum (Roemer), Comanche Peak Limestone.

Some Crinoids are found, as, for instance, in the Edwards Limestone, but they are not numerous.

4. WORMS are found in the Austin chalk, Fort Worth and Edwards Limestones, but they have been studied only in a general way. Some species have been described by Prof. Robert T. Hill and others, but there is yet much material to be worked up.

5. Of the MOLLUSCOIDEA, the *Bryozoa* are represented in the Fort Worth, Del Rio and Edwards Limestones. They, too, have not yet been thoroughly studied. The *Brachiopoda* are represented by a *Rhynchonella* from the Fort Worth, a *Terebratula* from the Eagle Ford Shale, one from the Edwards Limestone, and *T. Wacoensis* from the Fort Worth Limestone.

6. The MOLLUSCA are best represented. Some of the most commonly known are:

Lamellibranchs—

Radiolites austinensis (Roemer), Austin Chalk and Ponderosa or Taylor Marl.

R. rugosa (Giebel), Edwards Limestone.

R. davidsoni (Hill), Edwards Limestone.

Monopleura marcidi (White), Edwards Limestone.

M. coralliochama (Stanton), Edwards Limestone.

Spondylus hilli (Cragin), Del Rio Clays.

Ostrea munsoni (Hill), Edwards Limestone.

O. carinata (Lamark), Fort Worth Limestone.

O. subovata (Shumard) Fort Worth Limestone.

Exogyra arietina (Roemer), Del Rio and Shoal Creek formations.

Lima wacoensis (Roemer), Fort Worth and Comanche Peak Limestone.

Inoceramus deformis (Meek), Austin Chalk.

Gryphæa washitaensis (Hill), Fort Worth Limestone.

Mytilus tenuitesta (Roemer), Fort Worth Limestone.

Trigonia emeryi (Conrad), Walnut Clay.

Cardita (several species), Fort Worth Limestone.

Pinna petina (White), Comanche Peak Limestone.

Hippurites texanus (Roemer), Edwards Limestone.

Gasteropods—

Turrilites brazoensis (Roemer), Fort Worth Limestone.

Turritella seratim-granulata (Roemer), Fort Worth Limestone.

Pleurotomaria austinensis (Shumard), Fort Worth Limestone.

Cerithium bosquense (Shumard), Edwards Limestone.

Tylostoma tumidi (Shumard), Edwards and Comanche Peak Limestones.

Cephalopoda—

Scaphites (several species not well studied).

Schloenbachia leonensis (Conrad), Fort Worth Limestone.

S. wacoensis (Roemer), Edwards Limestone.

Nautilus texanus (Shumard), Fort Worth Limestone.

Many Nauteloids are found in the Fort Worth Limestone and in other divisions of the Cretaceous. They vary in size from two inches in diameter to over a foot. Ammonites are also numerous, and they likewise vary in size, say from two inches in diameter to over two feet, while one large species from the Upper Cretaceous measures from three to six feet.

7. THE VERTEBRATES are represented in the Cretaceous by a number of species. I have collected within a radius of six miles from Waco examples of

Clidastes,
Ichthyodectes,
Protosphyraena penetras,
Oxyrhina extenta,
Tiphactinus audax,
Cimoliosaurus,
Mosasaurus,
Plesiosauras,
Squalodouts,
Cestraciont sharks,

Besides numerous fishes as shown by the teeth and vertebræ found. These vertebrate specimens were sent by me to the U. S. National Museum, where they were studied by Dr. F. A. Lucas. The same forms have been found in Kansas and Dr. Williston, of the University of Kansas, and Dr. Lucas are of the opinion that the formations from which the Texas specimens were taken (Eagle Ford Shoals and Austin Chalk) are identical with the Niobrara of Kansas.

Wood Preserving by Painting with or Immersing in Tar Oils.

E. P. SCHOCH. M. A., C. E.,
Instructor in Chemistry, the University of Texas.

The value of good creosote as a wood preserver is beyond question, but the expense of the operation coupled with the fact that creosoting plants are not sufficiently numerous to be of easy access everywhere, reduces the advantages of the process so that in the erection of occasional small buildings by the farmer and others, they are almost *nil*. A wood preserver that is easily and cheaply applied is highly desirable. The immense economic value of such an article needs no special emphasis. Everything considered, of all substances that have been extensively employed for the preservation of timbers, creosote has given the best and most uniform results. Hence in searching for an effective preserving substance that is easily and cheaply applied, one should naturally begin by enquiring into the value of the different constituents of creosote, more particularly, the different coal tar distillates.

It has long since been found that the efficiency of creosote varies greatly with different samples. Leaving out of consideration the many adulterated samples that we have to contend with in this country and confining ourselves to pure creosote oil, we find that the results obtained with samples from different tars have been clearly presented and well discussed by Mr. S. B. Boulton in a paper presented before the "Institution of Civil Engineers" of England in 1885, entitled "The Preservation of Timber by the Use of Antiseptics." From Mr. Boulton, and other authorities, I have gathered the following facts and conclusions concerning the value of different constituents of creosote:

1st.—Carbolic Acid. Of all coal tar products, the tar acids first attract our attention. Carbolic acid is the best known representative of this class of bodies and is present in tar in larger quantities than any other acid. It is popularly thought that the preservative qualities of creosote are manily due to the presence of carbolic acid. However, as a germicide it is not as effective when compared with solutions of the same strength of other constituents of coal tar discussed further on. Accurate quantitative data on this point have so far not been obtained, but experiments have been outlined and partially begun at the Chemical Laboratory of the University of Texas. From all facts that have come under my observation, and as far as I can learn through reference, the antiseptic properties of the other constituents of coal tar are far greater, solutions of the same strength being considered. Furthermore, Dr. Koch has found that carbolic acid dissolved in oils does not exhibit any antiseptic action. Another function that carbolic acid has been thought to perform, is the coagulation of albumen in the wood; it being assumed, first, that this is present; second, that albumen once coagulated will resist decay. Both of these assumptions are probably erroneous. Albumen is very likely not present in woody fibre. Even if it is, the coagulation will not prevent decay, since Herr F. Boillat found that albumen which has been coagulated by carbolic acid and then washed with water to remove the carbolic acid, decays within from two (2) to forty (40) days.

These facts, together with the experiments of Mr. S. B. Boulton, who showed that carbolic acid could be entirely removed from creosote oils by washing with water, together with researches of Mr. Greville Williams on a large number of creosoted timbers, which had been in the ground for a period, varying from one (1) to thirty-two (32) years, and in all of which the carbolic acid had entirely disappeared, showing conclusively that carbolic acid, and hence all tar acids, have no value for wood preserving.

2nd.—Highboiling Oils. Samples of timbers had been pickled in creosote oil, and remained in the ground as follows:

One specimen, sixteen years.
One specimen, seventeen years.
Two specimens, twenty years.
Two specimens, twenty-two years.
One specimen, twenty-eight years.
Two specimens, twenty-nine years.
One specimen, thirty years.
One specimen, thirty-two years.

These were subjected to dry-distillations with the following results:

Fourteen (14) out of the seventeen (17) yielded semi-solid constituents, e. g., napthalene in twelve (12) of these. Only small percentages remained of oil distilling below 240° C.; in the majority of instances from 60% to 75% of the total bulk of distillates did not distil until after a temperature of 315° C. had been reached. Evidently these timbers had been preserved by the presence of the less volatile oils found in the creosote with which they had been treated.

Mr. S. B. Boulton impregnated wood shavings with the different boiling portions of creosote. After six months exposure the shavings prepared with the highest boiling oils were found to be perfectly sound, while those prepared with the low boiling oils, which also contained carbolic acid, were attacked by decay. It is to the high boiling tar oils, then, that particular attention should be paid. These tar oils have strong germicidal effect—even the solids, such as napthalene, inhibiting the growth of lower forms of life.

3rd.—Tar Bases. In examining these high boiling oils, tar acids are found to be absent, but tar bases, notably acridine and cryptidene, are found present. These tar bases are very effective germicides. Acridine is very slightly soluble, or practically insoluble, in water, and acts as a powerful germicide. It has been used to protect the sides of sea-going vessels against the attacks of barnacles and teredos. Even after an exposure of nine (9) months at sea, acridine was still present in the paint with which it was mixed, and the hulls were free from attack. This substance was found to be present in most of the samples of creosoted timbers mentioned above, and it is the opinion of the highest authorities that acridine is one of the most important constituents of coal tar distillates intended for wood preservers.

M. H. H. Cousins, of the Southwestern Agricultural College at Wye, England, carried out experiments with a view to throw light on the relative preservative powers of various constituents of ordinary creosote. The following tables are taken from his report in the "Analyst" of June, 1900:

TABLE 1.

Breaking strain of string after ten (10) months exposure (original breaking strain, 33 lbs.).

Treatment.	Condition.	Breaking Strain.
Untreated	Rotten	
With tar acids	Rotten	
With volatile distillates from creosote	Rotten	
With Phenol	Rotten	
With Cresol	Rotten	
With Naphthalene	Partly rotten	3
With tar bases	1 in 6 rotten	16
With Bone oil	Sound	18
With non-volatile oils from creosote	Sound	16

TABLE 2.

Breaking strain (transverse) of deal rods exposed ten (10) months (breaking strain 630 lbs.).

Treatment.	Condition.	Breaking Strain.
Untreated	Much decayed	300
Tar acids	Little decayed	430
Tar bases	Surface good	360
Napthalene	Surface decayed, sound within	410
Non-volatile residue	Sound	570
Animal oil	Surface fair	440
Creosote	Sound	470
Cresol	Much decayed	230

These experiments again point out the value of the high boiling coal tar distillates, and of the tar bases (bone oil is used in this connection because it is rich in these bases). Tar acids and volatile (low boiling) distillates are evidently valueless.

Attempts to preserve timbers by superficial applications are as old as the first attempts in wood preserving. Charring timbers, painting, coating with tar, or with solutions of tar, or pitch or asphalt in lighter oils, are all attempts in this direction. Even today the market is flooded with patent preparations of the sort just indicated, passing under various names as "Carbolineum," "Phenoline," etc. The public has found these compounds far from reliable because so many worthless compounds are offered under those names, and looks with distruct upon preparations whose manufacturers seek to shield themselves by claiming that the wonderful composition of their preparation cannot be revealed by chemical analysis.

In seaching for data on the question whether wood could be preserved by these simple means, my attention was directed to a compound which is commercially known under a trade-mark, as "C. A. Wood Preserver," which compound had been used by the Athletic Association of the University of Texas, and about which Prof. R. L. Batts, then at the head of the Athletic Association, had the following to say:

"The Athletic Association of the University of Texas has used the 'C. A. Wood Preserver' with most satisfactory results. Pine posts treated with it were sound after being in the ground three years. Posts not treated were decayed after a single year."

This led me to analyze the article, and I found that it contains 85% of indifferent (neutral) tar oils, boiling point above 270° C., a relatively large per cent.—about 4%—of acridine, and a small amount of lighter oils, with only a trace of tar acids. It is free from the tarry and carbonaceous matter. By comparing this with results set forth above, we find it may be considered as a compound of only those portions of coal tar distillates which have been found to be of any value, to the exclusion of useless portions, such as soluble acids, and the low boiling, hence volatile oils; and also to the exclusion of the thick carbonaceous matter which would close the pores and form a coating. The constituents are exactly those found by analysis in the seventeen (17) samples of creosoted timbers which had been exposed for long periods, up to thirty-two years, as stated above. I have since learned that extensive experiments are being made with this preserver at various places, among which may be mentioned the Texas Agricultural and Mechanical College, at College Station, Texas; the Agricultural College at Knoxville, Tennessee; Clemson Agricultural College, at Clemson, South Carolina; San Diego, California; Havana, Cuba; the United States Navy Yards at Key West, Florida, and Tampa, Florida; several of these, notably the one at Tampa, reporting very satisfactory progress.

In reference to carbonaceous matter forming a detrimental outer coating, I wish to say that it has been proved by practical tests that the closing of the poors of the wood will cause "dry-rot." In Germany, tests were made by treating mining timbers with coal tar, lime, tar oil of the character above described, and the results were very much in favor of the latter. The timbers having received the tar coating, appeared sound externally, while the core was completely rotten. I may quote another instance where it was clearly demonstrated that outer coatings on timbers produced injurious results. Timbers that had been treated with a compound above referred to (tar oil distillate) were unaffected after years exposure, while other timbers of the same character that received a coat of oil paint after having been treated, decayed in a short time, thereby showing that the outer coating formed by the oil paint was the direct cause of the decay. This explains why coal tar is valueless as a preserver.

A comparison of results leads us to the following conclusion: To preserve timber by means of superficial application, the substance used should be a coal tar distillate boiling above 270° C., free from low boiling (volatile) oils and carbolic acid; that it should contain a high percentage of tar bases, notably acridine; and that it should be free from tary or insoluble carbonaceous matter which would close the pores. With such a substance the action is probably as follows: Let us assume that we have a piece of fairly seasoned wood which has been treated by painting with, or immersing it in this substance. Let it be exposed to the usual influences it would meet with in the ground or in the air. Organisms that bring about decay are usually carried into the interior of the wood by moisture. Since the moisture can enter through the treated portion, it will absorb enougt antiseptics to render it germicidal, and hence the germs cannot operate extensively although they may have entered through some exposed place.

PROCEEDINGS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1900.

THE TEXAS ACADEMY OF SCIENCE.

OFFICERS FOR 1900-1901.

President, Henry Winston Harper, M. D., F. C. S.
Vice President, O. C. Charlton, A. M.
Treasurer, Robt. A. Thompson, M. A., C. E.
Secretary, Frederic W. Simonds, M. S., Ph. D.
Librarian, William L. Bray, M. A., Ph. D.

Other Members of the Council.

Thomas U. Taylor, M. C. E.
James C. Nagle, M. A., M. C. E.
Henry L. Hilgartner, B. S., M. D.

PAPERS PRESENTED AT REGULAR MEETINGS.

JANUARY 12, 1900.

"The Red Sandstone of the Diablo Mountain, Texas," Edwin T. Dumble, Houston, Texas.

"Outline Geology of West Maryland," A. C. McLaughlin, Galveston, Texas.

"Note on Prismoidal Formulæ," W. H. Echols, Professor of Mathematics, University of Virginia. Presented by Professor T. U. Taylor.

"Monogamous Marriage," Dr. S. E. Mezes, University of Texas, Austin, Texas.

FEBRUARY 16, 1900.

"Astronomy in the XIX. Century," Dr. H. Y. Benedict, University of Texas, Austin, Texas.

"An Elementary Account of the Greater Problems Solved by the Modern Group Theory," Dr. L. E. Dickson, University of Texas, Austin, Texas.

"The Possibilities of Lake McDonald," Professor T. U. Taylor, University of Texas, Austin, Texas.

MARCH 26, 1900.

"Floating Sand and Floating Stones" (announced by title), Professor Frederic W. Simonds, University of Texas, Austin, Texas.

APRIL 28, 1900.

"The Failure of the Austin Dam," Professor T. U. Taylor, University of Texas, Austin, Texas.

"A Consideration of the Interpretation of Unusual Events in Geological Records," Professor Frederic W. Simonds, University of Texas, Austin, Texas.

FORMAL MEETING—JUNE 18, 1900.

"The Nature of Justice," Dr. S. E. Mezes, University of Texas, Austin, Texas.

"The Development of the Present Texas Railway System," R. A. Thompson, M. A., Engineer to the State Railroad Commission, Austin, Texas.

"Mind and Brain," Dr. Edmund Montgomery, Hempstead, Texas.

"Note on the Mart and Bluff Meteorites" (announced by title), O. C. Charlton, M. A., Professor of Science, Baylor University, Waco, Texas.

"The Relation of the Work of the Sanitary Engineer to the Public Health," J. C. Nagle, M. C. E., Professor of Engnieering, A. and M. College of Texas, College Station, Texas.

"My Experience with a Syphon Pipe Line," John K. Prather, B. S., Waco, Texas.

"Research Work Done in Organic Chemistry in the University of Texas" (announced by title), Dr. Jas. R. Bailey, and Messrs. S. F. Acree, M. S., Louis Knox, Louis Kirk, and Omerod H. Palm, University of Texas, Austin, Texas.

OCTOBER 26, 1900.

"Some Advances made in our Knowledge of Immunity and Protective Inoculation"—The Annual Address of the President, Dr. Henry Winston Harper, University of Texas, Austin, Texas.

NOVEMBER 23, 1900.

"The Present Foundation of the Austin Dam," Professor Thomas U. Taylor, University of Texas, Austin, Texas.

"An Application of the 57.3 Rule," Professor Thomas U. Taylor, University of Texas, Austin, Texas.

"Eros and the Solar Parallax," Dr. H. Y. Benedict, University of Texas, Austin, Texas.

FORMAL MEETING, DECEMBER 28-29, 1900, BAYLOR UNIVERSITY, WACO, TEXAS.

"The Problem of Forest Management in Texas," Dr. William L. Bray, University of Texas, Austin, Texas.

"Recent Progress in Insect Warfare" (announced by title), Professoı F. W. Malley, A. and M. College of Texas, College Station, Texas.

"The Value of Coal Tar Products as Practical Wood Preservers," Instructor E. P. Schoch, University of Texas, Austin, Texas.

"A Mathematical Problem," Dr. J. B. Johnson, Baylor University, Waco, Texas.

"The Cretaceous as the Kindergarten of Paleontology," John K. Prather, B. S., Waco, Texas.

"The Silt Problem in Connection with Irrigation Storage Reservoirs," Professor J. C. Nagle, A. and M. College of Texas, College Station, Texas.

"The Need of Technical Education in the South," Dr. William T. Mather, University of Texas, Austin, Texas.

"The Modern Presentation of Botany," Instructor A. M. Ferguson, University of Texas, Austin, Texas.

"Note on the Occurrence of Mammoth Remains in McLennan County," Professor O. C. Charlton, Baylor University, Waco, Texas.

"The Hydrographic Survey of Texas," Professor Thomas U. Taylor, University of Texas, Austin, Texas.

"Theorem Concerning the Centers of Curvature of a Roulette" (announced by title), Dr. M. B. Porter, Yale University, New Haven, Connecticut.

"On the Floral Provinces and Vegetation Formations of the West Texas Region," Dr. William L. Bray, University of Texas, Austin, Texas.

JOHN TURNER SMITH,

B. S., University of Texas, 1893.
Jun. Mem. Am. Soc. C. E., 1895.

Born ....March 21, 1870.
Died ....September 24, 1900.

LAWRENCE SMITH WILLIAMS,

B. S. and M. S., University of Texas, 1897.
Associate Professor of Chemistry, Armour Institute, Chicago.

Born ....January 24, 1868.
Died ....February 19, 1901.

LIST OF PATRONS, FELLOWS AND MEMBERS.

PATRONS.

Brackenridge, George W., San Antonio, Texas.
Halsted, Mrs. George Bruce, Austin, Texas.

Patrons, 2.

FELLOWS.

Bailey, Dr. James R., Adjunct Professor of Chemistry, University of Texas, Austin, Texas.
Benedict, Dr. H. Y., Adjunct Professor of Mathematics, University of Texas, Austin, Texas.
Bray, Dr. William L., Adjunct Professor of Botany, University of Texas, Austin, Texas.
Bruce, Dr. W. H., Principal of Bruce Academy, Athens, Texas.
Cerna, Dr. David, San Buenaventura, Coahuila, Mexico.
Charlton, O. C., Professor of Science, Baylor University, Waco, Texas.
Cline, Dr. I. M., Director of Weather Service, Galveston, Texas.
Curtis, George W., Weatherford, Texas.
Dumble, Edwin T., Geologist, 1708 Prairie Avenue, Houston, Texas.
Dutton, C. E., Major, Ordnance Corps, U. S. A., Washington, D. C.
Ellis, Dr. A. Caswell, Adjunct Professor of the Science and Art of Education, University of Texas, Austin, Texas.
Halley, R. B., Professor of Science, Sam Houston Normal Institute, Huntsville, Texas.
Halsted, Dr. George Bruce, Professor of Mathematics, University of Texas, Austin, Texas.
Harper, Dr. Henry Winston, Associate Professor of Chemistry, University of Texas, Austin, Texas.
Harrington, H. H., Professor of Chemistry, A. and M. College, College Station, Texas.
Herff, Dr. Ferdinand, San Antonio, Texas.
Hilgartner, Dr. Henry L., Austin, Texas.
Hill, Robert T., Geologist, U. S. Geological Survey, Washington, D. C.
Howard, Dr. William R., Professor Fort Worth University, Fort Worth, Texas.
Hyer, Dr. R. S., Chancellor, Southwestern University, Georgetown, Texas.
Keiller, Dr. William, Professor of Anatomy, University of Texas, Galveston, Texas.
Lefevre, Arthur, Principal of High School, Victoria, Texas.
Macfarlane, Dr. Alexander, Gowrie Grove, Chatham, Ontario, Canada.
McDaniel, Dr. A. C., 119 Alamo Plaza, San Antonio, Texas.
Malley, F. W., Professor of Entomology and State Entomologist, A. and M. College, College Station, Texas.
Mather, Dr. William T., Associate Professor of Physics, University of Texas, Austin, Texas.
Mezes, Dr. S. E., Professor of Philosophy, University of Texas, Austin, Texas.
Montgomery, Dr. Edmund, Hempstead, Texas.

Nagle, James C., Professor of Civil Engineering, A. and M. College, College Station, Texas.

Ness, H., Professor of Botany, A. and M. College, College Station, Texas.

Paine, Dr. J. F. Y., Professor of Obstetrics and Gynecology, University of Texas, Galveston, Texas.

Pearce, James E., Principal of Austin High School, Austin, Texas.

Porter, Dr. M. B., Instructor in Mathematics, Yale University (218 Mansfield Street), New Haven, Conn.

Puryear, Charles, Professor of Mathematics, A. and M. College, College Station, Texas.

Reichmann, Dr. Fritz, Ryerson Physical Laboratory, University of Chicago, Chicago, Ill.

Schoch, Eugene P., Instructor in Chemistry, University of Texas, Austin, Texas.

Simonds, Dr. Frederic W., Professor of Geology, University of Texas, Austin, Texas.

Smith, Dr. Allen J., Professor of Pathology, University of Texas, Galveston, Texas.

*Smith, John T., Civil Engineer, Austin, Texas.

Smith, Dr. M. M., Austin, Texas.

Spence, D. W., Professor of Physics, A. and M. College, College Station, Texas.

Sutton, William S., Professor of the Science and Art of Education, University of Texas, Austin, Texas.

Taylor, Thomas U., Professor of Applied Mathematics, University of Texas, Austin, Texas.

Thompson, Dr. James E., Professor of Surgery, University of Texas, Galveston, Texas.

Thompson, R. A., Engineer to Railroad Commission, Austin, Texas.

Townsend, C. H. Tyler, Special Deputy Collector of Customs, El Paso, Texas.

Wheeler, Dr. William M., Professor of Zoology, University of Texas, Austin, Texas.

Fellows, 47.

MEMBERS.

Averitt, S. D., Professor of Science, Decatur Baptist College, Decatur, Texas.

Askew, H. G., Auditor, Railroad Commission, Austin, Texas.

Banks, A. L., Adjunct Professor of Mathématics, A. and M. College, College Station, Texas.

Battle, Dr. William James, Professor of Greek, University of Texas, Austin, Texas.

Boon, J. D., Professor, Granbury College, Granbury, Texas.

Brown, R. L., Attorney at Law, Austin, Texas.

Burgoon, C. E., Assistant Professor of Mechanical Engineering, A. and M. Collgee, College Station, Texas.

Callaway, Dr. Morgan, Professor of English, University of Texas, Austin, Texas.

Capps, Dr. E. D., Fort Worth, Texas.

Carroll, J. J., Waco, Texas.

Carson, J. W., Superintendent of Farm, A. and M. College, College Station, Texas.

Carter, Dr. W. S., Professor of Physiology and Hygiene, University of Texas, Galveston, Texas.

Cline, Dr. J. L., Galveston, Texas.

---

*Deceased.

Cline, R. R. D., Professor of Pharmacy, University of Texas, Galveston, Texas.
Cole, Dr. W. F., Waco, Texas.
Connell, J. H., Professor of Agriculture, A. and M. College, College Station, Texas.
Cooke, Dr. Henry P., Dean of the Medical Department, University of Texas, Galveston, Texas.
Cox, T. S., Superintendent Public Schools, Hillsboro, Texas.
Crow, Dr. C. L., Weatherford, Texas.
Davidson, Dr. W. T., Assistant Surgeon, U. S. A.
Dohmen, Franz J., Soloman Street, 25 a pt., Leipzig, Germany.
Duggan, Dr. Malone, Quarantine Inspector, Eagle Pass, Texas.
Duval, E. P. R., Fellow in Mathematics, University of Texas, Austin, Texas.
Endress, George A., Assistant Engineer, Monterey Steel Co., Monterey, Mexico.
Ferguson, A. M., Instructor in Botany, University of Texas, Austin, Texas.
Flavin, Dr. Thomas, Demonstrator of Anatomy, University of Texas, Galveston, Texas.
Foster, L. L., President, A. and M. College, College Station, Texas.
Freshney, Alfred, Teacher of Science, Austin High School, Austin, Texas.
Garrison, Dr. George P., Professor of History, University of Texas, Austin, Texas.
Geisecke, F. E., Professor of Drawing, A. and M. College, College Station, Texas.
Halbert, Dr. O. I., Waco, Texas.
Harper, Dr. W. A., Austin, Texas.
Head, W. Burris, President, Grandview College, Grandview, Texas.
Hexter, J. K., Victoria, Texas.
Holmes, W. E., Reef, Arizona.
Houston, David Franklin, Dean of Academic Department, University of Texas, Austin, Texas.
Houston, Otho Sam, President First National Bank, Stephenville, Texas.
Howard, E. E., Instructor in Civil Engineering, University of Texas, Austin, Texas.
Huberich, Charles H., Instructor in Law, University of Texas, Austin, Texas.
Hunnicutt, W. P. H., Land Office, Austin, Texas.
Hill, Dr. H. B., Austin, Texas.
Hitt, I. R., Bruce Academy, Athens, Texas.
Johnson, Dr. J. B., Professor of Mathematics, Baylor University, Waco, Texas.
Jones, W. G., Temple, Texas.
Kerr, E. W., Assistant Professor of Mechanical Engineering, A. and M. College, College Station, Texas.
Leitnaker, A. N., Vice-President, Austin & Northwestern Railroad, Austin, Texas.
Long, W. H., Jr., University of Texas, Austin, Texas.
Mackensen, B., Teacher of Science, San Antonio High School, San Antonio, Texas.
Magers, S. D., University of Chicago, Chicago, Ill.
Magnenat, Dr. L. E., Demonstrator of Biology, University of Texas, Galveston, Texas.
Means, J. H., 215 San Pedro Avenue, San Antonio, Texas.
Miller, Thomas D., Gas Works, Dallas, Texas.
Mitchell, J. D., Victoria, Texas.
Moore, Dr. J. D., Demonstrator of Medicine, University of Texas, Galveston, Texas.
McLaughlin, Dr. J. W., Professor of Medicine, University of Texas, Galveston, Texas.
O'Connor, James L., Architect, Austin, Texas.

Palm, Omerod H., Assistant, School of Chemistry, University of Texas, Austin, Texas.

Parker, R. D., Assistant Engineer, I. & G. N. R. R., Palestine, Texas.

Pittuck, B. C., Agricultural Experiment Station, A. and M. College, College Station, Texas.

Poston, W. C., Professor in Weatherford College, Weatherford, Texas.

Price, R. H., Professor of Horticulture, A. and M. College, College Station, Texas.

Primer, Dr. Sylvester, Associate Professor of Teutonic Languages, University of Texas, Austin, Texas.

Prather, John K., Waco, Texas.

Prather, Dr. William L., President, University of Texas, Austin, Texas.

Raines, C. D., Librarian, Department of Agriculture, Insurance, Statistics, and History, Austin, Texas.

Reber, Samuel, Captain, Signal Corps, U. S. A., Governor's Island, N. Y.

Reynolds, H. P., Teacher of Science, El Paso High School, El Paso, Texas.

Rhea, W. Alex., Lawyer, Dallas, Texas.

Rice, C. D., Instructor in Mathematics, University of Texas, Austin, Texas.

Rucker, Augusta, Instructor in Zoology, University of Texas, Austin, Texas.

Sammonds, J. W., County Surveyor, Anderson county, Palestine, Teaxs.

Schmidt, E. F., 508 Travis Street, Houston, Texas.

Seltzer, H. K., Care Waddell & Hedrick, Bridge Engineers, Kansas City, Mo.

Smith, Dr. H. S., Austin, Texas.

Smith, Robert F., Associate Professor of Mathematics, A. and M. College, College Station, Texas.

Smith, Dr. Q. C., Austin, Texas.

Smith, Noyes D., Austin, Texas.

Stanfield, S. W., Professor of Sceince, Coronal Institute, San Marcos, Texas.

Stevenson, J. D., Attorney at Law, San Antonio, Texas.

Sublette, G. W., 2616 First Avenue, Minneapolis, Minn.

Swearingen, P. H., Attorney at Law, San Antonio, Texas.

Tilson, P. S., Associate Professor of Chemistry, A. and M. College, College Station, Texas.

Warfield, Dr. Clarence, Galveston, Texas.

Weller, William M., Care J. S. Cullinan Co., Corsicana, Texas.

Wells, Dr. E. H., Professor of Natural Science, Baylor Female College, Belton, Texas.

Whitten, Harriet V., Tutor in Geology, University of Texas, Austin, Texas.

*Williams, Lawrences, Associate Professor of Chemistry, Armour Institute, Chicago, Ill.

Wilson, Dr. R. L., U. S. Marine Hospital Service, Honolulu, H. T.

Wilcox, O. M., Assistant, School of Chemistry, University of Texas, Austin, Texas.

Wipprecht, Walter, Bryan, Texas.

Worrell, S. H., Assistant, School of Chemistry, University of Texas, Austin, Texas.

Wyche, Benjamin, Librarian, University of Texas, Austin, Texas.

Members, 92.
Total, 141.

---

*Deceased.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901,

TOGETHER WITH THE PROCEEDINGS FOR

THE SAME YEAR.

VOLUME IV, PART II.

AUSTIN, TEXAS:
PUBLISHED BY THE ACADEMY.
1902.

COMMITTEE ON PUBLICATION.

Frederic W. Simonds.

R. A. Thompson.

J. C. Nagle.

VON BOECKMANN, SCHUTZE & CO., PRINTERS, AUSTIN, TEXAS.

CONTENTS.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901.

THE INFLUENCE OF APPLIED SCIENCE.

J. C. NAGLE,
Agricultural and Mechanical College of Texas,
College Station, Texas.

VOLUME IV, PART II, NO. 1.

AUSTIN, TEXAS, U. S. A.:
PUBLISHED BY THE ACADEMY.
1902.

The Influence of Applied Science.

[ANNUAL ADDRESS BY THE PRESIDENT.]

J. C. NAGLE,
AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS,
COLLEGE STATION, TEXAS.

THE TEXAS ACADEMY OF SCIENCE.

[ANNUAL ADDRESS BY THE PRESIDENT.]

THE INFLUENCE OF APPLIED SCIENCE.

J. C. NAGLE,
Agricultural and Mechanical College of Texas,
College Station, Texas.

Were I qualified to attempt it, an exhaustive review even of the most salient features of the subject of this address is precluded by the shortness of the time available. My purpose, therefore, is to touch upon a few only of the general features of the world's progress in which applied science has been an aid not only to material development but to researches in pure science as well, and to suggest, if possible, some means by which the workers in applied science may be brought to contribute more largely towards advancing the purposes and usefulness of the Texas Academy of Science.

If the recorded history of the world's progress in thought and material prosperity for the last two thousand years be roughly divided into two parts—the latter one dating practically from the beginning of the nineteenth century—and if the causes making for the amelioration of man's condition during these two periods be examined, we shall see that a single century of applied science has done more for the world's direct advancement in enlightenment, tolerance and real culture, as well as in material progress, than was accomplished in the preceding nineteen hundred years. Furthermore, a comparison of the opportunities and advantages possessed by man at the beginning, the middle, and the end of the nineteenth century will show how much the rate of progress was accelerated during the latter half of the century, and if, judging by this, any predictions for the future may be ventured, we may gain some faint idea of the place applied science is destined to fill during the next fifty years.

Applied science has placed the world's store of accumulated knowledge in more accessible form, has disseminated it throughout the world, and has caused it to be greatly augmented by reason of the facilities afforded for investigation and research, particularly along scientific lines. It has done more, for it has caused the scientific method of study and research to be extended to other fields than those included in the domain of science; it has overcome fanatical prejudice and has taught charity even to ignorance.

The intelligent applications of science naturally presuppose a knowledge of the underlying fundamental principles, but it has sometimes happened that invention, hit upon almost at haphazard, has served to suggest important researches and to verify principles that once recognized and formulated are capable of indefinite extension. It has been the custom to speak of Pure Science as a thing apart from Applied Science, the two being assumed to be governed by entirely different purposes. Pure Science was supposed to have for object the discovery and simplification of truths that pertain in any way to the mysteries of nature, regardless of ultimate utility, while Applied Science held only that to be good which was suitable for use in furthering the material interests of man. This view does not do either branch of science justice, for, each is, in great measure, indebted to the other for its present stage of development—and for the facilities afforded for further advancement. Without pure science there could be no applied science, but it is not usually recognized that pure science owes many debts to applied science also.

In speaking of the work of the applied scientist Dr. L. O. Howard says, in *Science*, for January 18, 1901:

"I have a strong conviction that humanity gains far more from scientific work undertaken with an economic aim than from the labors of the other class of scientific men, and I believe it to be a most unfortunate condition of affairs that hundreds of the men, best fitted by brains and training to attack the many economic problems that are fairly crying for solution, are delving away in their search for truths and principles which when found have only a remote bearing, if any at all, upon the sum total of human happiness. I was once filled with the resounding majesty of the phrase 'science for Science's sake,' but now, while I admit the grandeur of the idea, I have come to parallel it and its opposite in my mind with the contrast between abstract and practical Christianity—both beautiful, but one for gods and the other for men."

Dr. Howard has perhaps put the case too strongly, for the true man of science is never blind to the potential possibilities for good inherent in every important discovery of scientific truth. Surely no well-wisher of humanity could ever really indorse such sentiments as are embodied in the toast said once to have been proposed to pure mathematics, "May it never be of any use to anybody." It seems to me that notwithstanding the ever-increasing present tendency towards specialization there is now a closer bond between pure and applied science than has ever existed heretofore. Pure science seeks always to add something to the world's store of knowledge, rejecting nothing because an immediate material use is not apparent, well knowing that in the light of future discoveries and applications some value will always attach to any facts that lead to a better understanding of nature's truths. Even though no economic use may ever arise such knowledge has a tangible value if it in any way broadens man's understanding. Applied science also understands and appreciates this.

In order that a people may take their proper place among the nations of earth something more than the mere accumulation and hoarding of knowledge is necessary. India and China have been the storehouses of the accumulated knowledge of the centuries, yet a glance at the conditions existing among the native populations of these countries will show how far they have lagged behind their younger and more scientific fellows. The recent marked advance of Japan is a striking example of what the acceptance of the evidence of the value of science and scientific methods can do in an industrial way.

As a pure science mathematics is not only the oldest but the most effective, in many respects, as a means of mental training; yet we are told that geometry had its origin in the necessity for preserving or recovering Egyptian land boundaries obliterated by the annual overflows of the Nile. Again, spherical trigonometry reached its developed stage before plain trigonometry because astronomy had need of it in the solution of problems concerning the places and orbits of celestial bodies.

Apparently astronomy would be the least likely of the sciences to be of material benefit to mankind and yet its influence upon economic problems has been such that progressive nations now sustain, at public expense, astronomical departments in which not only are the questions concerning navigation and surveying investigated but much time and labor are expended in research upon problems that can apparently have no connection with material productiveness.

Among some of the intensely practical results of astronomy are the facilities afforded man to locate himself upon the earth's surface, to define the boundaries between individual and national possessions, and to guide the commerce of the world safely over trackless seas. More than that, it has given us some of the greatest and grandest conceptions of nature that we possess, pointing out, as it does, something of the enormous magnitude of the stellar universe and the insignificance of man in comparison therewith. It is not a bad thing for man to pause sometimes and reflect upon the smallness of his importance in the economy of nature.

On the other hand the highest progress in astronomy has been made possible only by the aid of applied science and invention, which is the offspring of applied science. In proportion as the construction of instruments for accurate observation and measurement has improved so has the field of the astronomer been widened; the telescope has opened up fields for observation, the limits of which have been extended as the power and definition of the instrument have increased and accurately graduated circles enable the astronomer to locate with precision the positions of celestial bodies at the times when pointings are made. Successive groups of bodies have thus been located and described and in later years photography has been able to automatically map the positions of bodies that are invisible under even the highest power of the best of modern telescopes. By the aid of the spectroscope man has been able to measure the proper motion of the stars, to tell us what chemical constituents enter into their composition, and something of their physical conditions. Astronomy as a pure science thus owes its progress largely to applied science, which has contributed the instruments employed and has installed them properly upon rigid supports or has transported them from point to point as needed.

Experimental research has been the most potent factor in the advancement of physical science, many of the most important laws having been suggested by observed phenomena and others verified in this way. The applications of physical principles underlie almost all the operations of life more or less directly. At least a partial verification of some of the most important of physical laws, such as the laws of gravitation and the principle of the conservation of energy, has been experimentally made, within the limits of accuracy afforded by observation, and these have given rise to some of the most practical of practical results.

The worker in pure science in physics is dependent upon the man of applied science for the instruments required in pushing his work. Expensive machinery is required in their manufacture and some of these machines exhibit an almost lifelike intelligence, and much more than human accuracy, in the discharge of their duties. The machines for making ruled gratings and circles of precision are of this nature.

In recent years the progress in electric applications and discoveries has been so rapid that almost by the time results have been recorded in permanent form the reading resembles ancient history; yet it is altogether probable that we have little more than entered upon the field that electricity will occupy in the future. A hundred years ago when Volta discovered the possibility of producing an electric current he could not possibly have dreamed of the wonders it was destined to work, nor could Davy have had the faintest idea of the hundreds of thousands of arc lamps, which, in the cities of all the civilized world turn night into day, that were to follow his discovery of the electric arc. What would the shades of these and other pioneers in electrical discoveries say could they see how applied science has harnessed a small portion of Niagara's enormous energy and in a city more than twenty miles away, by the mere turn of a switch, converts a scene of daylight beauty into perfect fairyland through the agency of a hundred thousand incandescent lamps! Or, again, what would they think of transmitting electric energy 184 miles at the enormous pressure of 40,000 to 60,000 volts, as is done in California by the Bay Counties Power Company, the energy derived from the water power of the Yuba River being utilized to generate the current.

In the beginnings of science new truths were discredited, or were received with doubt even by those possessed with more than the ordinary share of learning, and had constantly to fight against the prejudices of the masses. Slowly, as the manifold applications of these principles to man's use were made, and their economic value shown, prejudice gave place to tolerance, and tolerance to warmest welcome. The world has been so dazed with the wonderful applications of science that the wildest and apparently most improbable statements are received and credited if they come even within the shadow of the mantle of science.

The discoveries of Benjamin Franklin were not accepted even by the Royal Society at first and no publisher would risk the reputation of his paper by putting them in print, but when Roentgen announced the discovery of the X-rays the fact was scattered broadcast throughout the world, the experiments repeated, the meaning of the discovery enlarged and the wildest speculations as to its power and utility immediately indulged in. So also with liquid air, for somewhat more slowly following Dewar's researches upon extremely low temperatures came the machinery for producing liquid air on a commercial scale, and again the masses indulged in prophecies of all manner of applications and uses. From Hertz's experiments upon electric waves has come the principle of wireless telegraphy, still in its infancy, yet already enjoying governmental notice and financial aid in many quarters. Applied science has taught the world to stand ever ready to seize upon and make use of every new principle as soon as unearthed and often furnishes the suggestions that lead to further discoveries.

The printing press and the electric telegraph now serve to spread information throughout the world, but by far the most potent factor in everyday civilization at the present time is the facility of transportation by sea and by land. Scarcely a hundred years ago it cost as much to transport a ton of wheat one hundred miles on land as it did to produce the wheat on the farm. The advent and growth of the steam railway during the last seventy-five years has changed all this. Prior to that those countries that bordered upon the great waterways enjoyed immense advantage over their inland neighbors, because of their facilities for marine transportation. Steadily and swiftly railroad lines have been pushed outward into hitherto inaccessible regions, increasing property values wherever they have gone, and bringing communities into closer touch with each other. Transportation has been steadily cheapened and the time of transit shortened. while the influences of civilization have been extended to all parts of the habitable globe. Upon the civil engineer has fallen much of the hardship in this pioneer work and to him is due much of the credit for the advances made. John Findley Wallace, in his presidential address at the annual convention of the American Society of Civil Engineers, held in London, England, July, 1900, said, among other things:

"No one agency has been a more potent factor in the advancement of civilization than improved transportation facilities, and the profession of civil engineering has been the force which has conceived, designed and executed the works and machinery which have furnished the world with these facilities. There is hardly a branch of the profession which does not touch on the principle of transportation. The construction of steamships, harbor and river improvements, docks and wharves, canals, water supply, sanitation, manufactories, the utilization and transmission of power—in fact, it is difficult to name a branch of the profession which does not, either directly or indirectly, bear on the subject of transportation.

"The great engineers of this century have been responsible and should receive credit for the conception, design and execution of these works, without which the Americas, Asia, Africa, Australia and the isles of the sea would still be among the uncivilized, unknown or inaccessible portions of the world. * * *"

In chemistry, perhaps, the influence of applied upon pure science has been more pronounced than in any other line. Take, for example, the case of the coal tar derivatives as applied to the color industry and follow its history with William McMurtrie, as outlined in his address before the chemical section of the American Association for the Advancement of Science, at the Springfield meeting, and the influence of the technologist upon theoretical investigations along this line will readily be seen. Originating from a troublesome by-product, which results from the commercial production of coal gas, the color industry has grown to be of great commercial importance. In speaking of technical investigations along this line, and of Perkin's discovery of the oxidation product of analine, McMurtrie says:

"The search after the production of a commercial product yielded, accidentally as it were, and almost empirically, the seed from which this great and flourishing tree has sprung."

Again, in speaking of the relation between pure and industrial chemistry he says:

"The coal tar color industry, which has so frequently been cited and described as the direct outcome of scientific investigations, will serve admirably to illustrate the relations we are considering. No one of the industries has been so rapid in growth or has attracted the same degree of attention from both scientists and technologists, or has had so wide an influence upon the progress of the other industries and scientific work."

In many chemical lines the distinction between technical and scientific methods has either disappeared or is passing away, for, in many chemical operations, the processes used require to be constantly regulated and controlled by laboratory analyses, and the pressure due to commercial work has, in many instances, given rise to methods that have been adopted in scientific laboratories in preference to those that have been there developed.

Growth in any one branch of science is dependent upon growth in other branches, and this is particularly true of applied science. Consider the structures and machines of the engineer and note how they have gone on increasing in size and power in proportion to the improvements made in metallurgical methods. The problem of transportation across the North River from New York City has presented enormous difficulty and several schemes for supplanting the method by barges, now in use, have been proposed. One of these is for a suspension bridge of 3100 feet clear span—almost three-fifths of a mile. In order that the structure be able to sustain itself and the several lines of railway that would cross it, this would require a very high working and ultimate strength in the material of which the bridge would be composed. If my memory serves me right the specifications called for an ultimate strength of 180,000 pounds per square inch in the material composing the cables. The longest clear span so far built is across the Straits of Carquinez, in California, where the Bay Counties Power Company's cables that carry high pressure electric currents have a clear span of 4,427 feet between towers. Because of their use as conveyors of electric currents these cables had to have high conductivity as well as great strength, which made it more difficult to secure the proper material. Notwithstanding the two conditions that had to be satisfied, it is stated that the cables have a breaking strength of 192,000 pounds per square inch. A few years ago it would have been impossible to manufacture steel with anything like such high tensile strength. The constant increase in the size and weight of locomotives, and rolling stock generally, has necessitated material increase in the size and strength of bridges and the weight and strength of rails. Better alignment, easier grades, and improved roadbeds better maintained, have all contributed to make travel at high speed safer and more comfortable than it has ever been before.

In bacteriology the last ten or a dozen years have witnessed the most wonderful advancement in consequence of which the whole subject of sanitary science has undergone remarkable changes, followed by similar changes in sanitary engineering. It is well that this is so, for there is nothing of so much importance to man as life and health, and recent advances in bacteriology have pointed the ways by which improved health conditions have been attained. Professor Wm. T. Sedgwick, at the meeting of the Society of American Bacteriologists, last December, attributes the real origin of the science of bacteriology to the investigations of Pasteur and said, in part, that "he brought to the study of all the problems I have enumerated—and I hardly need remind you that among them are some of the most elusive, some of the most profound, and some of the most intensely practical problems in all the field of natural knowledge—a thorough working familiarity with physics and chemistry. Though not exactly a chemist, he was able to meet chemists upon their own ground. Though not exactly a microscopist he was highly trained in physics and mineralogy, and thus quickly became a master of the microscope."

Pasteur not only confirmed Schwann's theory of fermentation but proved that all decomposition and decay in nature is due to slow fermentation or putrefaction. Going further, he proved that for each particular fermentation there was a specific or characteristic ferment. Pasteur thus led up to the germ theory of disease and his work, together with the researches of a number of later investigators, has led to the identification of the specific bacteria of many forms of disease. Not only have these discoveries led to radical changes in medical practice, but have similarly affected matters pertaining to sewage purification and water supply engineering. Growing from its fruitful beginnings in pure science, bacteriology has attained its highest development and produced its richest results under the care and culture of science as represented by the medical profession and the sanitary engineer; has made possible the more successful combat of disease; and has opened up to the mind of man a clearer conception of some of the secrets of nature. The achromatic microscope has been the chief instrument of the bacteriologist, being to him what the telescope is to the astronomer.

It is our pride, as Americans, to point to the phenomenal progress in material advancement that has been made by the United States, and few, if any, fail to credit this to fruitful results of invention and applied science generally. The applications have reached into all the ramifications of human industry—each advance in science being the means of achieving greater results with smaller expenditure of energy. In manufacture, in engineering, in the application of machinery to agriculture, we may trace applied science all along the line, with the result that the total wealth of the country has steadily increased. During the forty years preceding 1895 rural wealth was said to have quadrupled and urban wealth to have increased sixteen-fold in the United States, the latter due largely to manufacture, and both being heavily indebted to transportation. The applications of machinery and improvement in farm methods also contributed their part to the advance. It was stated at that time (1895) that one farm hand in the United States would produce as much wheat as three in England, four in France, five in Germany and six in Austria, the advantage of the American being due mainly to the greater assortment of mechanical appliances he possesses. Labor is beginning to appreciate the fact that the introduction of labor saving machinery does not necessarily mean that workmen will be thrown out of employment, but rather that the character of their work will be changed to a higher type at more advanced wages, usually, and that those whom machinery has displaced will be needed for other forms of work that are constantly springing up under the touch of applied science.

Before applied science had demonstrated the value of scientific work, it was almost impossible for any form of research work to receive substantial recognition of its value. Financial aid was needed, but was not forthcoming. At the present time the situation is improved, and national governments maintain departments and bureaus that are engaged in research work in pure as well as in applied science. According to Dr. Charles W. Dabney the United States, in 1897, had all told twenty-eight different agencies scattered through the various departments, engaged in scientific work. Our law makers do not confine their appropriations to work for utilitarian ends only, for to the average man the collection and preservation of fossil remains, or studies in ethnology, can have no apparent relation to useful ends. The value of investigations that relate to material affairs is easily understood and appreciated by all, but with the other class of investigations it is different. People have come to understand, however, that it is not possible always to say wherein a certain investigation may be useful, nor what unexpected application may be made of some apparently non-utilitarian discovery. Biological investigations upon the habits of parasites may have no meaning to the unscientific man, but when he has been shown that it is through such investigations that the agency of the tick in transmitting Texas fever among cattle was discovered, he can appreciate the value of the investigations carried on by the veterinarian of our experiment station. The results of these investigations has been to lead up to inoculation as a means of warding off the fatal effects of this fever. Where formerly from sixty to one hundred per cent. of cattle that were brought in from points north of a certain line were lost, less than ten per cent. of the cases that are taken promptly in hand now prove fatal. In like manner the recent Havana investigations upon yellow fever, and the agencies by which it is transmitted, appears to have fastened the blame upon a particular species of mosquito, and may point a way to immunization, or at least to prevention and control of this disease. The same may also be true of malaria.

In educational matters one would naturally think that the importance of science would have been most readily appreciated, but the history of education shows clearly what opposition and prejudice had to be overcome before science was accorded recognition even in the universities, for some of the strongest opposition came from those whose lives had been devoted to the cause of education as understood in the old order of things. Not until applied science had demonstrated the necessity for better training did pure science receive even a moiety of the recognition now accorded it in institutions of learning. The new order of things has meant a revolution in educational methods, and we now find technological schools scattered all over the country, devoted especially to the study of applied science, but encouraging research work in pure science as well. Even the most conservative of the older institutions, wedded through tradition to the classical form of education, have been forced to adopt the newer methods. Instruction in applied science has been extended downward into the secondary, and even into the primary schools, and the advocates of this extension are to be found in so many quarters that one almost wonders if the world has gone mad on the subject of training eyes and hands. In its place, manual training is a good thing, but it seems to me that to do this before requiring some knowledge of the elementary principles that underlie the work is not without danger to the resultant product of such a system. All technical and technological training—even manual training—should be used to impress principles, and should follow, or at least should not precede, the necessary theoretical training. We have inanimate machines in abundance without endeavoring to transform the youth of the land likewise into machines. As a workman, the man who makes use of his highest gift—the ability to reason clearly—is worth much more than one who is mechanically skilled only. Germany has done more, perhaps, for technical education than any other nation, especially in mono-technical schools, and the effect of this has been felt in an economic way. During the last twenty-six or twenty-seven years her manufacturing industries have increased more than ten-fold, and her shipping more than twenty-fold. Her experience and that of other nations show clearly that commercial prosperity in the future will be largely influenced by the form and character of national education.

What possibilities the future may hold for both pure and applied science may not be even guessed at, but the past century has shown enough to cause one to be lost in wonder. The last ten years have been the most fruitful of all in applications of science to the wants and purposes of man, yet at Rochester, in 1892, Professor John B. Johnson summed up the results of applied science to that date in the following striking language:

"When we see what miracles have been accomplished in a single century of scientific applications, nearly all by a system of blind experimenting and repeated failures or only partial successes; how we have imitated the great motor of the solar system and revivified the world through the agency of heat; how we have obliterated time and space on this little earth and made our antipode our neighbors; how we have brought near the far off desert and made it to blossom and bear fruit and so have doubled the size of the habitable world; how 'the continuous woods where rolled the Oregon and heard no sound save its own dashings' now teems with happy life and resounds to the hum of wheels and the joyous cries of happy children; how the thought, inspiration, discovery, or learning of one is multiplied a million fold by the press and at once becomes the common property of the world; how the hours of labor are shortened so that all mankind may enjoy sufficient leisure to become learned and cultured if they will; how the comforts of life which formerly could be enjoyed only by kings and princes are now available to every industrious citizen; how the causes and sources of disease have been discovered and largely eradicated so that sickness today is almost a crime; when we ponder on these marvelous achievements of one short century of crude empiricism in applying the discoveries of science, what may we not hope from the endless future with an intelligent direction given to the labors of those who seek to garner the fruit of all science and not only to know the law but to control its operation, to harness the very laws of nature to the car of human progress?"

To us, as members of the Texas Academy of Science, the question of greatest moment at present is how the influence of our organization may be extended so as to accomplish the greatest good for the State at large. It appears to me that somewhat of this object may be attained by bringing the workers in applied science into closer touch with the Academy and its objects. Within our great State the workers in pure science alone are few in number, but there is the nucleus of a small army of those engaged in intelligent applications of some phase of applied science, and if these could be brought to clearly understand the objects and purposes of the Academy many of them would align themselves with us. Within a few months our organization will have completed the first decade of its existence, but its membership is not a tenth of what it should be. Originating in January, 1891, chiefly through the efforts of a few broad minded men in the University of Texas, it has been kept alive so far chiefly by the efforts of these same men, or their successors and coadjutors, together with the efforts of a few of those engaged in educational work in kindred institutions and a few of the general workers in science throughout the State. Good has been accomplished in maintaining somewhat of a scientific interest among the few, but much more could and should be done, indeed, must be done before the Academy receives the recognition it deserves from the citizens of the State at large.

There are great enterprises requiring the skill of the engineer now in progress, but this phase of the work of the applied scientist is only at the beginning in this State. Railroad building in the past has been the principal line of operation of the engineer's skill, but there are greater works in building railroads and kindred structures yet to be done than have been even thought of in the past. Bridges of all kinds are to be built, the structural engineer has almost a virgin field before him, and the same may be said of the mechanical and electrical engineers. Sanitary engineering and sanitary science scarcely exist at all within the State, but the growing necessities of denser population will make this branch of the work imperative in the comparatively near future; except for small water supply systems, the hydraulic engineer has been almost without occupation, but the field before him is of vast extent. There are millions of acres of land in the arid and semi-arid regions that are open to development if it can be shown that irrigation by storm water storage can be carried on at a profit, and even in the sub-humid and humid areas intensive farming may yet make irrigation there a necessity; the duty of water in different sections has yet to be determined and the character of vegetation adapted to various localities remains to be investigated. Within the last two or three years we have seen the coastal plain of Texas transformed from a barren clay prairie into splendid rice farms, the development of which means far more to the State than do the immense riches of oil and mineral deposits so far discovered, great as they have been. The work of the geologist should be fostered, not only for its importance in connection with coal, oil and metal deposits, but for its value for other economic purposes, agricultural, structural, and some forms of manufacturing especially. In at least two widely separated localities in the State it has been demonstrated that we can manufacture Portland cement that will compare favorably with imported brands; vitrified clay pipe of good quality is produced at one place, and there is no apparent reason why pottery works should not flourish. In forrestry there is much to be done if the complete destruction of our East Texas timber is to be prevented, to say nothing of forest extension westward. The botanist has his field to himself, and much good should result from a study of the grasses and other flora of the State. Entomology, which has received some slight State aid for two specific purposes, has an almost untouched field open to the workers in that line. The chemist likewise has an untold wealth of study upon economic problems ahead of him, and so on through all the lines in which applied science has so far demonstrated its value, to say nothing of the new lines which we may reasonably expect to see developed.

Every year we ship immense quantities of raw material from the State only to buy a large part of it back again in the form of manufactured articles, for which we pay an advanced price in addition to the freight charges both ways. We need manufactories for cotton and other staples, to preserve to ourselves the profits now expended in transportation charges and to furnish employment for those who find it now difficult to get. We may well profit by the example North Carolina has set us. A recent bulletin from that State declares that there are something like 254 different factories for working cotton into some form of manufactured goods, distributed through forty-five counties. I quote from memory, as the bulletin is not at hand at this writing. Within the last year several cotton mills have been built in Texas, but a single dozen would more than cover their total number. Compare these numbers, and the vastly different areas of the two States, and the vast amount of development required to bring us even up to North Carolina's present position will be apparent. In other manufacturing lines Texas is in no better condition. All of this must be materially changed if Texas is to take her proper place among the States of the Union. She can and will produce immense quantities of the finished products of cotton, cane, iron and steel, paints, cement, pottery and a multitude of other things, in all of which the applied scientist will have an active part.

One of the articles of the constitution specifically states that the Academy holds itself ready to investigate and report upon such scientific problems as may be submitted to it by the State government. Although nearly ten years have passed since it first came into existence, I am not aware that any such service has been asked of the organization, and it is doubtful if one per cent. of the people of the State even know of its existence. We must make the Academy and its objects better known throughout the length and breadth of the State, and to do this we must publish more and scatter these publications among a larger number of interested persons. To do this we need greater financial resources, and this means a greater number of members and a larger amount from annual dues. The merely nominal dues could be increased without becoming a burden to any one, but even this would not suffice without a larger membership. It may not be pertinent to here suggest how our financial affairs may be improved, but the necessity for a wider sphere of usefulness is sufficient warrant for such suggestions as I may be able to make regarding increased membership. It seems clear to me that there are many who are interested in science in the State who would be glad to join us if they were fully informed of the scope and purpose of the organization and if an invitation were extended to them. Recently the Cornell Association of Civil Engineers, having the same annual dues as the Texas Academy of Science, sent out a communication to its membership stating that two other similar organizations had offered to furnish their publications to the full membership of the association in exchange for a similar courtesy and the secretary estimated that the additional numbers of the publications would necessitate no more than twenty-five cents extra charge to each member. In comparison with the benefit to be derived from the exchange this extra charge amounts to almost nothing, and it occurs to me that possibly our organization might make similar arrangements with others and so add to the extent and amount of scientific matter that each member would receive. Such an arrangement, if it could be made, would be an additional inducement to join the Academy.

Scattered over the State are a considerable number of science teachers who would be desirable members, a larger number of engineers and a still larger number of medical men, together with other workers in applied science, who could be brought into the membership very soon and by so doing the usefulness of the organization would be greatly increased. The number of workers in applied science in the State, while large in comparison with the number of those engaged in pure science research, is small in comparison with what it must be at the end of the next twenty years. The number in each branch scarcely justifies special technical organizations, and the scope of the Texas Academy is surely broad enough to include them all. As we grow in numbers there can be divisions into special sections, as has been done in the American Association for the Advancement of Science, as necessity requires and in a few years a very respectable showing can be made. It rests with us to further any movement looking to an upbuilding of the Academy and an increase in its efficiency.

There are many meritorious investigations that can not now be undertaken because they require too great an expenditure of time and money to be attempted by individuals and yet which would be of material benefit to the State, for which, if our organization can not itself assist financially, we may yet arouse sufficient interest in other quarters to secure the required assistance. We should look forward, then, to a future growth that shall make the Academy something of which the whole State may be proud; which shall benefit the whole State and which shall some day receive official recognition and perhaps financial assistance in some of its investigations, and which, acting directly upon the individual members, and indirectly upon thousands of others, shall bring a better understanding of the objects and methods of science and a broader measure of tolerant intelligence to all, aiding thus the great cause of education generally and making for betterment of cultural as well as economic conditions.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901.

A CONSIDERATION OF S. B. BUCKLEY'S "NORTH AMERICAN FORMICIDAE."

WILLIAM MORTON WHEELER,
Professor of Zoology, University of Texas.

VOLUME IV, PART II, NO. 2.

AUSTIN, TEXAS, U. S. A.:
PUBLISHED BY THE ACADEMY.
1902.

THE TEXAS ACADEMY OF SCIENCE.

A CONSIDERATION OF S. B. BUCKLEY'S "NORTH AMERICAN FORMICIDAE."*

WILLIAM MORTON WHEELER,
Professor of Zoology, University of Texas.

During the years 1866 and 1867, Mr. S. B. Buckley, who was State Geologist of Texas from 1874 to 1875, published descriptions of some sixty-seven presumably new species of ants from the United States. The work was undertaken without any previous training in entomology, and has been regarded as something of a taxonomic fiasco.† Nor could this have been otherwise when one reflects that there are scarcely any insects more difficult of analysis and description than the Formicidæ. As Buckley lived in Texas during his study of the ants, it happens that some thirty-eight, or more than half of the species described, are from the State of the Lone Star. The area from which he drew his specimens comprises Central Texas (Travis and the neighboring counties west to San Saba, Mason and McCulloch counties), and the northern portions (Wichita and Buchanan [now Stephens] counties). This is, of course, a rather limited region, and hence represents only a part of the great ant-fauna of the State. The very different ant-fauna of the Trans-Pecos, as well as that of Southeastern Texas, was in great part unknown to Buckley.

The sixty-seven odd descriptions are, indeed, fearfully and wonderfully made. With a persistency, which at times seems almost intentional, the author selects for description the worthless, insignificant

---

*Contributions from the Zoological Laboratory of the University of Texas, No. 30.

†A study of S. B. Buckley's character and attainments should be undertaken by anyone who would estimate his work properly. Some valuable notes on this subject have been collected by Mr. Robert T. Hill (The Present Condition of Knowledge of the Geology of Texas, Bull. No. 45, U. S. Geol. Survey, 1887, p. 32 et seq). I am indebted to my friend Dr. W. B. Phillips, Director of the State Mineralogical Survey of Texas, for calling my attention to this interesting paper.

features of the ant's body,* and passes without a word over the important, distinctive characters. His conception of generic characters is even more nebulous than his appreciation of specific differences. Sometimes he mistakes the sex of the form he is describing, and at other times confounds several very distinct forms in a single description.

No wonder, therefore, that Prof. Forel wrote, in 1884: "Quant aux descriptions de Buckley, elles sont telles que je suis obligé d'en faire absolument abstraction, vu qu'elles ne permettent pas de reconnaître une seule espèce, ni même les genres." Dr. Gustav Mayr and Prof. Emery, however, who have occupied themselves somewhat more extensively with the ants of the United States, have gone to considerable pains to determine the species described by the Texan geologist. They have, indeed, succeeded in identifying some of the forms more or less accurately, but the great bulk of Buckley's names still clogs our taxonomy and exasperates the student.

To some, the wisest course would seem to be to follow Forel and ignore Buckley's work *en bloc;* and certainly the writer of these pages would be the last to drag these names from their well-merited neglect, were it not that the Formicidæ, for the following reasons, occupy a somewhat peculiar position among insects: First, the number of species representing the family in a given portion of the United States, or, in fact, in the whole country, is not very large. This greatly facilitates identification by elimination. Second, in any locality as circumscribed as that from which Buckley obtained more than half of his species, certain forms are always very abundant and cannot fail to arrest the attention of the most superficial observer and collector. Third, the habits of the species are often more characteristic than their morphological traits, so that when the former are recorded they are a great aid in recognizing species.

Now these considerations have some bearing on Buckley's work. As I have devoted my leisure hours during the past three years to studying and collecting the ants of Texas, especially in the very spot which for many years was Buckley's home, I am naturally in a better position to judge of his Texan species than those who have had to study the ant-fauna of this region at long range. It is clear that Buckley must have left us descriptions of the more striking and ubiquitous ants of Central Texas, and this is borne out by a study of his work. Moreover, in several cases the ethological notes appended to his descriptions leave no doubt as to the species he had in hand.

---

*Such, e. g., as the distance (sometimes measured to within one or two hundredths of an inch!) to which the wing tips of the female project beyond the abdomen as if, forsooth, the abdomen of these insects were incapable of expansion or contraction.

But after all attempts at identifying Buckley's species by Mayr, Emery, and myself, there still remains a most perplexing residuum consisting of a number of forms belonging to difficult genera like *Formica, Camponotus, Lasius, Prenolepis, Myrmica, Pheidole, Cremastogaster,* etc. In my opinion, these will never be recognized, and should be consigned to that taxonomic rubbish-heap which has for many years past been receiving the worthless entomological names and descriptions of Walker, Macquart, Bigot, F. Smith, and others.

In the following pages I have seen fit to cite Buckley's species *seriatim* with their conjectural identifications. I am not aware of having made any effort to strain a point in favor of Buckley,—for I hold that no zoologist deserves a particle of credit for writing a worse than useless description,—but if I have succeeded in throwing a little light on some of his species, I could wish this to be regarded as a tribute to a pioneer naturalist who long ago searched the woods and hill-slopes of Texas, collecting ants and observing their ways "with much pleasure and satisfaction."

1. *Formica nova-anglæ;* female, worker. Maine.

This may be *F. exsectoides,* Forel, or some form of *F. rufa,* L. (e. g., *F. obscuripes,* Forel), but the description is too vague, and should be discarded.

2. *Formica Nortonii;* female, worker. Conn.

Probably either *F. pallide-fulva,* Latr., subsp. *nitidiventris,* Emery, or *F. obscuripes,* Forel, but the description is worthless like the preceding.

3. *Formica americana;* female, worker. Conn.

This is very probably one of the northern varieties of *Camponotus marginatus,* Latr. (e. g., var. *minutus,* Emery), as Emery ('93, p. 676; '94, p. 337) suggests; since the female is described as black with the exception of the mouth-parts and legs, and has no discal cell, whereas the worker has a red thorax. The description, however, is too vague, and Emery's varietal name should not be supplanted by Buckley's.

4. *Formica connecticutensis;* female, worker. Conn.; N. Y.; D. C.

This is almost certainly a form of *F. fusca,* L., but the description is so loose as to apply to any of the following subspecies and varieties, which are not uncommon, as I know from collecting in Connecticut: *F. fusca.,* var. *subsericea,* Say, var. *subænescens,* Em., and subsp. *subpolita,* Em., var. *neogagates,* Em.

5. *Formica gnava;* male, female, worker. Texas; D. C.; N. Y.; Conn.

Buckley certainly included several species of *Formica* under this name. The description throughout was evidently drawn from a Texan variety of *F. fusca.* intermediate between var. *subsericea,* Say, and var. *neorufibarbis,* Em. Emery suggests (*in litteris*) the name *sub-*

sericeo-neorufibarbis for this form, which differs from the typical *neorufibarbis* in presenting a darker clouding of the vertex and thoracic dorsum. It is the only *Formica* of the kind occurring in Central Texas. It is very common in rather damp, shady localities in Travis and the adjoining counties. It must have been known to Buckley, who gives Central Texas the first place in his list of localities. Of course, his mention of New York, etc., in this connection shows, that he had also some other species (in all probability, *F. nitidiventris*) in mind while he was writing the description. His ethological notes, "very active and brave; bites sharply, and emits a strong odor of formic acid," and his description of the workers as being of a "bronze color when first caught, or seen in their cells," can refer only to the Texan form, and to no other similar *Formica* known to me. As the name suggested by Emery (*in litt.*) is rather cumbersome, while Buckley's is very brief and descriptive, I would suggest that the mid-Texan form of *Formica fusca* be henceforth known as var. *gnava*, Buckley.

6. *Formica occidentalis;* female, worker. N. Y.; Conn.

Emery ('94, p. 337) suggests that this may be *Lasius claviger,* Mayr. It is evident that the description refers to a yellow *Lasius,* but the species of this genus are too difficult of separation to be identified from descriptions like those of Buckley.

7. *Formica monticola;* female, worker. N. Y.

This, too, is a yellow species of *Lasius;* and as the head of the female is described as being narrower than the thorax, we may suppose that Buckley had before him specimens of *L. myops,* Forel, or *L. brevicornis,* Emery, but, as in the case of the preceding species, there is no possible way of deciding.

8. *Formica gracilis;* female, worker. N. Y.

Very probably, as Emery suggests ('94, p. 337), the common *Tapinoma sessile,* Say. It may be safely put down as a synonyn of that common and well-known Dolichoderine.

9. *Formica parva;* worker. D. C.

The small size (.1 inch) would indicate that this can hardly be a *Formica.* It may be merely a small form of the preceding.. The description is utterly worthless.

10. *Formica atra;* worker. D. C.

This is evidently a *Camponotus.* Emery suggests that it may be the same as the form which he has called *C. marginatus,* subsp. *discolor,* var. *cnemidatus.*

11. *Formica virginiana;* worker. D. C.

Perhaps a variety of *F. pallide-fulva,* Latr., according to Emery ('94, p. 337).

12. *Formica arenicola;* worker. D. C.

Buckley's description of this species agrees pretty well with specimens of *Prenolepis imparis,* Say, which sometimes nests in very sandy soil. But this ant is decidedly hairy, and Buckley expressly states that his form is "not hairy."

13. *Formica politurata;* worker. Mich.

Emery suggests ('94, p. 338) that this may be a variety of *F. fusca,* subsp. *subpolita,* Emery, but the description agrees about equally well with *F. lasioides,* Em., var. *picea,* Em. The name and description may be safely discarded as worthless.

14. *Formica septentrionale;* female, worker. Mich.; Ill.

Evidently a *Camponotus* which Emery ('94, p. 338) believes may be a variety of *C. marginatus,* Latr.

15. *Formica floridana;* worker. Fla.

Recognized by Emery ('93, p. 670) as a variety of *Camponotus abdominalis,* Fabr., and listed as *C. a.,* var. *floridanus,* Buckley. Mayr ('86, p. 423) obtained one of Buckley's types of this species from Norton.

16. *Formica tejonia;* male. Cala.

The absence of the discal cell, which is nearly always present in *Formica,* indicates that this is a *Camponotus.* Buckley's description agrees well with males of *C. maculatus,* Fabr., subsp. *vicinus,* Mayr, var. *nitidiventris,* Em., from California.

17. *Formica tenuissima;* worker. Tex.

Mayr ('86, p. 432) believed that this was very probably *Forelius* (*Iridomyrmex*) *McCooki,* Forel. I cannot accept this determination for three reasons: First, Buckley could not have recorded this species as "rare"; second, he has given a description of *McCooki* as *F. fœtida* (see No. 27); third, Buckley's *F. tenuissima* is very probably a variety of *Brachymyrmex Heerii,* Forel, with pale yellow males and rather hairy body in the worker. This form is really rare in Central Texas according to my own observations, and occurs "in the ground beneath stones," as Buckley says. The description does not, however, completely fit my specimens.

18. *Formica perminuta;* worker. Tex.

This form was regarded by Emery as perhaps a species of *Brachymyrmex.* It may be the form referred to in connection with the preceding species. But Buckley's description also agrees very well with immature workers of a small *Prenolepis* very common under stones in Central Texas (see No. 19). This is another very dubious and therefore worthless description.

19. *Formica picea;* worker. Tex.

According to Mayr ('86, p. 431), who saw some of Buckley's types, this is *Prenolepis vividula,* Nyl. (=*P. parvula,* Mayr, according to Emery). I have not yet been able to find the true *P. parvula* about Austin (Buckley's type locality), nor, indeed, anywhere in Texas, but instead I have often found a very closely allied form which Emery (*in litt.*) regards as an undescribed species (see, however, Buckley's *F. terricola,* No. 28). I believe that it would be best to accept Mayr's synonomy or to discard Buckley's name and description altogether.

20. *Formica Lincecumii;* male, female, worker. Tex.

Emery ('94, p. 338) believed that this might prove to be a species of *Formica,* but no such tree-inhabiting *Formica* is known to me to occur in Texas. Buckley may perhaps have had specimens of a *Dolichoderus, D. Taschenbergi,* Mayr., e. g., which should occur in Texas, as it is known to occur in Louisiana. Unfortunately, only the worker of *D. Taschenbergi* is known, so that the description of the male and female of Buckley's species can not as yet be utilized in the determination. Buckley's form could be identified as *Camponotus* (*Colobopsis*) *impressus,* Rog., which lives in trees, were it not that he expressly mentions the presence of a discal cell in the female, and could scarcely have overlooked the peculiar configuration of the head in this sex.

21. *Formica festinata;* female, worker, soldier. Tex.

This species is recognizable with certainty as a variety of *Camponotus fumidus,* Rog., of very common occurrence on the dry hill-slopes of Central Texas. It is characterized by the absence of hairs on the antennal scape of the worker major.* This is such a large, conspicuous and widely distributed ant that Buckley simply could not have overlooked it. Moreover, his ethological notes are reasonably correct and apply to no other species in the State: "They are very active, traveling beneath rocks and sticks where they have cells and galleries in the earth to a depth of twelve or eighteen inches. They are not war-like, and rarely bite when caught, nor are they often seen in the open air, hence they probably seek food by night." A good instance of Buckley's superficiality as an abserver is shown in his supposition that the dark-headed workers major are simply older individuals than the slender honey-yellow minors. The Central Texas form of *C. fumidus* may be known as var. *festinatus,* Buckley.

22. *Formica insana;* female, worker. Tex.

This is undoubtedly a synonym of *Dorymyrmex pyramicus,* Roger. Besides the fact that the description agrees well with the commoner

---

*In Trans-Pecos Texas this form is replaced by another variety (*fragilis* Pergande or *pubicornis* Emery).

Texas forms, McCook ('79, pp. 185-186), who suggested this determination, claims to have seen two of Buckley's types in the collection of the Philadelphia Academy of Natural Sciences. Buckley's ethological notes are correct and will scarcely apply to any of our other ants, but his English name, "Crazy ant," is a misnomer, as this species is by no means *non compos mentis.* Always alert and self-assertive, it is one of our few species that can adapt itself to the extremes of a Texas drought and make a livelihood when most other ants are compelled to æstivate in the depths of the soil.

23. *Formica masonia;* worker. Tex.

If I am not mistaken, this is a *Liometopum.* The description agrees very well with *L. apiculatum,* Mayr, which I recently captured in the Trans-Pecos (Paisano Pass, Brewster county). But as it would apply almost eually well to *L. microcephalum,* Panz., var *occidentale,* Em., which in all probability occurs in Western Texas, Buckley's name should not be substituted for that of Mayr.

24. *Formica saxicola;* female, worker. Tex.

Emery ('94, p. 338) conjectures that this may be a species of *Lasius.* As yet I have been unable to find any species of this genus in the State. Buckley's specimens were from North Texas (Buchanan [now Stephens] County), however, and it is not improbable that *Lasius* may occur in that region. Buckley's color description points to a form like *L. americanus,* Em., or *L. aphidicola,* Walsh.

25. *Formica discolor;* female, worker. Tex.

Emery ('93, p. 677) regards this form as a subspecies of *Camponotus marginatus,* Latr., now known as subsp. *discolor,* Buck. He is undoubtedly correct in this determination. The form under consideration is very common throughout Central Texas. It is sometimes found beneath logs as stated by Buckley, but small colonies are far more frequently found inhabiting the abandoned galls of *Holcaspis cinerosus,* Basset, on live-oak trees (*Quercus virginiana*).

26. *Formica sansabeana;* male, female, worker. Tex.

This, too, is unquestionably a *Camponotus,* and is adopted by Emery ('93, p. 673) as *C. maculatus,* Latr., subsp. *McCooki,* Forel, var. *sansabeanus,* Buckley. The species is common, but local. Though it is sometimes found in decaying stumps, as Buckley states, it occurs far more frequently under stones in shady places. Males and winged queens are present in the nests throughout the year.

27. *Formica fœtida;* female, worker. Tex.

This is another ant concerning which there can be no question. It is simply *Iridomyrmex* (*Forelius*) *McCooki,* Forel, and it is surprising that McCook, who was familiar with the species and with Buckley's work did not recognize the fact. The description of the female—notably, the brown bands on the abdomen—will apply to no other Texan ant. The habits are also correctly described, e. g., its peculiar custom of going in single file, ascending and descending trees, its disagreeable odor ("resembling rotten cocoa-nut"), and the number ("ten or twelve") of deälated queens often found in a single nest. I suggest, therefore, that Forel's name as of later date be regarded as a synonym of Buckley's, which should, of course, be changed to *Forelius* (or *Iridomyrmex*) *fœtidus*, Buckley.

28. *Formica* (*Tapinoma*) *terricola;* male, female, worker. Tex.

According to Mayr ('86, p. 431), who saw Buckley's types, this species is *Prenolepis vividula*, Nyl. (=*P. parvula*, Mayr). This is possible, but I am inclined to believe that Buckley's specimens represented the closely allied *Prenolepis* mentioned above (see No. 19). The description of *F. terricola* is more explicit than that of *F. picea*, and includes all the sexes. It applies, moreover, perfectly to the only *Prenolepis* I have as yet taken at Austin (the type locality). The nests contain males and winged queens throughout the year. Buckley mentions their occurence in March, which would be early even in Texas for the appearance of these sexes in any other ants except certain species of *Camponotus*. Buckley's specific name may, therefore, be retained for this apparently distinct species, of which I shall give a full description in a subsequent paper.

29. *Formica* (*Tapinoma*) *wichita;* worker. Tex.

Mayr ('86, p. 431) saw the types of this species, which he regards as identical with the common northern *P. nitens*, Mayr (=*P. imparis*, Say). This species does not occur in Central or Western Texas so far as my observations extend. Buckley's specimens were from the northern border of the State (Wichita River).

30. *Formica* (*Hypochira*) *subspinosa;* worker. Tex.

This species, described from Central Texas, appears to be a *Dolichoderus*, as Emery suggests ('94, p. 338), but up to the present time I have looked in vain for any ant that will agree with Buckley's description. His account of the metathorax certainly does not apply to any of the known species of *Dolichoderus* from the United States.

31. *Polyergus texana;* female. Tex.

This is another enigma. At first one is inclined to believe that Buckley may have described some dark colored male *Eciton* as a female Polyergus, but since the discovery of a species of *Polyergus* with black legs and abdomen (*P. breviceps*, var. *bicolor*, Wasmann) by Father Muckermann in Southern Wisconsin, and of a very closely allied variety by myself in Northern Illinois ('01, p. 715; foot-note), one is inclined to suspect that there may be a completely black race of *Polyergus* in this country, and that Buckley may have been fortunate enough to find a virgin queen of this form. But the dimensions given by Buckley (0.17 inch) are certainly small for either a female *Polyergus* or a male *Eciton.*

32. *Ponera texana;* worker. Tex.

This is, in all probability, a species of *Leptogenys,* as Emery ('94, p. 338) suggests. It seems to be merely a variety of the species described as *P. elongata* (see No. 35).

33. *Ponera amplinoda;* worker. Tex.

Undoubtedly a synonym of *Pachycondyla harpax,* Fabr., which is local, but by no means "rare," as Buckley claims, throughout Central Texas.

34. *Ponera pennsylvanica;* worker. Pa.

Recognized by Emery ('94, p. 267) as the American form of *P. coarctata,* Latr., and retained as a subspecies (*P. c.,* subsp. *pennsylvanica,* Buck.).

35. *Ponera elongata;* worker. Tex.

This is undoubtedly the same as the species which was later described by Mayr as *Leptogenys* (*Lobopelta*) *septentrionalis.* The type locality is Austin, and Buckley's description agrees almost perfectly with the worker. He has even noted the difference in the red coloration of the individuals of the same nest. This difference, which is very striking, depends, of course, on the degree of maturity. The ant is common in certain localities about Austin. Buckley says it is "not active," but this is true only during cold weather. It is to be regretted that Buckley's specific name must be substituted for Mayr's, which expresses the fact that this is the only species of *Leptogenys* known to occur as far north as the United States.

36. *Ponera* (*Ectatoma*) *Lincecumii;* worker. Tex.

Undoubtedly a species of *Pseudomyrma,* as Emery maintains ('94, p. 270). Of the four Texan species of this genus known to me (viz.: *P. gracilis, flavidula, pallida,* and *brunea*), the description would apply only to an immature specimen of the last, but this form is itself doubtful on account of the meagreness of F. Smith's description; so that this identification would be simply explaining the obscure by the more obscure.

37. *Odontomachus texana;* worker. Tex.

Of the two species of *Odontomachus* known to occur in the United States, viz.: *O. hæmatodes,* L., subsp. *insularis,* Guér., and *O. clarus,* Rog., Emery ('94, p. 269) conjectures that Buckley's species is probably synonymous with the former, on account of its smaller size. I believe, however, that Buckley's species must be a synonym of *O. clarus,* Rog., as this species is common and widely distributed in Texas (from Austin to the Trans-Pecos and north to Bosque County), whereas I have never been able to find *insularis* in the State. Size cannot be a criterion, as I have seen many specimens of *O. clarus* that were smaller than specimens of *insularis* in my collection. Besides, Buckley is apt to underestimate the length of his species. But perhaps any attempt to determine the exact synonymy of Buckley's species is of very little moment, since *O. clarus* may be regarded merely as an extreme subspecies of *O. hæmatodes.* (See Forel, '01a, p. 124.)

38. *Myrmica rubra;* worker. Tex.

Undoubtedly *Eciton cœcum,* Latr., according to Emery ('94, p. 258). Buckley's name is, of course, of no account, because it was in use even in his day as the name of a very different and very common European and American ant.

39. *Myrmica subrubra;* female, worker. D. C.; Va.

This is treated by Emery ('94, p. 301) as a synonym of the common northern *Stenamma* (*Aphœnogaster*) *tennesseense,* Mayr, without further comment. If this is correct, Buckley must have described the male of *tennesseense* as the female. He describes this sex as black and as having short epinotal spines, whereas the queen of Mayr's species is red and has very large and peculiar epinotal spines, which Mayr described at length when he first mentioned this peculiar female under the name of *Aphœnogaster lœvis* ('62, pp. 95-96). In a later paper ('86a, p. 365) Mayr also claims that Buckley mistook the male of *Stenamma tennesseense* for the female.

40. *Myrmica californica;* worker. Cala.

Recognized by Emery ('94, p. 311) as a species of *Pogonomyrmex,* and now known as *P. californicus,* Buckley.

41. *Myrmica novaboracensis;* female. N. Y.

This ant, described from a female only, is supposed by Emery ('94, p. 286) to be some form of *Cremastogaster lineolata,* Say.

42. *Myrmica* (*Monomarium*) *diversa;* female, soldier, worker. Tex.

This name covers a multitude of sins, for I am confident that Buckley included under it several species of *Pheidole,* with *Solenopsis geminata* into the bargain! The first part of the description of the soldier seems at first sight to refer to *Ph. Kingii,* André, var. *instabilis,* Emery, especially where he says that the head varies "much in size." This is the only *Pheidole* measuring as much as 0.22 inch, and with variable head, to be found about Austin, but *instabilis* has the eyes very distinctly in front of the middle of the head, so that the remainder of the description must refer to another species and the previously mentioned variation in the size of the head was probably due to confounding several species. This could be done very readily by a superficial collector, as there are about a dozen species of *Pheidole* in the neighborhood of Austin, and some of these are very common. The female described by Buckley is certainly not the female of *instabilis,* as the latter has a very characteristic coloration quite unlike that of any other Texan species known to me. Again, some of the ethological remarks must refer to *Solenopsis geminata,* as, e. g., when he describes the ants as "throwing the excavated earth without order over the surface."

43. *Myrmica* (*Monomarium*) *minima;* female, worker. Tex.

There can be no doubt, as Emery has shown ('94, p. 274), that this is merely a variety of *Monomarium minutum,* now known as *M. m.,* var. *minimum,* Buckley.

44. *Myrmica* (*Monomarium*) *cœca;* worker. Tex.

Emery ('94, p. 260) suggests that this is probably an *Eciton.* It may be either *E. opacithorax,* Emery, or *E. Schmitti,* Emery, but the description is too vague to be intelligible.

45. *Myrmica* (*Monomarium*) *marylandica;* worker. D. C.; Md.

Very probably some form of *Cremastogaster lineolata,* Say, as Emery maintains ('94, p. 286). This is shown by the locality and by Buckley's remark, "it often carries its abdomen turned up erect."

46. *Myrmica* (*Monomarium*) *montana;* worker. Tex.

This is probably the small agricultural ant which I have described as *Pogonomyrmex imberbiculus* ('02). The description agrees equally well, however, with *Xiphomyrmex spinosus,* Pergande, which is often found in the same localities, though the latter does not, as a rule, live under stones. I am certain that Buckley's rather vague account must refer to one or the other of these two species.

47. *Myrmica* (*Monomarium*) *lineolata;* female, worker.

Another unintelligible description, probably referring, as Emery suggests ('94, p. 338), to some species of *Myrmica.* The omission of any mention of locality renders it utterly worthless.

48. *Myrmica* (*Monomarium*) *columbiana;* female, worker. D. C.

This is obviously a *Cremastogaster,* but it can not be *C. lineolata,* subsp. *læviuscula,* Mayr, as Emery suggests, since the queen of this subspecies has a red head and thorax and the latter merely striped with black, whereas in the female of Buckley's form the head and thorax are black. It must be some other form of *lineolata,* possibly var. *cerasi,* Emery.

49. *Myrmica* (*Monomarium*) *aquia;* female, worker. Va.; N. Y.

This is treated by Emery ('94, p. 304) for good reasons as a subspecies of Roger's *Stenamma* (*Aphænogaster*) *fulvum*. See also Mayr ('86a, p. 365).

50. *Myrmica* (*Monomarium*) *saxicola;* worker. Tex.

In all probability, as Emery suggests, merely one of the numerous varieties of the "fire-ant," *Solenopsis geminata,* Fabr.

51. *Myrmica* (*Monomarium*) *atra;* worker. D. C.

The description is ostensibly drawn from a worker, but Emery ('94, p. 274) believes that Buckley really had before him a small deälated queen of *Monomorium minutum,* Mayr, var. *minimum,* a form which he had already described under No. 43.

52. *Myrmica* (*Tetramorium*) *exigua;* female, worker. D. C.

There can be no doubt, as Emery ('94, pp. 277-278) maintains, that this is the common little "thief-ant," *Solenopsis molesta,* Say (=*S. debilis,* Mayr). In this case again, Buckley has described the male as the female. Of late the synonomy of this species has been called in question by Forel ('01b, pp. 344, 345), who regards Say's description of *Myrmica molesta* as referring to *Monomorium pharaonis,* because Say mentions the occurrence of this ant in houses. Forel is quite positive in his assertions that *Solenopsis molesta* does not have this habit, but he is certainly mistaken in this matter. Not only has Pergande found this species to be a common house ant in Washington (see Emery, '94, p. 277), but another careful observer, Mr. C. E. Brown, of the Milwaukee Public Museum, has recently sent me numerous specimens taken in the houses in the city of Milwaukee. Should Say's specific name be discarded, which I deem inadvisable, Buckley's should be substituted. This would necessitate a change of *S. exigua,* Forel, to *S. pygmæa,* as Forel suggests.

53. *Myrmica* (*Diplorhoptrum*) *scabrata;* worker. Conn.

This is one of the most enigmatic of Buckley's descriptions. An eyeless, myrmicine ant of the color and size recorded by Buckley and occurring in Connecticut, baffles even conjecture.

54. *Myrmica* (*Atta*) *sabeana;* worker. Tex.

There can be little doubt that this is merely another synonym of *Solenopsis geminata,* Fabr., as Emery ('94, p. 276) has pointed out.

55. *Myrmica* (*Atta*) *sublanuginosa;* worker. Tex.

No Texan ant answering to Buckley's description is known to me.

56. *Atta Lincecumii;* soldier, worker. Tex.

This, again, is almost certainly *Solenopsis geminata,* Fabr. (Emery, '94, p. 276.)

57. *Atta picea;* soldier. Tex.

Evidently a species of *Pheidole,* and, judging from the color description, probably some variety of *Pheidole dentata,* Mayr., or *Ph. Hyatti,* Emery, but the exact species will never be determined. A *Ph. picea* was later described from Mexico by Mayr.

58. *Atta brazoensis;* soldier, worker. Tex.

Probably *Solenopsis geminata,* Fabr., according to Emery ('94, p. 276).

59. *Atta pennsylvanica;* soldier, worker. Pa.

This species, taken near Philadelphia, must be a *Pheidole,* as Emery ('94, p. 338) surmises. For geographical reasons, it is probably *Pheidole bicarinata,* Mayr., or some form of *Ph. vinelandica,* Forel, but this can never be decided.

60. *Atta coloradensis;* soldier, worker. Tex.

Specimens of *Pheidole* sp. mixed with *Solenopsis geminata,* according to Mayr ('86a, p. 365).

61. *Œcodoma virginiana;* worker. Va.

It is exceedingly difficult to interpret Buckley's description of this species. Emery ('94, p. 329) believes that it may refer to a *Strumigenys,* possibly to *S. clypeata,* Emery, but it would agree even more closely with a small specimen of *Atta* (*Trachymyrmex*) *septentrionalis,* McCook. It is certainly one of the most exasperating descriptions in the series.

62. *Œcodoma texana;* male, female, worker. Tex.

This, of course, refers to *Atta fervens,* Say, the common "leaf-cutting ant" of Texas.

63. *Myrmica* (*Monomarium*) *molefaciens;* female, worker. Tex.

Now known as *Pogonomyrmex barbatus,* Smith, var. *molefaciens,* Buckley (Emery, '94, p. 308), the common Texan "agricultural ant."

64. *Œcodoma pilosa;* worker. Tex.

Emery ('94, p. 330) referred this species to the group *Attii,* but was unable to give a more precise determination. It cannot refer to either of our species of *Cyphomyrmex* (*C. rimosus,* Spin., and *C. Wheeleri,* Forel), nor to the form included under Buckley's next description; so that we can only suspect that there is in Texas still another fungus-growing ant which, to judge from Buckley's description, must resemble *Apterostigma* or *Sericomyrmex.* Northern Texas, however, would seem to be a very improbable locality for such a form.

65. *Œcodoma tardigrada;* male; female, worker. Tex.

Mayr, after comparing some of Forel's specimens of *Atta* (*Trachymyrmex*) *septentrionalis,* McCook, with a type of Buckley's *A. tardigrada* in his possession, pronounced the species to be the same, so that Forel ('84) and subsequent writers have relegated McCook's specific name to the synonomy. This I believe to be an error. *A. septrionalis* is known to occur only in the Atlantic States (from New Jersey to Florida). I have never found it in Texas, but instead have taken another species of *Atta* (*Trachymyrmex*) which agrees fairly well with Buckley's morphological description. This is a dark brown species with pointed posterior angles to the head. It occurs near Austin (Walnut Creek), and I have seen dozens of its nests while riding through three of the large counties of the Trans-Pecos. Specimens examined by Prof. Emery were pronounced to belong to an undescribed species. Although this may be the *Atta tardigrada* of Buckley, I nevertheless hesitate to regard it as such, since its nests differ widely from Buckley's description. These ants do not throw "the excavated earth in the form of a crater," nor do they descend to cells "two or three feet beneath the surface by a hole about half an inch in diameter." These dimensions are also far too great for McCook's species (*Cf.* his figure and description, '80). His specific name should therefore be restored for the eastern *Trachymyrmex* and Buckley's name should be abandoned, at least for the present. In further support of this conclusion I may add that there is in the State (in Brewster County) still another *Atta* (*A.* [*Acromyrmex*] *versicolor,* Pergande) which would also meet the requirements of Buckley's description. The new Texan *Trachymyrmex* will be described in a subsequent paper.

66. *Œcodoma* (*Atta*) *arborea;* female, worker. Tex.

This species was regarded as a synonym of *Cremastogaster lineolata,* Say, by McCook ('79, p. 187), and this determination was accepted by Mayr and Emery. I believe that it is possible to go still further, and to refer the form to the subspecies *læviuscula,* Mayr., var. *clara,* Mayr., since the queen of the subspecies *lineolata* has the head and thorax black or dark colored, whereas the queens of *læviuscula* have a yellowish red head and thorax and the latter merely streaked with black. Buckley describes some of the queens as having a yellow head, others as having the whole body black, "excepting the abdomen, which is banded with yellowish white." This is either arrant carelessness of observation or confusion of several species. His notes on the habits of *C. arborea:* "has cells in the decayed parts of trees and when disturbed often turns up its abdomen into a nearly vertical position; often seen going in ranks up and down trees," together with the size leave no doubt that the form is *læviuscula,* var. *clara,* which is a very common and conspicuous ant throughout Central Texas. Mayr's name, though later than Buckley's must be retained, however, as F. Smith published a *C. arborea* as early as 1858.

67. *Œcodoma* (*Atta*) *bicolor;* worker. Tex.

This form is regarded by Mayr ('86, p. 463) as a synonym of *C. lin-*

eolata, subsp. *læviuscula,* var. *clara,* and Buckley's name was dropped because Smith had previously published a *C. bicolor.* I am confident, however, that this is not the form designated by Mayr, but either a variety of *C. opaca,* Mayr, which I have taken in North Texas under stones, or *C. punctulata,* Emery, which has a similar habitat in Central Texas and New Mexico. Buckley's species, however, is too vaguely described to be recognized with any degree of certainty.

BIBLIOGRAPHY.

'66-'67. *Buckley, S. B.* Descriptions of New Species of North American Formicidæ. Proc. Ent. Soc. Phil., Vol. VI, 1866-1867, pp. 152-172, 335-350.

'93-94. *Emery, C.* Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Abth. f. Syst., Bd. 7, 1893, pp. 633-682, Taf. 22; and Bd. 8, 1894, pp. 257-360, Taf. 8.

'84. *Forel, A.* Etudes Myrmécologiques en 1884. Bull. Soc. Vaud. Sc. Nat., Vol. 20, 1884, pp. 1-65, Pl. XI.

'01a. *Forel, A.* Fourmis Mexicaines Recoltées par M. le professeur W. M. Wheeler. Ann. Soc. Ent. Belg., Tome XLV, 1901, pp. 123-136.

'01b. *Forel, A.* Variétés Myrmécologiques. Ann. Soc. Ent. Belg., Tome XLV, 1901, pp. 334-382.

'79. *McCook, H. C.* Formicariæ (pp. 182-189, in J. H. Comstock's Report upon Cotton Insects), Washington, 1879.

'80. *McCook, H. C.* Note on the New Northern Cutting Ant, Atta septentrionalis. Proceed. Acad. Nat. Sci., Phila., Part 3, Oct. to Dec., 1880, pp. 359-363. 1 Fig.

'62. *Mayr, G.* Myrmecologische Studien. Verhand. k. k. zool.-bot. Ges., Wien, Jahrg. 1862, pp. 649-776, Taf. XIX.

'86. *Mayr, G.* Die Formiciden der Vereinigten Staaten von Nordamerika. Verh. k. k. zool.-bot. Ges., Wien, Bd. 36, 1886, pp. 419-464.

'86a. *Mayr, G.* Notizen über die Formiciden-Sammlung des British Museum in London. Verh. k. k. zool.-bot. Ges., Wien, Jahrg. 1886, pp. 353-368.

'01. *Wheeler, W. M.* The Compound and Mixed Nests of American Ants. Am. Nat., Vol. XXXV, Nos. 414, 415, 417, and 418. 1901.

'02. *Wheeler, W. M.* A New Agricultural Ant from Texas with Remarks on Some of the Described Species. Am. Nat., Vol. XXXVI, 1902.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901.

THE SILT PROBLEM IN CONNECTION WITH IRRIGATION STORAGE RESERVOIRS.

J. C. NAGLE, Assoc. M. Am. Soc. C. E.,
Agricultural and Mechanical College of Texas,
College Station, Texas.

VOLUME IV, PART II, NO. 3.

AUSTIN, TEXAS, U. S. A.:
PUBLISHED BY THE ACADEMY
1902.

THE SILT PROBLEM IN CONNECTION WITH IRRIGATION STORAGE RESERVOIRS.*

BY J. C. NAGLE, ASSOC. M. AM. SOC. C. E.,
Agricultural and Mechanical College of Texas,
College Station, Texas.

During the spring of 1899 Mr. Elwood Mead, of Cheyenne, Wyoming, Expert in Charge of Irrigation Investigations for the U. S. Department of Agriculture, assigned to me a portion of the work in connection with the investigation of certain economic questions relating to the effect of silt upon irrigation systems making use of storage reservoirs, the effect of silt upon canals and the effect that the use of certain waters would probably have on vegetation to which they might be applied. Later on it was decided to have the results of observations at other points pass through my hands also, and I have only recently completed my progress report for the present year, covering the results of measurements on certain streams in Texas, New Mexico, Arizona and Wyoming. A few of the results as contained in that report will be here presented.

In published analyses of river waters the quantity of suspended matter is sometimes given in grains per gallon and sometimes in parts per 100,000, but in such analyses as I have observed the results were obtained gravimetrically. Now, in a storage reservoir, it is not the ratio of the weight of dried silt to the weight of the water that the reservoir would contain that is wanted, but the ratio by volume, for when the capacity of the reservoir is diminished its value is likewise impaired. In Power systems this is not always the case, though sometimes it is. Mr. Mead desired, therefore, to know the ratio of silt to discharge, by volume, for certain streams, and also, incidentally, the proportion of silt carried at different depths in these streams, and he outlined a plan from which it has been found necessary to depart somewhat, in some cases, as occasion demanded. The plan was to collect four samples for each

*Read at the Waco meeting of the Texas Academy of Science, December 29, 1901.

These samples were to be allowed to stand in suitable glass settling tubes for one week—the tubes being filled to a depth of twenty inches. At the end of a week the depth of sediment at the bottom was to be noted, and from this and the original depth of water the percentage of silt was to be determined. A further period of settlement was to be allowed and the depths read at the end of one month to determine what further subsidence took place.

Eight settling tubes were sent me and on their arrival I found them so irregular in bore that it was necessary to calibrate them the first thing. Their capacities varied from 286 to 377 cubic centimeters, when filled to a depth of twenty inches, and they were not uniform in size. I first made a scale that could be read to thirty seconds of an inch and calibrated the lower portion of the tubes so that the volumes corresponding to given depths were known. With large quantities of sediment in the water this method gave fairly good results, but with small quantities the percentages were entirely too high. So I procured a number of narrow tubes, graduated to fractional parts of a cubic centimeter, and after allowing the water to settle perfectly clear in the large tubes I decanted it and transferred the sediment to the small graduates, using enough water to carry over all the sediment and to fill the tubes to a depth of about seven inches. The contents of the small tubes were allowed to stand for one week and the volumes of silt read at the end of that time. Occasional samples were allowed to stand for thirty days, to note what further subsidence took place. For the few samples that I was able to allow to stand for this length of time I found that the volume of the silt at the end of one month was about one-tenth less than the volume at the end of one week. One set of four samples showed even greater reduction in volume. It was set in the small tubes on the 20th of November, 1900, and at the end of one week showed an average of 3.8 per cent. of silt. On the 20th of December it showed only 3.21 per cent. of silt—a reduction of nearly one-sixth as compared with the volume at the end of one week. Lack of a sufficiency of settling tubes has prevented me from carrying the settling process still further. Professor Arthur Goss, of the New Mexico Experiment Station, found for one set of samples that was collected on December 4, 1899, that, at the end of one month, the silt at the bottom of the tubes amounted to about 4.4 per cent. of the original volume of water. This sample was taken from the Rio Grande river at Earlham Bridge, New Mexico. At the end of eleven months Professor Goss again read the depths of silt in the tubes and found an average of about 3.75 per cent. of sediment—a reduction during ten months of about 15 per cent. of the volume at the end of one month. From the results of my own and Professor Goss's tests I have concluded that if the percentages at the end of one week be reduced one-fourth it will give a result that will not be less set, one from the top, one from the bottom and two intermediate points. The discharge was to be measured at the time the collections were made. than if the settling process had been carried on for one year, and will very probably be greater. If there is an error in this assumption it is on the safe side.

Most of the samples collected were taken with a tin can which was provided with a bale at the top and a wire loop soldered to the bottom. To this loop a weight could be attached and another attached to the bottom of a cord to which the can could be fastened at any desired distance above the weight at end of cord. A rubber stopper, having an arrangement to which another cord could be tied, was fitted tightly into the top of the can. On being lowered into the water the stopper could be withdrawn and the can filled at the desired depth. I made some collections myself with a special water sampler constructed for the Department. This sampler consisted of a brass cylinder, or drum, having sliding gates at the ends that could be held open by means of stops. A vane attached to the apparatus served to keep it end-on to the current. By pulling a cord the stops could be withdrawn and the gates suddenly closed by strong springs, thus imprisoning a cylinder of the water which had been flowing under normal conditions at the time of closing the gates. For the sake of comparing the results obtained by the two methods a few samples were collected in both ways at the same time, but no material difference was found to exist. Also a few samples were taken near the banks of the streams, where the current was slow, on the same occasions that samples were collected in midstream, and while some difference in the distribution of the silt in vertical planes was observed this was not decisive and the average percentages were practically identical.

I did not find it necessary to take four samples each time, but varied this somewhat as the conditions of the streams varied. If the water were very turbid four samples were collected, whenever possible, no matter how much sediment was carried. For comparatively small amounts of sediment three samples for each set only were collected and for still smaller amounts of sediment two, or even one, sample was deemed sufficient.

Two Texas streams were selected in which the observations were conducted under my own direction—the Brazos river, at the Jones bridge, six or seven miles west of College Station, selected because of its accessibility, and the Wichita river at Wichita Falls, chosen because of the fact that an immense irrigation system has been projected there, the construction of which the recently defeated constitutional amendment will very seriously delay. Had this amendment carried, the State at large would probably have had a splendid opportunity to witness the results of an extensive experiment without cost to any one save those directly interested. It was our intention to have the observations made at the site of the dam, about forty miles above Wichita Falls, but the inaccessibility of the place made it necessary to have them made at the town of Wichita Falls. A few samples were also taken with the sampler from the Pecos river and from the Rio Grande river, at El Paso, besides a number that were taken higher up the river with the collecting cans and examined by Professor Goss. While in El Paso I secured a number of samples that were collected in 1897 and 1898 by the International (Water) Boundary Commission and arranged with the Consulting Engineer of the Commission to have other samples taken from time to time. In Arizona Professor Forbes had charge of observations, and in Wyoming Professor Slosson was in charge.

From the Brazos river thirty or forty sets of samples have been collected and the results of the determinations of the sets of four and three samples each are given below:

Four sets of four samples each were taken with the water sampler and yielded the following average percentages:

From top	1.078 per cent.
From one-third depth	1.088 per cent.
From two-thirds depth	1.173 per cent.
From bottom	1.210 per cent.
Mean	1.137 per cent.

The average results for twenty-one sets of four samples each, including the above four sets and seventeen others taken with the collecting cans, were as follows:

From top	1.008 per cent.
From one-third depth	1.043 per cent.
From two-thirds depth	1.085 per cent.
From bottom	1.028 per cent.
Mean	1.041 per cent.

This would seem to indicate that the mean percentage of silt is carried at about the one-third depth, though if only the samples taken with the water sampler be considered the mean percentage would seem to fall a little lower in the section. However, the samples taken with the sampler were too few in number to base any general conclusions on the results, and in all cases the individual variations are very marked.

The average results for five sets of three each are as follows:

From top	1.032 per cent.
From mid-depth	1.008 per cent.
From bottom	0.990 per cent.
Mean	1.010 per cent.

For this set the top samples carried the most sediment, on the average. It requires only a casual glance at the turbid water to see that the cross-currents are constantly changing and streaks of very muddy water alternate with less heavily charged portions.

For eight sets of four samples each collected from the Wichita River the means at different depths were as follows:

From top ....3.420 per cent.
From one-third depth ....3.370 per cent.
From two-thirds depth ....3.370 per cent.
From bottom ....3.340 per cent.

Mean..............................3.375 per cent.

For one set taken with the sampler on July 21, 1900, the greatest amount of silt was carried at the bottom, though on the same afternoon the top sample showed the larger amount. Only two samples could be taken at this latter hour, however, because the rapid current made it impossible to get the sampler to the bottom of the river.

For six sets of three samples each the following average results were obtained:

From top ....1.845 per cent.
From mid-depth ....1.777 per cent.
From bottom ....2.047 per cent.

Mean..............................1.890 per cent.

The foregoing results are all based upon the volumes of silt found at the end of one week. Professor Goss has sent me the following results for the quantities of silt carried by the waters of the Rio Grande on three occasions, the samples having been collected at Earlham Bridge, and which were allowed to stand one month before being measured:

Collected.	Percentages of silt carried by the water.				
	Top.	One-third depth.	Two-thirds depth.	Bottom.	Mean.
July 23, 1899............	26.25	26.25	27.25	25.63	26.34
August 13, 1899............	33.75	33.75	33.13	34.37	33.75
December 4, 1899............	5.00	4.38	4.37	3.75	4.38

For these three sets the percentages were computed from the depths sent me by Professor Goss. The first and second show enormous amounts of sediment, due to the fact that the flood had come from rushing torrents that had abraded the mountain sides as the water came down. Much of this sediment seems to be deposited before the water reaches El Paso, for in the samples I secured from that point the amount of silt was very much smaller. In one sample from El Paso, selected because it showed an abnormal amount of sediment, I found something over fifteen per cent. of silt at the end of one week, but this was chosen as representing the extreme case.

However, for the Brazos and Wichita rivers the extreme percentages of silt are away below this. For the Brazos river the largest percentage of silt for any one set of samples was less than four, while for the Wichita river the maximum percentage was found on July 19, 1900, to be 6.84. This was on a rising river in the early stages of a small flood. In fact the smaller floods generally show a higher percentage of silt than do the larger ones, and there is more sediment when the stream is rising than after it has attained its highest stage. For such determinations as I have myself made the results were obtained at the end of a week and should be reduced about one-fourth in order to obtain the percentages at the end of a year, as has already been noted.

For the Wichita River there are only two general conditions of the water. When the river is low the water is clear, or nearly so; when the river is up the water is red, sometimes intensely so. For the Brazos River there are three conditions of the water. First, when the stream is low it is clear or nearly so, though when looked at from above both streams may appear red on account of the red sediment at the bottom of the stream. When the flood in the Brazos comes from near its head the water is red and very similar to the water in the Wichita at high stages, because the same character of country constitutes the watersheds. When the rains that fall over the black lands, and Cretaceous areas generally, swell the Brazos the water is dark and the percentage of silt small, while the red rises carry the largest percentages.

In order to determine the effect that the silt in any stream would have on an impounding reservoir it is necessary to know also the discharge of the stream at the time the collections were made. Indeed, both discharge measurements and silt determination should be made daily if very close results are desired. On both the Brazos and the Wichita rivers I have established gauging stations at which the gauge heights are read daily. These heights, together with as many discharge measurements as could be made, enabled me to compute the daily discharge, and as the observer also noted the appearance of the water daily it was possible for me to approximate the mean monthly discharge of water and silt for the two streams during the periods covered. Doing this for the Brazos river, for a period covering fifteen months, I found, as the approximate percentage of silt at the end of one week, 1.28, which if reduced to the probable percentage at the end of one year's settlement would yield 0.96 per cent. Taking only the latter twelve months of this period I got practically the same results. However, the last two years have yielded discharges much higher than the average, because the floods have been more frequent, so that it is probable that the mean results would fall below those found as above.

From August, 1899, to July, 1900, inclusive, the discharge of the Brazos river amounted to about 7,570,000 acre feet, while the calculated amount of silt during the same time was 95,740 acre feet, as computed from a week's settlement. During September, 1899, the discharge of water was about 30,000 acre feet with only about seventy-one acre feet of silt, while in February, 1900, the water discharge amounted to about 96,000 acre feet, but was clear all month, so that practically no silt passed. During April, 1900, the water discharged amounted to over 2,600,000 acre feet with over 49,000 acre feet of silt. For May of this year the water discharged amounted to about 2,044,000 acre feet with 21,660 acre feet of silt. During April two overflows occurred, one of these extending over into May, and for these two months an immense amount of red colored water passed down. No attempt was made to measure the flow during these floods except for the immediate channel of the river. The water stretched for miles across the overflowed bottoms, in many places having a strong current, so that probably much more water passed down than is here estimated. No discharge measurements were made at the very highest stages of the river, but I got one measurement very near the highest stage reached this year, the discharge then being 123,700 cubic feet per second. This measurement was taken on April 29. The lowest discharge measurement made was on September 10, 1899, and amounted to only 574 cubic feet per second. The gauge reading for this small flow was 1.7 feet and as this fell to 1.3 feet later on in the month the minimum discharge probably dropped as low as 300 cubic feet per second.

During the great flood of 1899 the river was two or three feet higher than for either of the overflows in 1900, and whereas the highest discharge for the latter year amounted to about 125,000 cubic feet per second, in and immediately adjacent to the channel of the river, it is probable that during the highest stages of the flood in 1899 the discharge within the channel may have reached 160,000 cubic feet per second. Add to this the flow that must have occurred across the overflowed bottom—a width of perhaps six or seven miles—and it is possible that the total discharge may have reached the enormous amount of 250,000 cubic feet per second. As to what this amount of water means it will be sufficient for those who witnessed the failure of the Austin dam to state that for a depth of 11.07 feet on the crest—the depth carried at the time of failure—the discharge was about 135,000 cubic feet per second. The Brazos river stood for days with a depth of about fifty feet above low water mark and a velocity of eight or nine miles per hour.

At such very high stages of the river it was no easy matter to measure the velocity, for the current meter could not be lowered to the bottom.

The only thing left to do was to measure the surface velocities, and afterwards to apply a suitable coefficient, and even then the drift sometimes made it hazardous to attempt to use the meter. For high stages the meter readings were checked by float observations. It must, therefore, be remembered that for high velocities the results obtained may be affected by a relatively large probable error.

The drainage area of the Brazos river above the Jones bridge, counting in that portion of the Llano Estacado that sometimes sheds water towards the river, is about 37,400 square miles, or if that portion of the area that lies above 3000 feet elevation be excluded, as probably contributing but little to the discharge, it will be about 30,150 square miles.

The drainage area of the Wichita river, above Wichita Falls, is about 3050 or 3060 square miles and the greatest discharge of which I secured a measurement was 16,740 cubic feet per second, which was on July 21, 1900. The gauge then read 12.1 feet, but during last December the river was much higher, with a discharge perhaps two or three times as great for a short time. The smallest measured discharge was obtained on July 16, 1900, and amounted to sixty-one cubic feet per second. The gauge then read 1.65 feet, and while the gauge has read as low is 1.4 feet it is not likely that the discharge has ever fallen below fifty or fifty-five cubic feet per second. I was unable to secure an observer to make daily gauge readings on the Wichita river until February of this year, since which time such readings have been taken. I have worked up the results for only seven months and these are given below:

RESULTS OF DISCHARGE AND SILT MEASUREMENTS ON THE WICHITA RIVER.

Month.	Discharge in acre feet.	Silt in acre feet.
February	5,970	0
March	9,530	0
April	78,550	995
May	124,040	1,053
June	72,770	172
July	142,160	3,930
August	74,460	146
Total	507,480	6,298

On account of the distance I had to travel I was only able to obtain seven discharge measurements of the Wichita river during the foregoing interval, but these measurements were fortunately at such stages of the river as to permit of a fairly good rating curve being drawn, and by means of this the daily discharges were obtained.

It will be observed that while the highest monthly percentage of silt is over 2.75, the average for the seven months covered is only about 1.24, which is lower than the result obtained for the Brazos river, notwithstanding the black rises in the latter river carry much less sediment than the average.

Recurring again to the enormous discharge of the Brazos for one year, amounting to more than seven and one-half million acre feet, it is clear that a storage reservoir on the lower reaches of the river would be out of the question even if a suitable site for a dam could be found, because it would be utterly impossible to construct a reservoir that would hold more than a small fraction of the total annual discharge, and the remainder that would have to be allowed to pass the dam would deposit a portion of its sediment on its way through the reservoir, just the same as occurred at the Austin dam where Professor Taylor has told us the lake was practically half filled with sediment in seven years after it first filled. This same matter of silt will be a serious problem to contend with in the event that navigation of the Brazos should ever be attempted, because with every flood the channel will silt up in places and the construction of locks and dams will facilitate the deposit of sediment above the dams. During the past year and a half the channel of the river has been deepened considerably at the Jones's bridge, where my observations were made, but on the subsidence of each flood it begins to silt up again. No better time could have been found for making a survey of the Brazos than we have had during the time the surveys have been carried on, if it be desired to produce a favorable impression as to the navigability of the stream, but when one considers that enough mud has passed the Jones's bridge in one year to cover more than 7000 acres ten feet deep, after reducing the quantities given in the foregoing pages to the probable results at the end of the year, it can easily be seen that the attempt to form any kind of lake by damming the river must lead to the deposition of no inconsiderable amount of mud. Along the upper reaches of the river it is possible, no doubt, to construct storage reservoirs, and one such system was projected in 1896, the dam to be situated in Knox county, and from the reservoir water was to have been taken not only down the Brazos valley, but also across the divide into the Wichita river valley as well.

For the Wichita river it is seen that there is a possibility of constructing a reservoir which should have a capacity fairly large in comparison with the total discharge. The seven months covered above yield considerably more than the average discharge and the point at which observations were made being forty miles below the site of the proposed dam the watershed at this latter point would probably be less than two-thirds of the watershed above the gauging station.

I have not been able to make any comprehensive computations of the total silt discharged by any of the other streams upon which determinations have been made, and for the purposes of this paper it may be just as well as it is, for I have already occupied too much space with the foregoing.

Several years ago it was proposed to throw a dam across the Rio Grande river at El Paso, above which a reservoir with the enormous capacity of about 537,000 acre feet would be formed. This international dam was intended to remove all cause of complaint on the part of citizens in the El Paso valley, on both sides of the Rio Grande, who, year by year, have been obliged to abandon more and more of their irrigated farms, some of which have been under cultivations for hundreds of years, probably since the Spaniards first found the Pueblo Indians practicing irrigation about the middle of the sixteenth century. Increasing irrigation along the upper reaches of the Rio Grande has caused the river to go dry frequently in the vicinity of El Paso, and the irrigators there have seriously suffered in consequence. During the time that surveys and estimates for this dam were being made under the general direction of Maj. Anson Mills, U. S. A., samples of the water were collected at frequent intervals and the quantity of silt present determined gravimetrically. Between June 10 and July 28, 1889, one hundred and eighteen samples of water were collected. It was assumed that a cubic foot of dry sediment would weigh eighty-five pounds, and on this assumption the average per cent. of silt for the period covered was figured at 0.345 of 1 per cent. The smallest value found was about one-fourth of 1 per cent., and the largest 1.5 per cent. for a local rain of twelve hours' duration. Major Mills concluded that it would take at least one hundred and fifty years to fill the reservoir with sediment. The United States Geological Survey carried on these sediment determinations at El Paso for upwards of one year, as described in Part II of the Eleventh Annual Report. For these determinations it was assumed that a cubic foot of the dried sediment would weigh one hundred pounds. The largest monthly discharge of sediment given was for April, 1890, when the amount was 1,671,700 pounds, and the smallest was for July, 1889, when the sediment amounted to 39,800 pounds. For the year ending July 30, 1890, the total silt, on the assumption that a cubic foot would weigh one hundred pounds, is given as sufficient to cover a square mile to a depth of 2.75 feet, equivalent to only 1,760 acre feet.

While it is possible that a cubic foot of dried sediment may weigh eighty-five pounds, or even one hundred pounds, it seems perfectly clear to me that this same cubic foot of sediment, if placed in water and allowed to absorb what it will, as must occur at the bottom of a reservoir, would swell very much in volume. If we take the three samples collected from the Rio Grande at Earlham Bridge, two of which contained an excessive amount of silt—which, from this very fact, would probably be more readily settled into a compact mass—and if we reduce the percentages found from Professor Goss's volumetric determinations at the end of one month by one-sixth, in order to have at least as large a percentage as would exist at the end of one year, we shall have for the sample collected on July 23, 1899, about 22 per cent. volumetrically, whereas the gravimetric method yielded only 10.78 per cent. For the sample collected August 13, 1899, the volumetric determination, reduced to the probable basis of a year's settlement, yielded 28 per cent., while the determination by weight yielded only 12.4 per cent. With the third sample, collected December 4, 1900, the reduction is much greater, as would be expected from the smaller quantity of silt present. At the end of one year the percentage by volume would be a little more than 3.7, whereas by weight the percentage was only 1.15 per cent., which is less than one-third of the volumes found for the silt gravimetrically. In a few determinations on the Brazos and Wichita river waters about the same relation was found, from which I have concluded that when the quantity of silt is determined by weight the results are only about one-third, or at most one-half of the quantity determined by volumes.

In regard to the method of determining the sediment volumetrically, it may be objected that the sediment at the bottom of the laboratory tubes is under a very different pressure from that which would exist at the bottom of a deep reservoir. However, I hope to be able to test the effect of increased pressure experimentally during the coming year, but I do not expect it to make very much difference, for the silt at the bottom of the tubes appears to become as compact as that which remained in the lake at Austin after the failure of the dam. Two months and a half after the break I visited the lake and observed the silt still remaining. In some places a crust had formed on top hard enough to support a man's weight, but everywhere the sediment was full of crevices, due to shrinkage in drying—many of these being several feet in depth. Below the crust the sediment was still wet and soft, and did not appear to have been very much compacted, notwithstanding the softer upper portions must have been swept out with the rush of water that followed the break in the dam, and which continued for a long time afterwards.

From what has been said, it will be seen that in order to extend the life of a reservoir as much as possible great care in its location should be exercised. The reservoir should be located on a stream of small flow, or on one which carries little sediment, and the capacity of the reservoir should be so large that the inflow from a stream that carries as much as 1 per cent. of silt, determined volumetrically, should be such that it would fill only once, or at most twice a year. Sluice gates at the bottom of the dam have not so far been found to prevent the deposition of silt, though if left open during the rising and flood stages of the river they may accomplish something in maintaining a current near the bottom that will reduce the deposition of silt somewhat. However, the area of such gates will necessarily be small in comparison with the cross section of the reservoir, so that the velocity through the body of the lake will be small, and considerable deposition must take place. If the location and cost permit it will be effective, for a time, to construct settling reservoirs above the storage reservoir proper, in which the bulk of the silt will be deposited, and as these fill up others may be constructed or the heights of dams raised. This latter expedient may sometimes be employed with the storage reservoir itself, and I have been informed by Mr. Wentworth Conduit, manager of the Tlahualilo hacienda, near Torreon, Mexico, that this is sometimes done in the interior of that republic. At Carlsbad, New Mexico, a storage reservoir was constructed in 1889 and 1890, and the dam failed in 1893. Professor W. M. Reed, of Roswell, has written me that at this time the deposit in the lake averaged three feet in depth, notwithstanding the water of the Pecos river carries a smaller average amount of silt than is carried in the waters of other streams upon which such reservoirs have been projected. In 1893, another storage reservoir was constructed ten or eleven miles higher up the Pecos and the old one repaired. Since that time the deposit in the lower lake has been little or nothing, the silt being caught in Lake McMillan—the upper reservoir. During 1899 the water in Lake McMillan got quite low, and Mr. Reed made some investigations on the depth of deposit. Close to the dam he found about sixteen inches of silt, and this increased regularly toward the upper end, ten miles above, where it was about four feet deep. Mr. Reed made his measurements by simply digging through the mud where it had been exposed by the fall in the lake level.

Col. E. S. Nettleton, formerly State Engineer of Colorado, has kindly given me the results of some of his observations, in Spain and Mexico, regarding silt removal from existing reservoirs. A portion of this I condense for use here: The Alicante dam in Southern Spain is one hundred and thirty-five feet high, being thrown across a narrow, rocky gorge only about twenty-five feet wide at the bottom. The reservoir extends for about 1.25 miles above the dam. The feeding stream is small, and the actual capacity of the reservoir is only about 3000 acre feet. The sides of the reservoir being very steep, the bulk of the silt is deposited in the old channel at the bottom of the reservoir—the most favorable arrangement possible for sluicing. At the very lowest portion of the dam there is a sluicing opening about six feet wide and eight feet high, closed by 12x12 timbers, set upright, with another set laid cross-wise of the others. The whole is supported by heavy posts set inside the gallery, and these are suddenly removed when it is found necessary to empty the reservoir. When this is done the opening is quite large in comparison with the cross-section of the reservoir, and the water is drawn off very rapidly, so that the current does the work· This cleaning is done about once every four years, and costs only about $50.00. The deposit is frequently thirty to fifty feet deep at the upper end of the reservoir.

The Villar reservoir impounds a portion of the flow in the Lozoya river and furnishes additional supply to the Isabella II Canal, from which it is drawn for irrigation, and for domestic use in the city of Madrid. The length of this reservoir is about the same as the Alicante, but the gorge above the dam is much wider, the capacity of the reservoir being about 14,000 acre feet. It is not subject to the same rate of silting up as is the Alicante reservoir, however. The dam has two sluicing galleries, with inlets of twenty square feet each, and are set one hundred and sixty-two feet below the overflow line. The sluicing outlets are opened and closed by gates operated by hydraulic power, but the opening is small in comparison with the cross section of the lake above and the side slopes of the latter are flatter than the Alicante reservoir, so that opening the gates only removes the silt from the natural channel of the old stream and high banks are left on each side. By means of ditches built on each side, and a little above the flow line of the reservoir, water is conducted from a point higher up the stream; by cutting the banks of this ditch and trailing the water across the banks of silt they are able to wash it down into the old channel, and then out. This moves the silt quite rapidly, but requires a large amount of water, which, on account of the smallness of the feeding stream, cannot always be well spared.

At the Lozoya reservoir a large flat boat is used to which is attached a large disc wheel, which revolves horizontally, and which can be raised or lowered. To the face of this wheel narrow wings or teeth are attached and these beat the sediment into fine mud that can be moved with a small current. The steam engine that propels the boat also drives this wheel. The apparatus does good work whenever the amount of water flowing through the reservoir is considerable; it wastes no water, and can be used whenever it is thought desirable to do so.

Col. Nettleton states that he has seen attempts in Old Mexico to sluice out reservoirs that had been three hundred years filling with silt, the dams being cut from top to bottom. Notwithstanding wide openings were made the results accomplished were insignificant, only a sinuous channel being cut through the sediment as wide as they could afford to carry the material to the stream that was winding through thirty or forty feet of hard packed silt. Perhaps not more than 5 per cent. of the material was removed in this way.

Col. Nettleton adds that "the Spanish people have learned to clean their reservoirs often, rather than let them go as long as these people in Mexico did."

I do not know of any attempts in this country to remove silt once deposited in large storage reservoirs, though for small ones it is sometimes sluiced out through pipes at the bottom, as in water supply reservoirs. Considerable manual labor is required at the same time to make the process effective. Wherever a good head of water can be obtained it would seem possible to move the sediment by means of a jet from a nozzle, as in hydraulic mining, but in the case of an irrigation reservoir such a source of water pressure is not available, at least not in any cases with which I am familiar. As far as experience has so far shown us the best plan seems to be to keep the silt from being deposited, whenever possible, or if the filling is inevitable to so plan the whole system that within the life of the reservoir the returns will more than compensate for the first cost. Otherwise, abandon the project.

The deposit of silt in irrigation canals is a source of much annoyance and expense. Sometimes sand gates are used to remove a portion of it near the upper end where the cross section of the ditch should be great enough to allow the bulk of the sediment to be there deposited, in case it is not possible to give sufficient fall to maintain a velocity that will prevent deposition. Moss grows rapidly in canals kept constantly full of water, and as this retards the flow very much, it is necessary to remove it. If the water cannot be cut off this involves considerable expense, but when the canal can be allowed to dry out for a few days the moss will wither and die and the attendant expense will be quite small.

I should like to have been able to give you some of the results of the chemical analyses of the waters of the Brazos, the Wichita and other rivers, but this paper is now long enough. For the former rivers, I will say, however, that both the sediment and the water at times of red rises carry considerable available plant food, and that at times of low water there is considerable alkali in the water, but very much less than that carried in the Pecos water, which is now being successfully used for irrigation in New Mexico and Texas.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901.

THE WATER POWER OF TEXAS.

THOMAS U. TAYLOR, C. E., M. C. E.,
University of Texas, Austin, Texas.

VOLUME IV, PART II, NO. 4.

AUSTIN, TEXAS, U. S. A.:
PUBLISHED BY THE ACADEMY
1902.

THE TEXAS ACADEMY OF SCIENCE.

THE WATER POWER OF TEXAS.*

THOMAS U. TAYLOR, C. E., M. C. E.,
University of Texas, Austin, Texas.

INTRODUCTION.

This paper is an abstract of a report to the Hydrographic Division of the U. S. Geological Survey, and it is here published with the consent of the Survey. It has been read in sections before the Texas Academy of Science during 1900 and 1901.

I am indebted to Chas. N. Campbell for much valuable assistance in collecting data.

T. U. TAYLOR.

Austin, Texas, March 1, 1902.

WATER POWER.

Water develops energy by virtue of its weight and the amount of its vertical fall. The amount of work done by a force of P pounds acting through a distance of h feet is Ph foot-pounds. If we assume that weight of one cubic foot of water is 62.5 pounds, and that the flow of a stream is Q cubic feet per second, and that it falls an effective vertical distance of h feet, the work it does is 62.5 Qh foot-pounds. In defining power much coarser units than the foot-pound are used. That in most common use is the *Horse Power*, which is equal to 550 foot-pounds per second. The *Mill Power* is variously defined. It is expressed by a certain discharge Q in cubic feet per second under a head h feet. Merriman gives at Lowell $Q=30$, $h=25$, 85.2 theoretical H. P.; at Minneapolis, $Q=30$, $h=22$, 75 theoretical H. P.; at Holyoke, $Q=38$, $h=20$.

*Read before the Texas Academy of Science on Nov. 23, 1900, and Nov. 22, 1901.

[NOTE.—Advantage has been taken of the delay in submitting this paper to the printers to include the results of Prof. Denton's experiments on the value of Beaumont oil as a fuel and an abstract of Mr. Wilbur F. Foster's report on the cost of rebuilding the Austin dam.—T. U. TAYLOR, April 1, 1902.]

If we know the flow in cubic feet (Q) and the fall h in feet, the work (W) that can be done per second by the total flow can be found from the following:

$$W = 62.5 \ Qh \text{ foot-pounds.}$$

To reduce this to horse power divide by 550.

$$\text{No. of H.P.} = \frac{62.5 \ Qh}{550} = \frac{5 \ Qh}{44}.$$

No machine can develop all of the power in the water on account of frictional resistances. They develop only a certain fraction of the theoretic power. This fraction reduced to per cent. is called the *efficiency* of the machine. A first-class turbine can develop $\frac{4}{5}$ or 80 per cent. of the theoretic power. Then, we have

$$\text{No. of H. P.} = \frac{5}{44} Qh \times \frac{4}{5} = \frac{Qh}{11} \text{.........(A).}$$

Rule: To find the H. P. that can be developed under favorable conditions multiply the flow in Q cubic feet per second by the effective head h, and divide the result by 11.

If the flow is given in gallons per minute, which is often the case, let G=gallons per minute. As each gallon weighs $8\frac{1}{3}$ pounds, the work in foot-pounds per minute will be given by

$$W = G \times 8\tfrac{1}{3} \times h \text{ foot-pounds.}$$

$$\text{No. of H. P.} = \frac{25 \ Gh}{3 \times 33000} \times \frac{4}{5} = \frac{Gh}{4950}.$$

$$\text{No. of H. P.} = \frac{Gh}{5000} \text{ nearly.........(B).}$$

For an efficiency of $\frac{3}{4}$, the last formula becomes

$$\text{No. of H. P.} = \frac{Gh}{5280} \text{.........(C).}$$

This formula can be easily remembered: Multiply the number of gallons per minute by the head in feet and divide the product by the number of feet in a mile.

It often happens that for easy transmission the water power is converted first into electric energy and then transmitted to the locality where it is needed. One horse power is equal to 746 watts, the unit of work in electrical measurements.

One kilowatt equals 737 foot-pounds per second.

One kilowatt $= \frac{1000}{746} \times$ one H. P. $= \frac{4}{3}$ one H. P., nearly.

Substituting this value in (A) and (B) we have

$$\text{No. of K. W.} = \frac{3 \ Qh}{44} \text{.........(D).}$$

For an efficiency of 78 per cent.:

$$\text{No. kilowatts} = \frac{Qh}{15} \text{.........(E).}$$

WATER POWER OF TEXAS.

The Texas streams will be considered in order from west to east. In addition to the main streams or drainage arteries, there are at least twenty streams that arise suddenly in springs and they constitute one of the most potential factors in the State's water supply and power in all of that region west of the Colorado river. These springs occur for the most part in the Edwards's Plateau, the most notable exceptions being those at Fort Stockton, Santa Lucia, and at the head of Toyah creek in Trans-Pecos Texas.

The water power in many localities is as yet in a very crude state, but there are many plants that have been built upon scientific principles where modern machinery is used and where a consequent high efficiency is obtained. A large per cent. of the plants in existence at present are confined to the Guadalupe, the Colorado, the Brazos and their tributaries. The Guadalupe river easily takes rank as the most effective power generating stream in the State.

TOYAH CREEK, TEXAS.

Toyah .creek rises in natural springs about forty miles southwest of Pecos, Texas. These springs are mainly in Section 256, patented by the State of Texas to Antonio Ball. They are in a flat valley hemmed in by a horseshoe curve of the Davis mountains. About three miles to the northwest is Phantom lake. It is stated by close observers that the water of this lake is of the same composition and general character as that of the Toyah springs, and it is probable that the lake is on the underground stream that issues from the earth in the springs. The largest of the Toyah springs is oval shaped, about one hundred feet long by sixty feet broad. Its water level is influenced by the weeds and long grass which grow in it, also by the atmosphere. As measured on September 5, 1900, the entire discharge was forty-six second-feet. A large percentage of the water is deflected into the ditch of the Toyah Creek Irrigation Company. The flow of the spring is equal to about eight heads; a head being defined as the amount of water flowing through an opening one foot square, the upper edge of which is four inches below the water surface. There is an unverified and hazy tradition that the flow once amounted to twelve heads, but this is doubted. The springs are about an eighth of a mile east of the postoffice at Toyahvale. India (known as Brogado postoffice) is about four miles below the springs, on the right bank, while Saragossa is nine miles below the head spring, on the right bank of the creek.

For several miles the creek skirts the foothills of the Davis mountains, and, in addition to the well-known springs mentioned, it is fed by small invisible springs and by seepage. It empties into Toyah lake, a large, flat depression charged with alkali, about thirty-five miles from Toyah-vale and about twelve miles south of Pecos.

A half mile above Saragossa, on the main Saragossa ditch, is the Clements grain and flour mill, a building constructed of adobe and timber, where there is a fall of twelve feet. The power is developed by a 35-inch Leffel turbine and fifteen horse powers are generated. The mill was rebuilt in 1893, and it now grinds both corn and wheat. The flow of the ditch is usually about thirty-five second-feet, only twenty-five of which are utilized for power purposes.

COMANCHE CREEK.

Comanche creek rises at Fort Stockton and has long been a factor as an irrigating stream. In appearance, character, and almost constant flow, it is a full sister to the big springs that form the San Marcos, San Felipe, and Comal. Its flow in 1899 was found to be sixty-six second-feet. The stream feeds four irrigation ditches upon one of which (the Rooney) is located a water power gin of seventy saws. The fall is ten feet and the power is generated by a 24-inch turbine. It is estimated that ten horse powers are developed.

Near Barstow there are two water power plants on the irrigating ditches of the Barstow Irrigation Company. These are used to operate the gins of Briggs & Dyer and of Geo. E. Briggs. The former is located on lateral No. 1 and has a head of 6.24 feet. The energy is developed by a 36-inch Leffel turbine and thirty horse powers are easily developed by the flow of water in the lateral. This as measured in January, 1902, was fifty-four second-feet. The Briggs gin is located on lateral No. 3 and has a head of 7.5 feet on the 36-inch Leffel turbine and twenty-six horse powers can be developed by the ordinary flow of forty second-feet.

PECOS RIVER.

The Pecos river rises in the mountains of New Mexico and flows in a general southerly course through southeast New Mexico and West Texas. Before its waters were controlled or arrested by dams in New Mexico at Roswell and Carlsbad, it had one of the most reliable flows of any river in Texas. The irrigation systems in New Mexico have at present means of arresting the whole ordinary flow of the river at Carlsbad and diverting it into Lake Avalon. The flow in the Texas portion must be accumulated from springs and seepage from the irrigation farms below Carlsbad. The first dam in Texas across the Pecos is located nine miles above the town of Pecos, and eighty miles below the dam at Lake Avalon. The dam at this point belongs to the Margueritta Canal Company and serves to deflect the water into the canals. The United States Geological Sur-

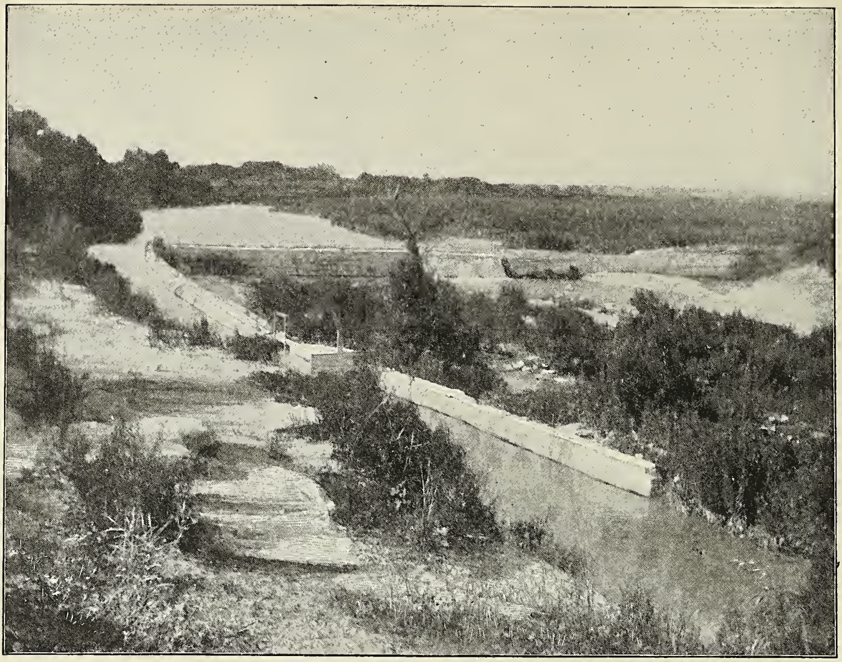


FIGURE 1.
Dam at Del Rio.

FIGURE 2.
Dam at San Antonio.

vey has maintained a gauging station at the flume since September, 1898. The flume is three miles below the dam and six miles above Pecos. The minimum flow of the river at the flume is twenty second-feet, as several measurements have indicated. Measurements taken on three separate days in April, 1900, gave the following measurements:

	April 22.	April 26.	April 30.
Flow of river........	21 second-feet.....	20 second-feet.....	21 second feet.
Flow of flume........	115 second-feet.....	118 second-feet.....	106 second-feet.
Flow of west valley ditch............	12 second-feet.....	10 second-feet.....	18 second-feet.
Total................	148 second-feet.....	148 second-feet.....	145 second-feet.

The minimum flows during 1901 occurred on July 10th and July 21st, when the total discharge was found to be 158 and 161 second-feet, respectively. The maximum flow occurred on November 4th, when the discharge was found to be 3230 second-feet.

These are the lowest measurements ever recorded of the river below the Margueritta dam. There is at the dam a minimum flow of a little less than 150 second-feet, and it would not be safe to calculate on more than this. Between Pecos and Great Falls there are no tributary streams and this low flow of twenty second-feet would cut little figure for water power or irrigation purposes. There are two other dams across the Pecos in the vicinity of the Great Falls. These belong to the Pecos Irrigation Company and the Grand Falls Irrigation Company, whose ditches are respectively on the west and east sides of the river. The efficiency of these two plants has fallen lamentably short of anticipations, chiefly on account of the use of the water in New Mexico and at Barstow, Texas.

From the Texas State line to a point near old Fort Lancaster, in Crockett county, the river flows through a rich alluvial soil. It takes the premium for being in details the most sinuous river in Texas, and it would show up favorably in this respect in an international contest. There is hardly a mile of it above Pecos that the river does not flow in all directions.

Near Fort Lancaster it enters the canyon that gradually deepens until the river reaches the Rio Grande. The only use of the water so far has been for stock. At High Bridge, at the crossing of the Southern Pacific Railroad, the low water level is 321 feet below the top of the rails on the bridge. The flow of the river at this place was measured by J. D. Dillard during 1900 for the Boundary Commission. The lowest flow during 1900 was 260 second-feet. During 1901, the lowest flow occurred on July 9th, when a discharge of 162 cubic feet per second was found at a gauge height of .80. The maximum flow occurred on November 17th and was found to be 2635 second-feet.

DEVILS RIVER.

Devils river is a magnified illustration of the effect of the large springs of the Edwards Plateau. The river rises in Pecan Spring, about forty-five miles north of the mouth and about sixty miles from Del Rio. This spring is on what is known as the old mail route from San Antonio to El Paso; this route followed the course of the springs on the southern edge of the plateau. The river is only about fifty miles long, and yet, of all the rivers of Texas, is has the largest minimum flow. This, as determined by semi-weekly measurements during 1900, was slightly over 500 second-feet. During 1901 the lowest flow occurred on August 29th, when a discharge of 509 cubic feet per second was found. The flow of this river could readily be utilized in irrigating vast tracts of land east of Del Rio. It would be necessary to construct a dam across the river above the railroad bridge and convey the water from the lake thus formed to the irrigated lands by pipe lines to prevent seepage. The water is clear as crystal and forms a strong contrast to the turbid water of the Rio Grande at their junction.

The Pecos and Devils rivers unite with the Rio Grande within twenty-five miles of each other and their waters serve to make the flow of the Rio Grande below Del Rio reliable and commercially valuable. The lowest flow at Eagle Pass during 1901 was found to be 1800 cubic feet per second. Half of this amount turned into irrigation ditches would bring into cultivation for ordinary crops 200,000 acres of land, and for rice in the lower and flatter country near Brownsville it would readily have a minimum capacity of half of the whole rice crop of Texas for 1901.

SAN FELIPE.

San Felipe creek, which skirts the extreme eastern limits of Del Rio, rises from large springs a little over a mile southeast of the town. The flow of these springs is utilized in the magnificent irrigation system between the town and the Rio Grande, and for one power plant. The irrigation system will be described fully in a water supply paper. The total flow of the stream was found to be, in 1895, —— cubic feet per second; in 1899, 113 cubic feet; in 1900, 149 cubic feet; in 1901, 150 cubic feet. The variation in flow was caused by the immense flood known as the Brackett Flood of June, 1899, and increased precipitation on the Edwards Plateau. There is installed on the San Felipe creek an electric light and ice plant, the power for running which is obtained solely from the flow of the creek. The dam (Fig. 1) is constructed of rubble limestone masonry, is something over one hundred feet long, about ten feet high, and is built with a portion straight across the stream, the remainder curving down stream, thus forming the race from that portion of the dam next the power house and the bank of the stream itself. The cross-section is approximately trapezoidal in shape, measuring three feet on top, about ten feet at the base, and averaging twelve feet in height. It is founded on solid limestone. The head obtained by this dam is practically constant and amounts to ten feet. The machinery consists of a Warren 30-kilowatt alternating dynamo and a 6-ton ice machine, which are run by 44-inch Leffel turbines; the one operating the ice machine giving twenty horse power with the gate partly open, and the one operating the dynamo giving thirty horse power with a full gate opening. The turbine that operates the ice machine runs only fourteen hours a day in the summer only, and the electric light turbine fourteen hours per day the year round. A fifty horse power emergency engine is also installed in the power house, but has never, as yet, been used.

At Castroville, Joseph Courand has erected a stone dam across the Medina river. The dam is 250 feet long, eight feet high, with an effective fall of eight feet. The power generated by a 35-inch Leffel turbine is used to operate a gin and mill. The Medina often stops flowing during the dry seasons and an auxiliary steam plant is used during periods of no flow.

SAN ANTONIO AND SAN PEDRO SPRINGS.

The San Antonio river rises about three miles north of the mission of San Fernando, which is the geographical center of the city. To better control and utilize the water of the San Antonio, two canals, an upper and a lower, were constructed in 1878 and 1881. A power house was built on each canal, called, respectively, the upper and the lower power house. The fall at the upper power house is about seven feet, and that at the lower twelve, while that at Guenther's upper and lower mills is three and one-half feet and six feet, respectively. The dam at Guenther's upper mill is shown in Fig. 2.

The San Antonio river became so low in 1896 that the water power was abandoned. Previous to this, in 1895, an auxiliary steam plant of 130-horse power was installed at the lower power house. The water at these power stations was pumped from artesian wells—one 12-inch being located at the upper station, and one 12-inch and three 8-inch wells being located at the lower power house. In 1891 a steam and electric power plant was constructed on the banks of the river, near Commerce street, at which there are four 9-inch and three 12-inch wells. An indication of the stage of the underground water can be obtained from the water level in the standpipes at the waterworks on Commerce street and at the lower power house. The artesian wells at these works are connected to standpipes some fifty feet high. The following table shows the heights to which the water rose at the respective plants:

Commerce Street.		Upper Power House.	
Date.	Height.	Date.	Height.
May, 1893	42.10 feet.	Jan. 1, 1900.....	1.8 feet.
Dec. 6, 1897......	33.80 feet.	Feb. 1, 1900......	6.76 feet.
April, 1898......	31.60 feet.	Mar. 1, 1900	13.76 feet.
April 29, 1900......	43.00 feet.	April 1, 1900......	13.77 feet.
May 1, 1900......	44.10 feet.	May 1, 1900......	15.57 feet.
May 5, 1900......	45.10 feet.	May 24, 1900......	18.74 feet.
May 9, 1900.....	46.20 feet.	June 1, 1900......	17.99 feet.
May 22, 1900......	47.10 feet.	July 1, 1900......	14.65 feet.
		Aug. 1, 1900......	12.76 feet.
		Sept. 8, 1900......	12.10 feet.
		Oct. 1, 1900......	11.47 feet.
		Nov. 1, 1900......	11.38 feet.
		Dec. 1, 1900......	10.51 feet.

The San Antonio river has had an eventful history. About 1895 it began to fail, and by the latter part of 1897 the flow above the city had entirely ceased. The following table of measurements gives its history:

Date.	Flow in Second-feet.			Locality.	Hydrographer.
	San Pedro.	River.	Total.		
Dec., 1895	9	40	49	Canal...........	C. C. Babb.
Nov., 1896	12	29	41	Canal...........	C. C. Babb.
Dec., 1897	....	....	11a	Hot Wells....	T. U. Taylor.
Mar., 1898	....	....	9a	Hot Wells....	T. U. Taylor.
June, 1899	....	....	10a	Hot Wells....	T. U. Taylor.
Sept., 1900	....	....	125	Hot Wells....	T. U. Taylor.
Sept. 19, 1900	9	94	103	Canal...........	T. U. Taylor.
Oct. 31, 1901	....	....	41	Hot Wells....	T. U. Taylor.

There are in all four dams across the San Antonio river within the city limits: (1) The upper power house, fed by upper canal where the head is seven feet; (2) the lower power house, fed also by a canal where the fall is twelve feet; (3) Guenther's upper mill, where the fall is three and one-half feet; and (4) Guenther's lower mill, where the fall is six feet. The fall from the upper power house to the lower Guenther's mill is —— feet. At this date (February, 1902) the upper power house is not used on account of lack of water. Its equipment consisted of two Risdon turbines, forty-three and sixty inches in diameter, with vents of 220 and 425 square inches. The lower power house has one Hercules 33-inch double capacity turbine and one 43-inch single capacity Risdon turbine. At present the water is held back in the big canal above the lower power house for twelve hours and then used for twelve hours through the wheel with gate one-third open. The intimate connection between the artesian wells and the river has been conclusively proven. A few years ago a series of stakes were driven in the still waters of the head lake and the height of the water marked thereon. The artesian wells were then all turned on and let run for twenty-four hours. The level of the water in the head lake or pond of the river had fallen two and one-half inches.

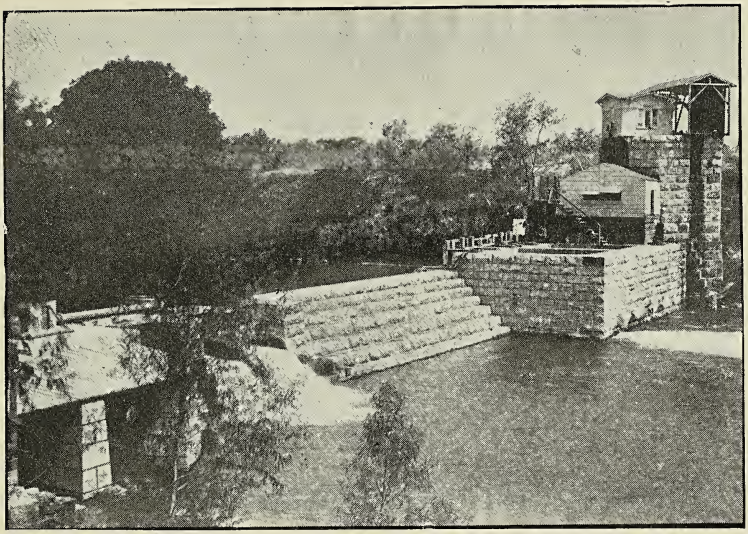


Figure 3.
Clemens Dam at New Braunfels.

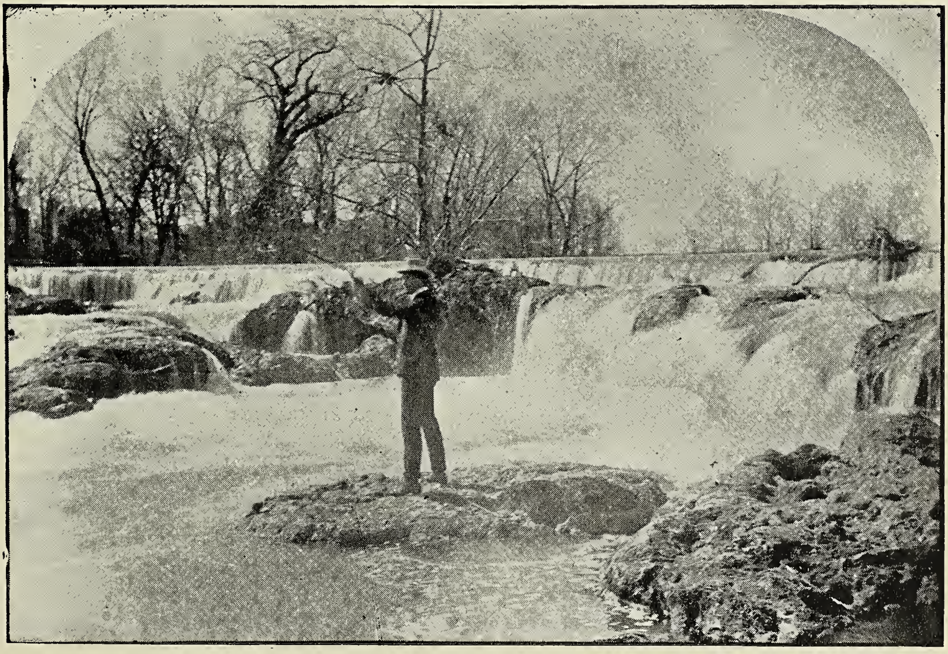


Figure 4.
Erskine Falls near Luling.

The wells were then checked and in about one day the water in the head lake was at its former level. Then again the artesian wells were by survey connected in a system of levels. An excavation was made on the land of the observer below the water line. It was possible by observing the height of water in this hole to obtain the height of water in any artesian well in the city.

GUADALUPE RIVER.

The Guadalupe rises in Kerr county in three forks, known as South Fork, North Fork, and Johnson Fork. The South fork rises in a spring about twenty-two miles west of Kerrville. After flowing three miles the river sinks, rising again one and one-half miles further down. The minimum flow above its junction with the Comal north of New Braunfels, has been found to be forty second-feet. Just east of New Braunfels, the reliable Comal enters, adding a steady and minimum flow of 320 second-feet.

Above New Braunfels there are five dams on the Guadalupe that develop power, namely, the Sherman dam, at Ingram; the Schreiner dam, at Kerrville; the dam of the Kerrville Roller Mills; the Witt dam, at Center Point; and the Flach dam, at Comfort.

Three miles above Ingram is located the first dam on the Guadalupe. The power plant belongs to John Sherman, and is used for grinding, sawing, and ginning. The dam is seven feet high and is constructed of cedar and cypress, and weighted with stone. The foundation is a natural fall of two feet, upon the crest of which the dam is located, giving it a fall in all of nine feet. The power is developed by a 42-inch Leffel turbine and is usually operated with gate one-third open. The dam is 300 feet long and was originally built in 1892. At Ingram there is another excellent site for a power plant that has never been utilized.

Two miles above Kerrville, Chas. Schreiner, in 1900, erected a wooden dam across the Guadalupe. The length of the dam is about one hundred feet and its maximum height is three feet. It is constructd of cedar and cypress plank. The foundation upon which it rests consists of rock bottom. The effective head is ten feet and the power is developed by one 30-inch Victor turbine, and it is usually run with the gates opening at one-fourth. The vent is 300 square inches, and it is estimated that fifty horse powers can be developed. This would require a discharge of fifty five second-feet. The dam deflects the water into a race on the north side of the river about 300 feet long. The banks of the river on the south side are low, while those on the north immediately adjacent to the river are low and flat to a distance of 150 feet from the river bank. Next the bluff there is a low swag through which the race was carried. The bluff constituted one side of the race and the south side had to be built out of frame work, consisting of vertical cedar posts to which stout cypress planks were spiked, constituting a water-tight fence.

At Kerrville a dam has been constructed by erecting cypress posts 12x12 inches in holes drilled in the rock bed of the river, and thoroughly filling the hole around the foot of the posts with cement. Instead of bracing the posts from below to withstand the thrust of the water, an iron tension rod is attached to the posts and to an anchor bolt in the rock above the dam. The upper face of the dam is formed of thick cypress lumber spiked to the 12x12 inch posts. The dam gives an average head of seven and one-half feet on the two Leffel turbines of forty-four and forty-eight inches diameter, respectively. The former is generally operated with full opening, and the latter with three-fourths, and possessing vents of 300 and 260 square inches, respectively. An auxiliary steam plant of forty-five horse power is used for operating the electric plant.

At Center Point a wooden dam was built across the Guadalupe in 1895. Its length is 300 feet and height seven feet, and cost about $2,000. The plant is owned by W. H. Witt & Co., and the power is utilized to operate the roller mills. The effective head is nine feet and the power is generated by one 48-inch Leffel turbine, which is generally operated with a gate opening of two-thirds. It is possible with this wheel to develop forty horse powers, which would require, with an efficiency of eighty per cent., a venting of forty-nine cubic feet per second.

The power plant at Comfort, twelve miles from Kerrville, is owned and operated by E. Flach. The power is used in the Comfort Roller Mills, electric light plant, and a cotton gin. The dam is made of cedar log pens, filled with rock, brush and clay. It was built in 1881, is 150 feet long and about five feet high. The head is eleven feet on an average, reaching twelve as a maximum and ten as a minimum. The energy is generated by two Leffel turbines, thirty-five and forty inches in diameter, respectively, having vents of 180 and 137 square inches. The horse power developed is estimated at forty and thirty, and this would require with an efficiency of eighty per cent. a flow of forty cubic feet per second through the larger and thirty through the smaller. The plant has an auxiliary steam plant of seventy-five horse powers for use in periods of low flow.

The mountains of the Edwards Plateau end about one mile northwest of New Braunfels and from the fissures at the foot of the bluffs the celebrated springs that form the Comal river gush forth. The waters have been used for power since 1860, but it is only since 1880 that systematic methods have been used. At present the waters are used by the Landa and Dittlinger mills. The Landa mill is about one-half mile from the main springs and is located near the banks of a dry branch of the Comal. A gravel dam deflects a large per cent. of the water from the Comal Springs creek into the Landa mill race. The Dittlinger mill is one-half mile below the Landa and is north of the court house.

The Comal is the most unique, picturesque, and reliable river in Texas.

Its flow is reasonably uniform and it has a fall of forty-three feet in its length of two miles. From the surface of Lake Comal (formed by the gravel dam) to the surface of Landa's mill pond, there is a fall of two feet; at Landa's mill a fall of twenty-two feet, developing 630-horse powers; from Landa's tail race to the surface of Clemens lake, a fall of three feet; a fall of eight feet at the Clemens dam, developing 275-horse powers, and from this dam to the Guadalupe there is a further fall of nearly ten feet. The flow was measured independently in 1882 by two civil engineers, by use of floats, and each found a discharge of 375 second-feet. From then until 1899 there was a gradual decrease of flow. Early in 1900, like all the sister springs of the Edwards Plateau, the flow increased to its former strength of twenty years ago.

The writer visited the Comal on December 25, 1900 (when it was certain that the power plants would be idle), in order to get a measurement of the flow that would be uninfluenced by the variations of the power required for different purposes. The sections selected were on the Landa race about fifty yards below the gravel dam, and on the Comal Springs creek 275 yards below the dam. The joint discharge was found to be 374 second-feet, the full capacity of the springs. The flow was again measured on December 26th, at the same section, while all mills were running, and a discharge of 373.6 second-feet was found. The level of the water in the race at the section selected was not affected by shutting off the power. About one mile below the junction of the Comal and Guadalupe there is an excellent location for a dam for power purposes. The flow below the junction, with a dam twenty-two feet high, is sufficient to develop (with the usual efficiency) 750-horse powers.

The Landa estate operates two separate plants, both taking their water from the same forebay. The first plant operates the roller flour mills, the elevator, an ice factory, electric light plant, a waterworks pump, and it is intended to add a pump for irrigation purposes. The power is generated by a 26-inch duplex horizontal Leffel turbine, with a head of twenty-two feet. The water is discharged into a race, 24 feet by 30 feet, cut through the west bank of the Dry Comal. The flour mill has a capacity of 3000 barrels per week, the elevator a storage capacity of 100,000 bushels, and the ice factory twelve tons per day. The electric light plant furnishes light to the town and for the Landa works. It consists of two motors, of sixty kilowatts and thirty kilowatts, respectively. The power is transmitted from the turbine by manilla ropes. The elevator is operated by a rope one and one-fourth inches in diameter; the ice factory by rope of the same size. The second plant consists of a horizontal Victor turbine, 30-inch diameter. On the horizontal shaft of the turbine is mounted a pulley that transmits the power by manilla ropes one and three-fourths inches in diameter to the shaft of the big oil mill, which possesses a capacity of eighty-five tons of seed per day. The oil mill machinery is operated by a shaft 240 feet long, varying in size from three and fifteen-sixteenths to two and three-sixteenths inches in diameter.

The Clemens dam (Fig. 3) has a length over all of 220 feet and a length between bulkheads of 130 feet. Its total height is fourteen feet, width of base eighteen feet, and has its foundation on a tough blue clay. The cross-section in general represents a trapezoid. The crest is flat, four feet wide, the up-stream face being vertical and the lower or down-stream face being formed of a series of steps whose height or rise is about nineteen inches, and whose tread varies from eighteen to twenty-four inches. The dam was constructed of limestone obtained five miles from New Braunfels. The stone was laid in the best Portland cement. It was built in 1882, and the plant cost about $100,000. There are three waste weirs, six feet deep and five and one-third feet wide. The head on the wheels is nine feet. The power at the north end is generated by two Stillwell-Bierce Victor upright turbines, thirty-five and forty-four inches in diameter. The shafts from the turbines are twenty-one feet long, five and fifteen-sixteenths diameter; one twenty-four feet long, four and three-eighths diameter; and another twenty feet long, six and fifteen-sixteenths inches in diameter. These transmit the power to a huge pulley fourteen feet in diameter, whose center is twenty-three and one-half feet above the crest of the dam. The power is transmitted from this pulley by a seven-eighths wire rope.

Across the river, a distance of 650 feet, is the Dittlinger flour mill, whose capacity is 1500 barrels of flour, 1200 barrels of corn meal, and 300 barrels of rye flour per week. It is estimated that the mill utilizes 100-horse power continuously.

At the south end of the Clemens dam a power plant, consisting of one 36-inch Stillwell-Bierce Victor cylinder gate turbine working under a head of eight feet. It is estimated that it develops forty-eight horse powers, thirty of which are utilized in pumping water into the standpipe for the city water supply. The bottom of the standpipe is ninety-five feet above the water surface of lake above dam. The standpipe is fifty-seven feet high and twenty-five feet in diameter. The pumps are run twenty-four hours per day. The turbine is usually operated under a five-eighths opening.

Adolph Ditmer has a plant on the Guadalupe river, five miles below New Braunfels. There is a natural dam of soft calcareous material at this point, with a fall of five feet. The plant consists of a 42-inch Risdon turbine and a duplex Worthington pump of 14-inch piston diameter and 10½-inch stroke. The intake pipe is twelve inches in diameter and about eight feet long; the discharge pipe ten inches in diameter and 750 feet long. The lift is forty-two feet, and it is intended to sell the surplus water pumped to neighbors for irrigation purposes.

Herman Ditmer has a similar plant one mile farther down the river.

He also has a natural dam, but its fall is six feet. His plant consists of an undershot wheel twelve feet in diameter and twelve feet long, and a centrifugal pump with a 4-inch suction pipe and 3-inch discharge. He pumps through eighteen feet of intake and 100 feet of discharge pipe, the lift being thirty-two feet. This plant was built in 1901, and, like the former, will sell water for irrigation purposes.

Below the crossing of the Southern Pacific Railroad, Köehler and Blumberg have utilized a natural fall in the Guadalupe to develop power by use of a 72-inch Leffel turbine. By artificial means the fall has been increased to seven feet. The power is used in operating a gin during the cotton season. At the lowest stages of the river, this fall could easily develop 200-horse powers.

At Seguin there are several water power plants in active operation. At the upper dam where the Guadalupe river passes over a limestone formation, known as Erskine Falls (Fig. 4), it branches, and across one branch (about eighty feet wide) is built a dam of crib work about ten feet high, and that portion of the flow which passes through the branch is utilized in operating a gin. Only one turbine is used, but it is to be torn down to make room for a new cotton factory and more powerful machinery. A rock dam, twelve feet high, is to be constructed across the river proper for the new factory, and from 350- to 400-horse power is expected to be obtained. It is the intention to put in three 50-inch Leffel turbines.

At the lower dam are two water power plants, one at each end. At the south end of the dam is located the electric light power house and a flour mill, owned by Scroell & Sons. The dam is partially a natural formation of irregular section and plan, and was raised one and one-half feet by dumping cemented gravel on the crest. The head obtained is seven and one-half feet, and the turbines used are one 66-inch New Success wheel, which gives 135-horse powers; and one 54-inch Alcott wheel, which gives 40-horse powers. The mill runs sixteen hours per day, and the electric light plant fourteen hours. At the north end of this dam is located the pumping machinery of the Seguin Waterworks Company. The head is, of course, the same as at the south end, viz., seven and one-half feet, and the water wheels consist of one 54-inch Leffel turbine, which generates forty horse power, and one 56-inch turbine, which generates fifty horse power. This latter turbine operates a pump whose capacity is 625,000 gallons per twenty-four hours, and which supplies the town at present. The smaller turbine operates a pump whose capacity is 378,640 gallons per twenty-four hours, and which is used during the summer months only.

At Wimberly, near the Blanco, fifteen miles north of San Marcos, there is a water power plant that runs a gin. It is located on Cypress creek.

The San Marcos river rises in a large spring about one mile northeast of the town of San Marcos. An earth-and-wood-and-stone dam, located about one-fourth mile below the head, backs the water over the springs. The fall at this dam is about twelve feet, and the power is utilized for the city water supply and to run the electric light plant, and for irrigation. The plant is equipped with three 35-inch turbines of the Leffel type. The water is pumped into a reservoir 195 feet above the lake. Two miles below the head springs is located the dam of J. M. Cape. This dam is constructed of frame work and earth, is 130 feet long, with a fall of nine feet. The plant is equipped with two 48-inch Leffel turbines, which under the fall or head develop seventy-eight horse power. One-fourth mile below Cape's gin is located the Thompson gin. The race is one-half mile long, and connects to the pond formed by the Cape dam. The fall at the Thompson gin is fourteen feet, but to guard against the times of low water an auxiliary steam plant of fifty-five horse power has been installed.

About five miles below San Marcos, on the San Marcos river, is located the gin and corn mill of J. C. Jones. The dam is constructed of cedar timber crib work, filled in with stones, gravel, and concrete. It is ninety feet long, seven feet high, and was built in 1896. The power is derived from two turbines, one Leffel-Samson 50-inch diameter, which, with the seven feet head obtained, produces ninety-five horse power; and one Leffel Standard 23-inch wheel, producing six horse power. The power is utilized in operating a cotton gin, corn mill, a small Westinghouse direct-current dynamo of thirty-five light capacity, and two small pumps that are used in supplying water for the irrigation of twenty acres of farm land near the mill site. The total cost of the plant, not including the pumps, is $6000.

About two miles northwest of the town of Martindale, W. S. Smith owns and operates a cotton gin and corn mill on the San Marcos river. His dam consists of a central portion of timber frame-work filled with rocks and gravel, seven feet high and 200 feet long, and constructed by placing alternately pieces of 10x10-inch cypress timber longitudinally and crosswise of the dam and filling in the spaces left between these in the rock and gravel. These timbers are not laid flat upon their squared faces, but are placed upon edge, and are dapped or let in several inches where they cross each other, and are secured by $\frac{3}{4}$-inch bolts that extend completely through the dam from top to bottom. The lowest course in which the timbers lay crossways of the dam rests upon large longitudinal logs and extends four feet beyond the toe of the frame work of the dam proper. Upon this extension are piled stones of all sizes up to the height of the dam, thus forming the down stream face. The top of the frame work slopes backwards and upstream to a slight extent, and is sixteen feet in width, thus making the dam twenty feet wide at the foundation and sixteen feet at the crest—the upstream side where the slope of the top ends being vertical. The ends of this wooden dam join on either side a dam of roughly shaped rock and concrete, the section next the gin and mill being 120 feet long and that on the far side 80 feet, making a total length of dam of 400 feet. This dam was built in 1897, and affords a head of nine feet on the turbines. It is intended to raise the dam several feet, however, in the near future. The power is derived from three turbines: one 40-inch 1893 patent Leffel wheel, which produces sixty-eight horse power under the nine foot head; one 30-inch 1899 patent Leffel wheel, giving forty horse power; and one 18-inch special wheel, giving five and one-half horse power, making a total of 113½-horse power. This is utilized in operating the cotton gin, cornmill, sorghum mill, and a small electric light system. The machinery consists of ten gins, two presses, one cane mill, one sorghum mill, and a 125-volt Westinghouse direct-current dynamo. The total cost of the plant was $25,000.

At the town of Martindale is located the gin and mill of J. W. Teller. The dam is constructed entirely of timber and rock and is similar to the central portion of W. S. Smith's. It is 250 feet long, was built in 1893, and gives an eight foot head. The power is derived from two turbines, one Leffel standard 61-inch wheel and one 35-inch special wheel. The power is utilized in operating a cotton gin, corn mill, sorghum seed thresher, and the electric light and waterworks systems of the town of Martindale. The machinery consists of five Munger gins, one corn mill, one Westinghouse 125-volt direct-current dynamo, one Munger press with Murray elevator, one sorghum seed thresher, and one pump. The total cost of the plant was about $20,000.

Near the town of Staples, on the San Marcos river, Q. J. Lowman is rebuilding a gin and corn mill that was destroyed by fire in October, 1901. He has a dam of timber frame work and rock 140 feet long and nine feet high, which was built in 1899. The original dam was constructed in 1867, but in 1899 it was practically rebuilt and raised several feet higher. The timbers of the old mill were unhurt by the fire and are to be used with the new machinery. They consist of one 66-inch Morgan Smith wheel; which develops eighty-two horse power under the nine foot head obtained; one 42-inch McCormick wheel, giving eighty-two horse power, and one Leffel 26-inch wheel, giving twelve horse power. The power is used at present in operating the waterworks of the town of Staples, but will be utilized for ginning purposes, the operation of a corn mill, and electric lights for the town, upon the completion of the mill. The machinery will consist of eight cotton gins, one 1000-volt alternating-current dynamo of 750 light capacity, a Gould pump with a capacity of seventy-five gallons per minute, and a fifty horse power Atlas engine and boiler; also a corn mill. The total cost of the plant will be $25,000.

At the town of Fentress, C. R. Smith & Co. own and operate a gin and mill on the San Marcos river. The dam is ninety feet long and is built of timber frame work and rock, like that of J. W. Teller's, a few miles above. A wing of timber sheeting two feet higher than the dam joins it to the bank opposite the mill. The dam in its normal condition gives a head of six feet on the turbines, but this can be increased to eight feet by a system of flash boards that are raised above the dam when needed and taken off when they are not required. These flash boards consist merely of 2x4-inch pieces two feet long that are bolted to transverse timbers in the top of the dam (spaced about six feet), and which can be raised or lowered at will. The under sides of these 2x4 pieces are notched, and when raised are propped up by means of sticks in these notches that rest upon the apron of the dam at the toe. Planks 2x12 are then placed against these 2x4 props thus held upright, and raise the water up to the required eight feet. The power is derived from one 66-inch Morgan Smith turbine, which gives thirty-five horse power with a six foot head and fifty-five horse power with an eight foot head. This is utilized in operating a gin, corn mill, and small waterworks and electric light plant. The machinery consists of seven Munger gins, two Meyer's pumps of about 200 gallons capacity, one 115-volt direct-current dynamo, a corn mill, and a fifty horse power Atlas engine and boiler. The engine is required when the mill and gin are run to their full capacity, and is connected directly to the turbine shaft. The entire cost of the plant was about $10,000, and it was built in 1879.

At the town of Prairie Lea is located the gin and corn mill of J. J. Jones. His dam is 120 feet long, eight feet high, and is constructed of timber frame work filled in with stones. It was built in 1896. The power is derived from one 61-inch Alcot turbine, which produces forty-five horse power under the seven foot head obtained. This is utilized in operating a gin, corn mill, and one 110-volt Wiley dynamo. The total cost of the plant was about $2400.

Three and one-half miles north of Luling a dam of timber cribbing, filled with rocks, about 120 feet long, is constructed across the San Marcos river. The power obtained by it is used in operating a saw mill, gin, grist mill, and the Luling electric light plant. A head of about nine feet is obtained and one 50-inch Sampson turbine produces about sixty-seven horse power. The dam was first built about thirty years ago, but has been repaired from time to time, and has, therefore, been practically renewed at least once since then. The foundation is the muddy bed of the river.

Farther down stream and nearer the town is the dam of F. Zedler, which furnishes power for the operation of a cotton gin, grist mill, and the water supply machinery of the town. The dam is about sixty feet long and is constructed of timber cribbing backed with stone and gravel. It is built in the form of two cribs, placed one upon the other, resting on

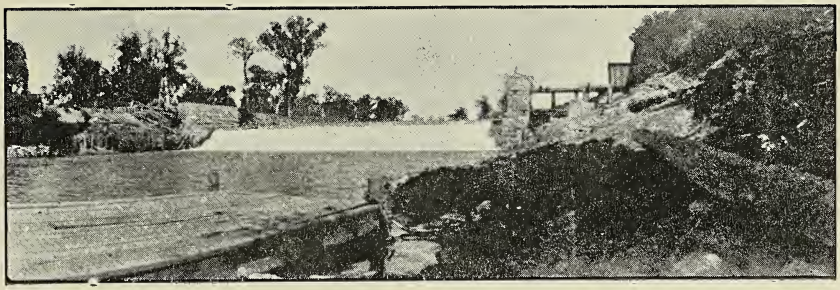


FIGURE 5.
Buchel Dam near Cuero.

FIGURE 6.
Marble Falls on the Colorado.

a foundation of hard sandstone. Two turbines are used to generate the power: one Leffel 66-inch wheel, giving ninety horse power, and one 54-inch Alcot wheel, giving sixty horse power, with an effective head of nine feet.

There is a dam on the same river at Ottine, a few miles below Luling. It is about 100 feet long, constructed of cribbing and stones, and is of an irregular shape. The power is generated by a 72-inch Alcot turbine which, under the seven foot head, produces seventy horse power and is used in running a cotton gin and grist mill.

The San Marcos join the waters of the Guadalupe a short distance above Gonzales, forty-two miles below New Braunfels. At Gonzales a timber and stone dam, 148 feet long, with a fall of nine feet, has been constructed and the power is used in running the gin and grist mill of Smith & Lowery, the electric light plant, and the pump for the waterworks. The dam was built in 1891 and 1892, and the power is developed by two 60-inch, one 72-inch, and one 66-inch turbines. The ordinary minimum flow at this dam is slightly in excess of 450 second-feet, and the capacity of the plant is reliably 400-horse power, with all the feeding streams on their minimum flow.

Forty miles below Gonzales, and three miles north of Cuero, is located the Buchel dam. The dam proper (Fig. 5) is a solid structure out of limestone, weighing 140 pounds per cubic foot; its foundations and fillings being of concrete made from gravel, sand, and cement. In a strata of very tough clay, thirty feet in thickness, a splendid foundation is found; the clay having been penetrated to a depth of five to six feet, here a foundation of concrete is laid twenty-five feet wide; then come courses of stone on the up and down stream side of the river, every course being set back until the low water line, fifteen feet from the base, is reached, where the dam presents a width of twenty-one feet; the middle being filled with layers of concrete. From this line, each layer of stone is set back on the down stream side so that its top, ten feet above the low water line (the coping), is six feet wide; the total length over all being 220 feet. According to surveys made up stream, it is found that from three to four feet may be added in height to this dam without affecting seriously the low bottom lands up stream and subjecting them to more than usual danger or damage by overflows. By doing this an increase of from forty to one hundred per cent. in power can be gained. The dam was begun on the 1st of December, 1896, and was finished on March, 1, 1898. The stone used in the construction of the dam was obtained from the quarries at Van Raub, twenty-six miles northwest of San Antonio. There were used in the construction of the dam and penstocks 129 carloads of limestone; 31 carloads of cement; 5200 cubic yards of gravel and sand; 9 carloads of cypress timber; 370 cypress piles, twenty to thirty feet long; 26 carloads of brick; and two carloads of iron columns and shapes. The abutment to the dam on the west side is in the shape of a T. Next to the east bank are the penstocks of the open type, built of cypress timber. They are of ample size, arranged to accommodate six turbines of sufficient capacity to utilize all the water of this stream, whenever a demand for the power be made. At this writing only two 54-inch vertical turbines of capacity of 163-horse power each, under a ten foot head, are installed. The entire forebay and wheel pits are floored with a layer of concrete twelve inches thick, and the penstocks are held up by twenty-nine cast iron piers and two sets of I beams weighing 360 pounds per yard, all resting on concrete foundations. Upon this bank, which is encircled by a brick wall, backed by piers of concrete, is situated the power house, twenty-eight feet above the crest of the dam. The pumping machinery for irrigating purpose is driven by a shaft seven inches in diameter, making ninety-four revolutions per minute. The power house is eighty feet long by thirty-eight feet wide. One-half of this building, excavated to a level of fifteen feet above the forebay water (about sixteen feet above the crest of dam), is used for a pump room. The pump for irrigating purposes is of the duplex piston type and made by the Laidlow-Dunn-Gordon Company, of Cincinnati, and its capacity is estimated at 3472 gallons per second (463 second-feet) under a normal speed. The suction pipe is twenty inches in diameter, and the discharge eighteen inches. The water is pumped into a reservoir of rectangular shape, with a capacity of 2,000,000 cubic feet, and is about 300 feet from the dam. From the reservoir, two pipes three feet in diameter lead into the irrigating ditches. Various crops have been tried, such as alfalfa, cotton, cabbage, etc., but in 1900 thirty-five acres of rice were tried. About sixty pounds were sowed per acre from April 15th to May 1st. The yield was seven and one-half barrels per acre, and was readily sold for $3.50 per barrel f. o. b. at Cuero. In 1901, the Company sowed 250 acres of Honduras rice and fifty acres in Japan. The cost of raising the rice at this plant will be exceedingly small as no fuel will be used. In addition to the power used for irrigating purposes, the power plant has just closed a contract to supply 225-horse powers to the cotton mill that was erected in 1901.

The flow of the Guadalupe was measured on the crest of the Buchel dam by electric current in March, 1901, when there had been no rains in the watershed for four months, and a flow of 551 second-feet was found.

PLANTS ON THE GUADALUPE RIVER.

Locality.	Owner.	Head in feet.	Material of Dam.
Ingram	John Sherman	9	Natural--wood.
Kerrville	C. Schreiner	10	Wood.
Kerrville	Waterworks	7.5	Wood.
Center Point	W. H. Witt	9	Wood.
Comfort	E. Flach	11	Wood.
New Braunfels	H. Landa	22	Masonry.
New Braunfels	Clemens	8	Masonry.
5 m. below New Braunfels	A. Dittmar	5	Natural.
6 m. below New Braunfels	H. Dittmar	6	Natural.
9.5 m. below New Braunfels	Koehler & Blumberg	7	Natural.
Seguin		10	Crib work.
Seguin	S. Scroell & Son	7.5	Natural.
Seguin	Water Co	7.5	Natural.
Wimberly	Cotton Gin		
San Marcos	W. E. Green	12	Earth—wood.
San Marcos	J. M. Cape	9	Earth—wood.
San Marcos	Thompson	14	Cape dam.
5 m. below	J. C. Jones	7	Wood—stone.
Martindale	W. S. Smith	7	Wood—stone.
Martindale	J. W. Teller	8	Wood—stone.
Staples	Q. J. Lowman	9	Wood—stone.
Fentress	C. R. Smith	6	Wood—stone.
Prairie Lea	J. J. Jones	8	Wood.
Luling		9	Crib work.
Luling	F. Zedler	16	Crib work.
Ottine	F. Zedler	7	Crib work.
Gonzales	Smith-Lowry	9	Crib work.
Cuero	O. Buchel	10	Masonry.

COLORADO RIVER AND TRIBUTARIES.

The drainage area of the Colorado extends (Fig. 7) into the southeast corner of New Mexico, and in its course it is fed by the waters of the Conchos, the Pecan Bayou, the San Saba, the Llano, and the Pedernales. The first use of the water for irrigation or power purposes occurs on the North Concho, in Sterling county, where the McGee Irrigating Company built a dam in 1894. There are ten dams across the Concho in Tom

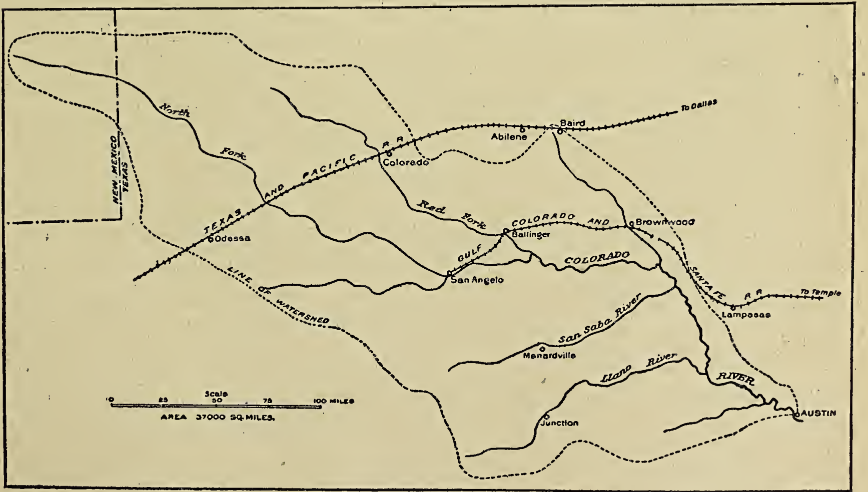


Figure 7.
Watershed of the Colorado River.

Green county, for irrigation purposes, the most elaborate of which is the Cunningham dam, near the site of the old town of Ben Ficklin.

The only two power plants in Tom Green county at present are located on the outfalls of the Baze and Bismarck irrigation ditches. The former belongs to Thos. Vinson, and is one-half mile north of Knickerbocker on the Baze ditch. The water for power purposes is that furnished by the irrigation ditch, which is the feeder both of the irrigation system and the power plant. The head on the turbine is fifteen feet, and the length of tail race from the gin to the creek is 1000 yards. It is estimated that fifteen horse powers are developed by the 24-inch turbine, and this is used in operating the 70-saw gin. The cost of the whole power plant was $1400.

Ten miles south of San Angelo, on the Bismarck ditch that takes its waters from the South Concho, is located the power plant of Payne & Jones, which operates the Bismarck gin. The dam on the river that deflects the water to the ditch is four feet high and is built of cedar timber, brush and stone. At the gin on the ditch there is a fall of eighteen feet, but the turbine is an old-fashioned one and its efficiency is estimated at about thirty per cent. The plant is run ten hours per day during the ginning season.

Near San Angelo on the main Concho a dam is being erected by the Concho Water Company, of which J. L. Millspaugh is manager. The dam is to be a combination of steel and stone, securely bolted to the rock bed of the river. The main part across the river proper is to consist of a steel frame work, which is to extend into the stone abutments. The length of the spillway is to be 166.5 feet, and its height eleven feet, while the height of the massive stone abutments is to be eighteen feet. The dam deflects the water into a canal 800 feet long, fifteen feet bottom width, twenty-five feet top width, and an average depth of seven feet. A head of seventeen feet will be obtained at the power house at the lower end of the canal. The power generated is to be utilized in operating the waterworks, pumps, dynamos, and for irrigation purposes. The surplus power will be sold to power users in San Angelo.

Across the Concho river, at Paint Rock, the county site of Concho county, thirty miles below San Angelo, a dam four feet high and 180 feet long has been constructed of stone and lumber. The dam belongs to J. F. Ford & Son, was built in 1896, and the power is used to operate the city waterworks, a mill and gin. The wheel is an undershort paddle wheel sixteen feet in diameter, and in addition to operating the gin, it pumps water into a reservoir forty-two feet above the town level. The water supply here is unfailing and is amply sufficient for all demands.

About eleven miles from Goldthwaite, in Mills county, J. D. Willis (postoffice, Ratler) has constructed a dam of logs, rock and gravel, four feet high, across the Colorado river. The power developed is used in operating a mill, gin and irrigation plant. The water wheel is four and one-half feet in diameter, and develops fifteen horse power. Five acres in peaches, grapes and garden can be irrigated.

The San Saba is at present almost undeveloped as a water power stream. Its capabilities for power or irrigation rank with the best rivers of the State. Its reliable flow from Fort McKavat to its mouth marks it as as stream of great usefulness. The great irrigation system at Menardville has been described. In addition to this, there is located four miles east of Menardville on the main ditch the water power gin of Gus Noyes, where a fall of twenty-three and one-half feet is obtained. The energy is developed by a 23-inch Leffel turbine and is used in operating a gin of 150 saws and for a corn sheller. The whole flow of the ditch is used for power after the irrigation season is over. Forty-two horse powers can be developed by a flow of twenty cubic feet per second.

On Mill creek that skirts the town of San Saba there are two dams. This creek is supplied by four springs of constant flow. Their combined flow, as measured on December 18, 1901, was ten cubic feet per second. The dam is built of masonry, fifteen feet high and four feet wide at top. The dam proper is ninety feet long, the right wing sixty feet long, the left 160. The original dam was built about 1856, but it has been repaired several times since its erection. A fall of twenty feet could easily be secured here. The plant is used for the water supply system of the town. The spring from which the water is pumped has a flow of three second-feet, and it is located in the backwater or pond. To prevent contamination, the spring is encased in a cement chamber which is tapped by the 8-inch suction pipe.

On the San Saba, eight miles above San Saba near Bakers, the river makes a horseshoe bend, across the neck of which is a slough. By replacing the present dam with one twenty feet high a fall nearly double that amount could be secured. The present plant is on the banks of the slough, above high water mark. The original dam was damaged by the floods of 1899, but it has been renewed by a brush dam. The present plant develops about thirty horse power by the use of a 26½-inch and a 33½-inch turbine.

In Mills county, about eleven miles west of Lometa, just below the junction of the San Saba and Colorado, Milam Chadwick owns and operates a power plant on the Colorado river. The dam was built in 1879, out of stone and cedar logs, is 196 feet long and gives a clear fall or head of five feet. The dam is curved up stream and has on its crest a course of burr oak logs to which cedar brush is spiked and bolted. The power is developed by a 36-inch Leffel turbine with a vent of 5850 square inches, and is usually run one-half open. The mill house is located high upon the bank out of reach of high water, and the power is transmitted from the turbine shaft to the mill house by a wire rope. The river here has a reliable flow and the power is used for running a flour and corn mill and cotton gin. The demands of the neighborhood are met by operating the plant one and one-half hours per day.

At Bluffton, sixty miles above Austin and twelve miles above Kingsland, a dam 400 feet long was constructed in 1898. It is built of logs, and the power developed is used in operating the gin and grist mill of the Tanner Bros. There is a natural fall here of eight feet and the dam raises the water an additional foot, giving an effective fall of nine feet. The dam cost only $125, and was constructed to fit the configuration of the cross-section of the river bed. At deep places planks were used as a face. A 27-inch double discharge turbine is used to develop the power. The water is conveyed from the lake formed by the dam to the turbine by a mill race 2400 feet long, ten to twelve feet wide, with a depth at the dam of one foot, increasing to eight feet at the wheel.

At Kingsland, on the Llano branch of the Houston & Texas Central Railroad, a dam, owned by J. M. McDaniel & Co., has been constructed across the Colorado river about one mile from its junction with the Llano. The dam was built in 1896, is 500 feet long, has a fall of five and one-half feet, and backs the water for three miles up the river. A frame work of live oak braces covered with 3-inch pine lumber constitutes the dam, and it has withstood successfully several floods—notably those of June, 1899, and April, 1900. The power is developed by a 35-inch turbine, and at low stages of the river twenty-five horse powers are generated which is utilized in running a gin and mill.

J. K. Finlay, of Llano, owns and operates two natural power plants on the Llano river, eight and one and one-half miles, respectively, above Llano. At the upper dam there is a natural fall of twelve feet, the few cracks and crevices being planked. At the very lowest stages of the river this dam with a reasonably good turbine can develop seventy-six horse power. At the lower dam there is a fall of eight feet, and the plant is equipped with two 30-inch turbines. The lowest flow can develop fifty horse power. At present only twenty horse powers are used in ginning cotton, grinding corn, and in polishing granite. A small outlay in constructing dams upon the top of these ledges could easily double the power. At Llano all the factors that enter into a successful water power plant are present in their very best varieties. The river bed is formed of continuous granite, which in the central two-thirds rises in a turtle-back formation, the visible portion extending over 300 feet below and 200 feet above the dam. This leaves two channels on each side approximately 150 and 100 feet wide, the bottom of which are some ten feet below the crest of the turtle back formation. The first essential of a good water power, a foundation for the dam, is here in the very highest perfection. The very best rock in a rough, irregular surface, with projections and depressions, extends from bank to bank. The central half could be constructed as easily as it could be done on banks, and then the two depressions near each bank would afford alternate gateways through which the water could be played from side to side while the work of construction was progressing. In addition to this, Llano is the very heart of the best granite region in the world, and good building granite could be obtained within one mile of the dam site. Thus a good foundation, ease of construction and convenient stone all unite in inviting the increase of the water power of the river. The flow here at the very low stages is about seventy-six cubic feet per second and a dam with an effective head of twenty-four feet could be easily constructed, thus developing at the very lowest stages 168-horse power, and 200-horse power at ordinary low flow. By a judicious use of flash boards on the crest of the dam, and by utilizing the power only ten hours per day, and conserving it at night and on Sundays, the very lowest power could be increased to 475-horse power. To produce this power by means of the McAlester bituminous coal would require ten pounds of coal every minute, or seven tons per day—about twenty-five cents for each horse power. At ordinary prices this would cost $35 per day, $13,000 per year. There seems to be no doubt but what the granite industry at Llano will soon be one of the biggest in the country, and power will be needed at various quarries for shaping and polishing. This power will have to be developed by fuel or water. The cheapest coal fuel, as the results of the Rapid Transit Railway of Austin have so far shown, is the Rockdale lignite, which costs about forty-eight per cent. of the McAlester coal. The Beaumont oil saves about sixty per cent. of the money formerly spent for good bituminous coal. To produce the 475-horse powers would cost about $5200 per year.

The most elaborate and scientific experiments to determine the value of Beaumont oil as a fuel were made by Prof. J. E. Denton, of Stevens Institute of Technology, from November 27 to December 13, 1901. These results were published in the *Engineering News* of January 30, 1902. We abstract the following:

"Specific gravity of oil, .920.
Weight of oil per gallon, 7.66 pounds.
Flash point, 142° F.
Burning point, 181° F.
Weight of barrel of oil, 322 pounds.
Gallons in barrel, 42.
Calorific value per pound, 19,060 B. T. U.

The net evaporation ranged from 14.74 to 15.16 pounds of water per pound of oil. Consequently for the two higher horse powers the net evaporation of 14.80 pounds of water per pound of oil may be considered to represent the best economy that is to be expected from the use of oil as a fuel with steam jet burners.

The boiler utilized about seventy-eight per cent. of the heat of the fuel, which represents the best average boiler practice, and the percentage of steam consumed by the burners is a minimum for steam jet burners.

The evaporation from and at 212° F. per pound of buckwheat coal (anthracite) was 9.17 and 8.94 pounds of water (for the 93 and 119-horse power boilers). The coal afforded 11.6 per cent of ash and 14,680 B. T. U. for pound of combustible when burned in oxygen in a calorimeter.

Ratio of oil to coal=15.1÷9.17=1.66.

Number of barrels of oil equivalent to 2240 pounds of anthracite coal, 4.23.

For producing horse power upon the commonly guaranteed basis of one horse power to ten square feet of heating surface and with an average percentage of moisture and ash in the coal:

Evaporation per pound of wet coal, 8.75 pounds.

Net evaporation per pound of oil from and at 212° F., 14.80.

Ratio of oil to coal=14.8÷8.75=1.69.

Number of barrels of oil equivalent to 2240 pounds of coal, 4.12.

In comparison with the bituminous coals mined west of Ohio and used in southwestern States the results are as follows:

Pounds evaporation per pound of wet coal, 7.5.

Pounds evaporation per pound of Beaumont oil, 14.8.

Ratio 14.8÷7.5=1.97.

Three and fifty-four hundredths barrels of oil are equivalent to 2240 pounds of coal."

The McAlester coal used in Texas is about equal to the bituminous coal referred to above. At present the Beaumont oil is sold to the city of Austin at fifty cents per barrel, delivered, while McAlester coal costs wholesale about $5.00 per ton. The three and one-half barrels of oil can be obtained for $1.75 against $5.00 for an equivalent amount of coal.

A small dam has been utilizing the power of the Llano river at Llano for several years. The two channels on each side of the turtle-back formation are dammed by wooden structures. The frame work consists of a triangular brace of cedar posts bolted into the granite, and on these longitudinal purlins are spiked, forming a base for the facing plank. The wooden part on the south side is about 150 feet, while that on the north is about 100 feet. The general course of that part of the dam that covers the south channel and the granite hump is at right angles to the axis of the river, but the northern end deflects about forty degrees to butt the end of the dam into a granite ledge. The total length of the dam is about 600 feet, and at the power house on the right (south) bank is a head of nine feet. The present power is developed by two Leffel turbines forty and forty-four inches in diamter. The plant supplies the city water system, the electric light system, a polishing plant, and will soon

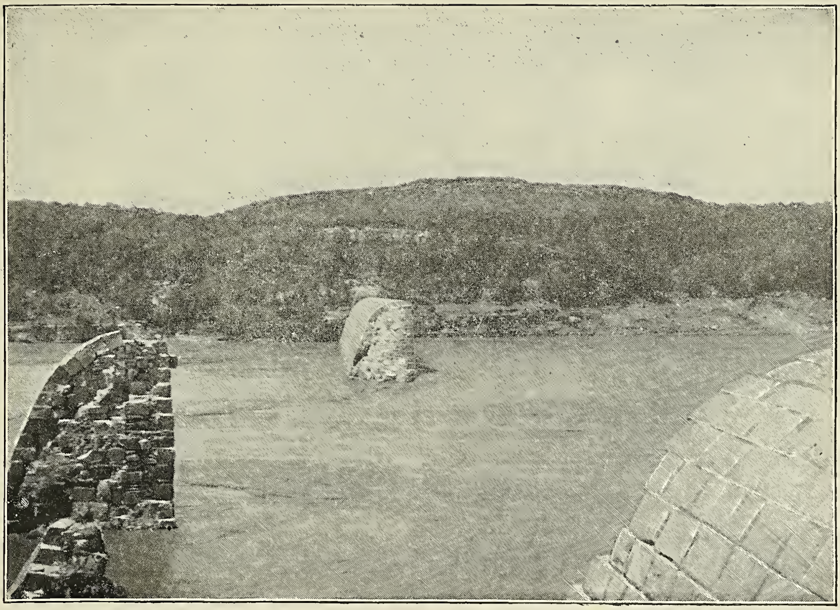


FIGURE 10.
Broken Dam from East End.

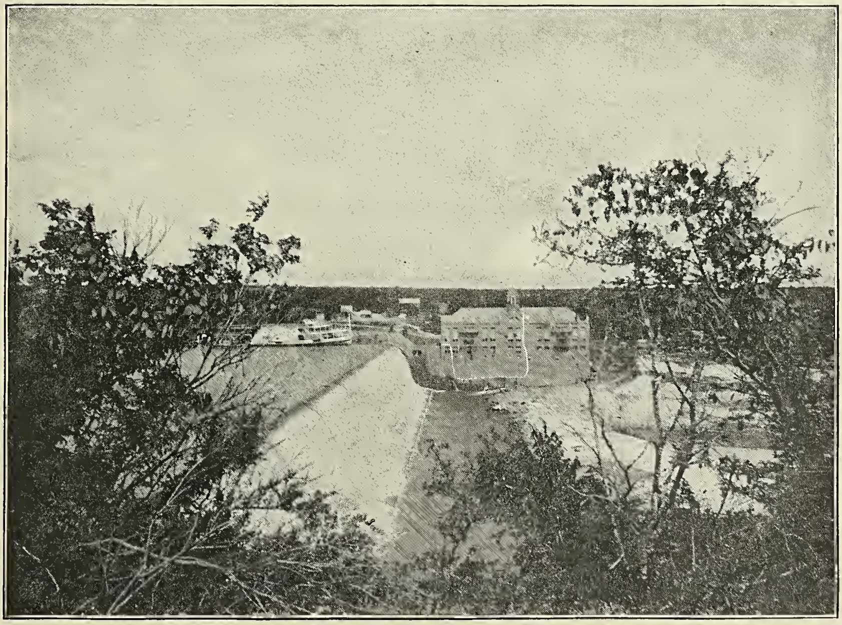


FIGURE 11.
Power House and Dam from West.

run the Llano Milling Company's plant. The city water is pumped into an elevated standpipe the bottom of which is fifty-six feet from the ground and forty-four feet above the low water level in the tail race and thirty-five feet above the ordinary lake level. The capacity of the tank is 30,000 gallons and the pumps are run all day. When pipes and tanks are full, the safety valve is so adjusted that the water wastes through an automatic valve. The power will be conveyed to the flour mill by a cable from the power house. The motor for the polishing plant is operated by a direct current, while that of the electric light is an alternating current. As a precaution against breakdowns and low water, an auxiliary steam plant is provided, which consists of a fifty horse power engine and fifty-five horse power boiler, but these have not been used since July, 1899, when the exceedingly low water stages of the Llano and Colorado almost stopped the turbines at the Austin dam, the water level in Lake McDonald sinking to ten feet below the crest of the dam.

At Marble Falls occurs the most remarkable natural dam (Fig. 6) along the course of the river. The formation of limestone rocks has constructed a dam where a fall of twenty-two feet has been utilized to pump the water supply for the city. The minimum flow found in recent years was 197 second-feet, which could develop 375-horse power if all of the flow were used. Below the power house, the water flows over a rough formation and in about a mile has a fall of about sixty feet. A grand water power of 1000-horse powers capacity could be inaugurated at this place, the only expense would be in constructing a mill race and erecting the power plant. There will certainly be a big demand for the power in the future. Granite mountain is only two miles away, and is right along the tracks of the railway. By combining the water power and the granite industry, a corporation could command the best and the most economical manufactured output. Marble Falls offers greater possibilities for water power than any other point in Texas.

In May, 1890, the city of Austin determined by a vote of its people to construct a massive dam across the Colorado river near the city, and to expend $1,600,000 on the enterprise. It was estimated than 14,000-horse power could be developed, and all the elements of a boom took a firm grip on the town. No hydrographic data had been collected except the hazy memory of the oldest inhabitants, and in the spring of 1890 a measurement of the flow of 1000 cubic feet per second was taken as the minimum. This proved to be one of the saddest disappointments of the whole enterprise, the greatest being the failure of the dam on April 7, 1900.

The dam was built above Austin, at a point where the deep cut or canyon, which the river has worn in the limestone rock, is about 1150 feet wide. The cross-section of the channel is not far from level on the bottom, and is bounded by nearly perpendicular walls of rock rising to the height of a little over sixty feet on the city side of the river and 125 or more on the other side. The spillway was 1091 feet long between the bulkheads at each end, which extended to the natural rock. The upper face of the dam was vertical and sixty feet high, measured from an assumed low water. The down stream face was a reverse curve of ogee form, which, at the toe of the dam, was horizontal. The width of the dam at the base was sixty-six feet. The rotten and loose rock excavation over the area covered by the dam was comparatively slight, being only a few feet in depth. It was designed to have two trenches, about four feet wide and somewhat greater depth, extending lengthwise along the upper and lower edges of the dam and filled with masonry to increase frictional resistance. The total exposed surface of the dam was constructed of squared granite and the interior of limestone rubble masonry, Portland cement being used throughout. As was afterwards proved, this granite facing was not sufficiently tied into the interior rubble, as in its case of great trial it acted like a coating of veneering.

The original cross-section of the dam, as recommended by Mr. Frizell, is shown in Fig. 8 (left half). The cross-section as adopted (Fig. 8—right half) was recommended by Mr. Fanning, who in his report to the Board of Public Works said:

"The profile (Fig. 8, left half) as shown to me seems not to fulfill the required conditions for passing the floods, because of the slightly rounded or nearly angular form at the front of its crest. Another diagram (Fig. 8, right half) presented shows an advised modification of the profile of the upper part of the dam, which is better adapted to pass the flood in a gliding sheet down the face of the dam and to deliver it to the lower level without a direct blow, and so that its velocity will be expended chiefly in

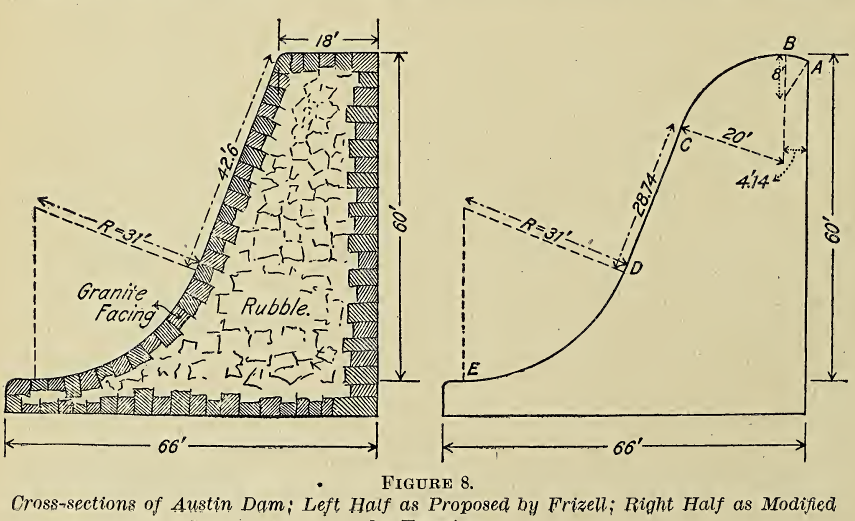


FIGURE 8.
Cross-sections of Austin Dam; Left Half as Proposed by Frizell; Right Half as Modified by Fanning.

a horizontal direction in the backwater below the dam and in eddies at a safer distance below the toe of the dam. The lower part of the down-stream face of the dam has a curve of thirty-one feet radius to which low water surface is tangent. The central part of this face has a batter of four and one-half inches to the foot.

"The new profile at the top part, as suggested, completes the down-stream face and crest of the dam with a curve of twenty feet radius, to which both the front batter and the surface of the pond at a level of the crest are both tangent, this curve ending on the crest at five feet from the upper angle of the crest. The upper angle of the crest is then rounded off with a smaller curve, and the entire front of the dam becomes a reverse curve of ogee form, the form of dam best of all adapted to pass a large volume of water through so great a height. The top curve conforms nearly to the theoretical form of a medium flood stream. At higher flood stages there will be tendency to vacuum under the curve stream immediately after it has passed the crest, which, together with the pressure of the atmosphere upon the top of the stream, will keep the full flood stream in full contact with the curved face of the dam, and cause even the highest flood to glide down the fall without shock upon the face of the dam or the soft rock foundation."

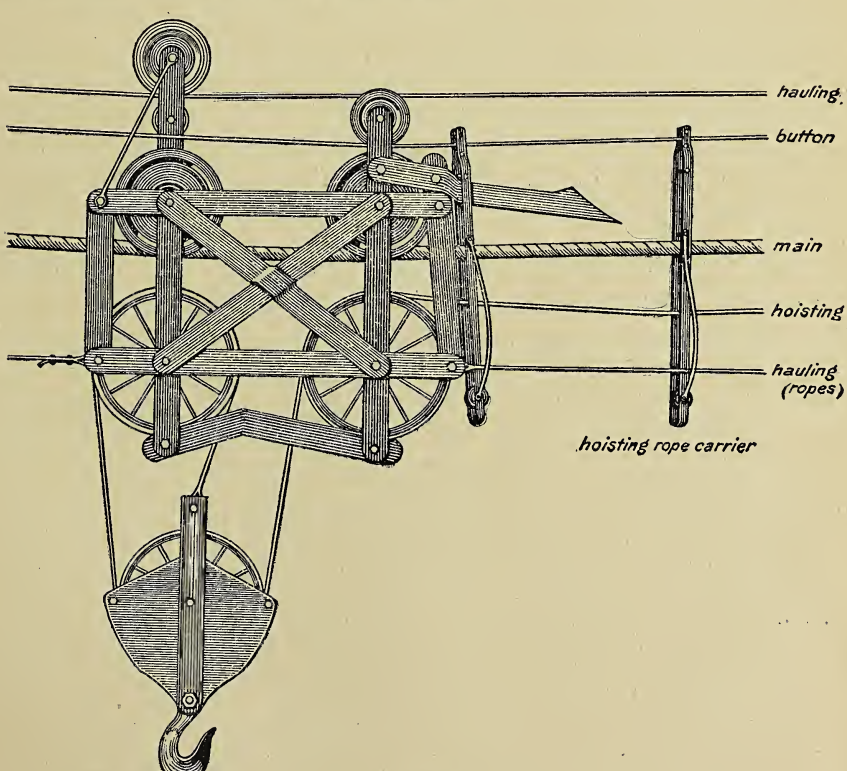


FIGURE 9.
Saddle Used in Construction of Austin Dam.

The best modern appliances were used in the construction of the dam. The granite material for the facing was obtained from Granite Mountain, near Marble Falls, being hauled from the quarry to the dam over the Austin & Northwestern Railway, a distance of seventy miles, and delivered at the east end of the dam. The granite blocks were of average dimensions and weighed four tons each. The four classes of material used—i. e., the limestone rubble, the cement, the sand, and the granite—were transported from the end of the dam to place by a cable two and one-half inches in diameter, stretched between two towers—one on the east and the other on the west bluff—1350 feet apart. The cable was anchored to "dead men" at the ends, weighted down by stone. The saddle shown in Fig. 9 was especially designed for this work, and ran on the main cable. The wire ropes were known as the "hauling rope," the "hoisting rope," and the "button rope." The hauling rope was attached to the lower part of the frame work of the saddle, passed over pulleys at both towers, and wound around a drum under the east tower. The endless hauling rope was operated by an engine to which its drum was attached. It was completely under the control of the operator, and could be stopped in any position along its course. After being checked in the position desired, the drum operating the hoisting rope was brought into motion and the load was lowered to the dam.

The granite blocks and the larger limestone rubble stones were handled by immense tong-like grips. The cement and sand were loaded into cages, transported to the place of construction, and there dumped on the dam. The cement mortar was made at the place where it was to be used, and the blocks of masonry were placed where needed by crane derricks.

A wire rope one-half inch in diameter was used in connection with the cable and saddle to prevent excessive vibration of the operating ropes. On this rope there were buttons which increased in size from the tower to the west. The hoisting rope was supported at different points by carriers which rested, when the saddle was stationary, on the main cable. This carrier consisted essentially of two parallel bars, between which and near the lower end a small pulley was supported to carry the hoisting rope. A series of slots were arranged in the upper part of the carriers through which some of the buttons could pass. When near the east tower the saddle supported all of the carriers on a horn. In moving from the tower to the west, the smaller button passed through all of the carriers except the last, which it took off the horn; the second button passed through all of the remaining slots except that in the second carrier, which it pulled off the horn; etc. The carriers were thus stripped off the horn by the buttons and rested on the main cable, affording a groove or support for the hoisting rope and reducing its vibration.

Not only was there a lack of hydrographic knowledge, but the location of the dam was ill-chosen. Under the dam, near its eastern end, a geologic fault was encountered. This, as stated by Mr. Groves, engineer in charge for part of the time, was seventy-five feet wide and the material filling it was clay with an occasional boulder. Joseph P. Frizell, the chief engineer in the early stages of the dam, states that at a point 300 to 400 feet from the east end of the dam, a very friable condition of limestone existed, and in 1896, in a letter to the mayor, he warned the authorities about this dangerous point, and suggested some supplemental work of protection. It is highly probable that the dam would have been standing today if this work had been executed.

The minimum flow of the river was overestimated about five times. Measurements taken by the writer in March, 1899, and since, indicate that the flow was less than 200 second-feet at low stages against an assumed 1000 second-feet. The flow at Marble Falls, seventy miles above the dam, was 197 second-feet, and that at the head of the lake a day or so later, no rain having fallen in the meantime, was 210 second-feet. Records of the depth of water on crest of the dam were kept from September 1, 1895, to January 1, 1900. The maximum and average depths of water on the crest of the dam as given by the gauge were as follows:

Year.	Maximum Depth.	Average Gauge Depth.
1896	2.60 feet	.496 feet.
1897	2.20 feet	.422 feet.
1898	4.20 feet	.280 feet.
1899	9.80 feet	.412 feet.
	Average	.408 feet.

On account of the inequalities of the crest line of the dam all depths must be increased by .009 feet to get an average for the whole spillway of 1091 feet.

Experiments with an electric current meter were made during January and March of 1900 to determine the coefficient C in the weir formula:

$$Q=CL\ H^{\frac{3}{2}}.$$

The results indicate that for the Austin dam C was nearly 3.09, the theoretical coefficient used by Frizell. Substituting this value of C and the length of 1091, we get

$$Q=3,371\ H^{\frac{3}{2}}.$$

The average flow through the penstocks for the four years was about 250 second-feet. The following table shows the maximum and average daily discharge in second-feet, including the flow through penstocks.

Year.	Gauge Heights.		Discharge in Second-feet.		
	Maximum.	Average.	Maximum.	Minimum.	Average.
1896	2.61 feet	.505 feet.	14,100	....	1,460
1897	2.21 feet	.731 feet.	11,000	200	1,200
1898	4.21 feet	.326 feet.	29,000	210	1,880
1899	6.81 feet	.421 feet.	103,400	....	1,170

The average depth on the crest for the four years was .417. Making H=.417 in the weir formula we get Q=910. Adding to this the flow through the penstocks, we have as the average flow for the four years 1160 second-feet. This, with the conditions prevailing at the Austin dam, would have given if it had all been used 6264-horse power. Thus, the average flow would not have produced half the power the minimum flow was supposed to produce.

The Austin dam failed on April 7, 1900. Upon the present condition of the foundation of that part of the dam that was broken out hinges the proper interpretation of the cause of its failure. So important was this special feature that the writer made an elaborate set of soundings in the latter part of 1900 in that part of the broken section through which at present the water flows. Four lines of soundings (marked x, y, z, and T) were made, parallel to and at distance of 0, 16.5, 42, and 60 feet from the upper face. The result is shown in the following table:

SOUNDINGS AT SITE OF WRECKED PORTION OF DAM, DECEMBER, 1900.

Distance.	Depths Below Top of Toe.			
	Line x.	Line y.	Line z.	Line T.
600	13.0			
550	9.5 feet	9.1 feet	10.1 feet	12 feet.
500	10.9 feet	11.8 feet	11.9 feet	14 feet.
450	12.6 (S)	12.9 feet	12.6 feet	14 feet.
400	11.6 feet	11.6 feet	12.2 feet	15 feet.
350	8.1 feet	8.9 feet	9.6 (S)	15 feet.

Distance were measured from east bulkhead.

All these soundings were to solid rock except those marked (s).

If we remember that the height of the top of the toe of the dam above the rock bed of the river was, on an average, six feet, and that the foundation was not (with the exception of the trenches) over eight feet below "low water," a glance at the above table will convince any one that there is no part of the foundation in the western 300 feet of the broken section remaining. From the present ordinary eastern water edge a large sand bank extends to the end of the eastern standing section, which covers 140 feet of the former bed of the dam. Soundings were not made through this sand bank, but the crest of the big section of the dam carried down stream, but still standing, is on an average only four feet lower than the crest of the standing dam, which indicates very clearly that its foundation went with it, as it is resting practically in the old tail race, whose bed was lower than the bottom of the dam.

In all seventy-four soundings were made, and sixty-seven of these show that the depth of present rock is over eight feet below "low water," and at the other seven soundings, the rod could not be driven through the sand, mud, or gravel, to solid rock. At no place was any solid rock encountered as near as eight feet to the "low water" mark in the area of soundings, which covered a space of 18,000 square feet.

The condition of the foundation, the detached standing section (BD, Fig. 12), and the condition and position of the other broken section that occupied the gap and which disappeared soon after the break, all preclude the theory that the dam broke at the level where it was thirty-one feet in thickness. This level was twenty-five feet above "low water" and thirty-five feet below the crest. If it broke on this level, then there was a section only thirty-five feet high that broke off and moved back. The broken sections moved down the stream about sixty to seventy feet, and rested

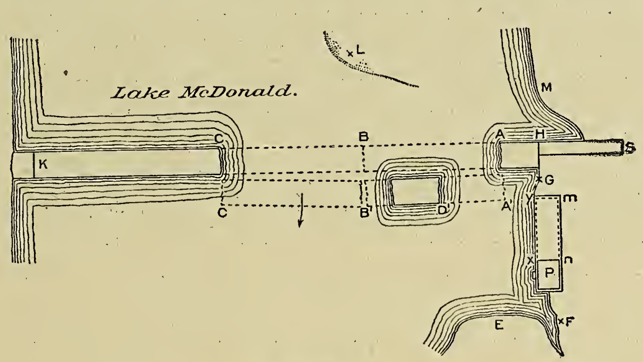


FIGURE 12.
Plan of Dam and Power House.

in a position practically parallel to the original positions, and in the tail race of the dam, the bottom of which was lower than the foundation of the dam. If the dam had broken at the level of thirty-five feet above "low water," then, when the upper thirty-five feet of the dam moved off, three things would have occurred: (1) The upper part would have turned over as it slid off of the lower part, which it did not do. This is shown by the section BD, still standing (Fig. 10), and by the other section that was carried bodily down stream, and which remained upright forty minutes after the first break. (2) When the 35-foot section moved down stream, if by any miraculous intervention it could have slid off, then fallen a distance of thirty feet, and landed in the tail race in an upright position, its crest would have been thirty feet below the crest of the standing portion. All this is disproved by the facts. The crest of the standing section (Fig. 10) is only four feet (instead of thirty) lower than the original crest, and that of the portion which stood for a while was as high or higher than the original crest. (3) The crest of the standing section is now fifty-three feet above ordinary flow, where it would have been only about twenty-two if the dam had broken at the 25-foot level above low water. (4) That section of the dam carried down stream and still standing can be examined and the 25-foot level will be found actually intact. The position of these sections, horizontal and upright, indicate that the cause of failure was a sliding out bodily on its base of that portion that failed.

On account of the immense importance of the Austin dam as an engineering structure—it being the largest in the world across a flowing stream—the writer here submits the opinion of some of the engineers who were connected with it from time to time.

Mr. Frizell has said that the location at Mormon Falls, two miles above the chosen site, presented points of decided superiority over the locality selected, but the Board of Public Works thought that location inconsistent with the purposes of the improvement. Mr. Frizell does not consider that the solubility of the rock had any bearing on the failure, and sees no reason to doubt that the immediate cause was the undermining on the down stream side, caused by the abrasive action of the current and the constant stream of water coming from the power house and flowing along the toe of the dam, on its way to the open channel of the river. A progressive weakening is attested by the fact that during the preceding year the dam had withstood a flood substantially as great as the one in which it failed. The toe of the dam, which was left without support by the undermining, contained granite blocks of more than six tons weight.

"It is on record that the breaking down of this unsupported toe was imminent, in which event each of these stones would become a mill-stone (propelled in such a flood by some two thousand horse power) in the work of grinding the friable rock bottom and extending the undermining. At the wooden dam across Connecticut river, at Holyoke, Massachusetts, an action of this kind became threatening in 1866. A pit twenty feet deep had formed on the down stream side of the dam. This danger was met by the construction of a massive apron of crib-work filled with stone, which prolonged the duration of the structure more than thirty years, or until the construction of the present stone dam. At Austin the engineer had in contemplation from the beginning an analagous work, namely, an extension of the massive apron by a bed of concrete, to be applied as soon as the abrasive action had made sufficient progress to indicate the character and extent of the work required for its suppression."

N. Werenskiold, one of the engineers of construction, in a letter to a friend in the latter part of 1900, said:

"There can be no doubt that the failure was not caused by any defective work in the dam itself, but by the entire body being pushed down stream and broken from the lateral pressure on account of too small frictional resistance under the dam. It is also proven conclusively that this resistance against sliding had been materially diminished by erosion below the toe of the dam, and to that extent the failure is chargeable to lack of care in maintenance.

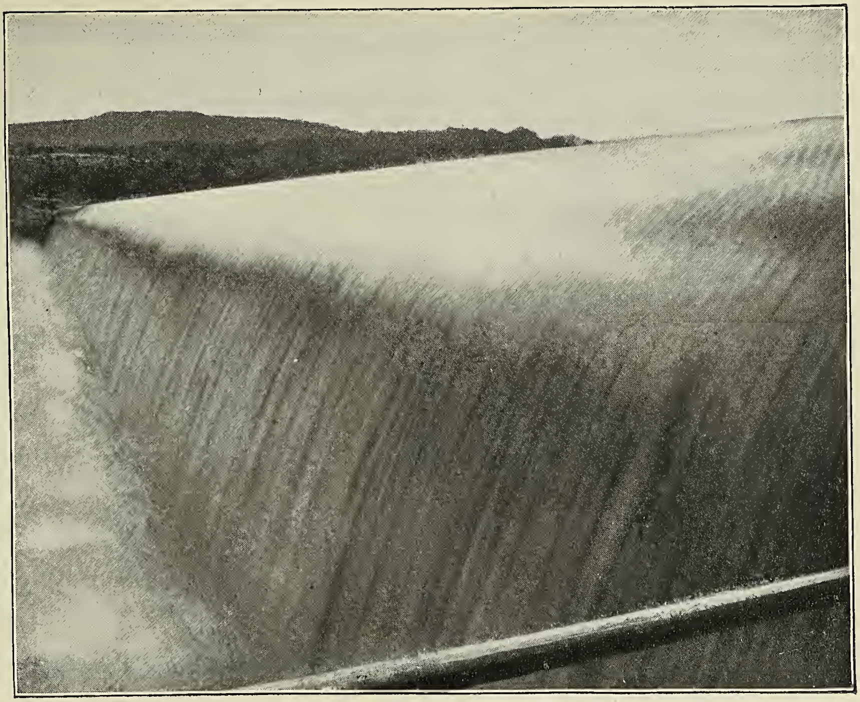


FIGURE 14.
Flood over Dam, June, 1899.

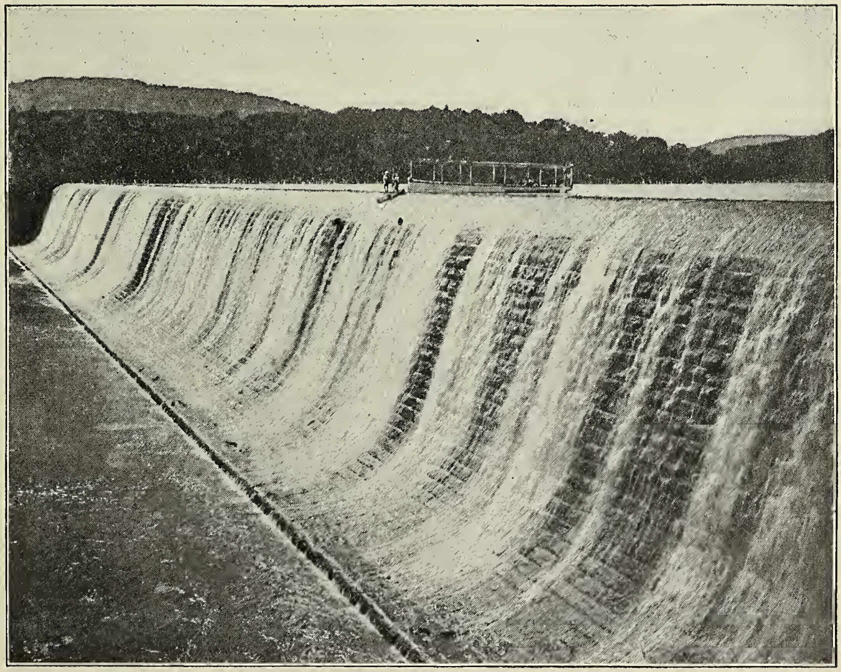


FIGURE 15.
Austin Dam from the West.

"I have no doubt but that all the masonry went, or slid, and I am inclined to the belief that some of the rock ledges underneath went with it. I think it possible that the foundation might have been good enough for a dam without overfall; but it proved not to be good enough for this bold structure. I think it probable also that vibrations of the dam, caused by the fall of the water, may have had a very detrimental effect on the underlying foundation and also increased the lateral pressure of the silt and earth against the dam far beyond the generally assumed water pressure, until this lateral pressure overcame the combined bending resistance of the dam proper, together with the frictional resistance under the base.

"As early as in May, 1893, in reply to a direct question from one of the leading members of the board, I stated that the foundation under the east end of the dam was not what it should be; that it was hard to say whether it was safe or not, but that I thought that the dirt filling against the dam on the waterside would prevent undermining and save the structure. I also suggested the necessity of close watching below the dam.

"On May 7, 1894, when replying to a letter from another of the leading members of the board, I suggested that they make borings below the dam for the purpose of ascertaining the necessity of taking some precautions for the safety of the dam, stating that there might or there might not be immediate necessity for so doing, but that I believed it would prove necessary in the course of time. In another part of the same letter I suggested concrete or paving in front of the power house. From this you will know they were not without friendly warnings.

"But in spite of all this I cannot say that the works were designed and built with due safety or precautions, or that to my knowledge proper borings and examinations of the underlying formations were ever made."

Mr. J. T. Fanning remarks:

"The theoretical stability of the masonry of the dam in its normal condition, as completed in 1893, was sufficient to resist a much greater volume of flood flow than the flood at the time of the break. The structure substantiates this view in the fact that the westerly part of the dam, nearly one-half its length, resisted the force that broke out a mid-section. It is evident that there was a large surplus of resistance, both as to sliding and overturning in the remaining part of the structure, as, otherwise, the moving sections would have pulled with them those portions of the dam now standing erect in place.

"*Undercutting*.—That there was undercutting of the toe of the dam at a point where the dam first yielded is attested by soundings made before the sliding of a portion of the dam.

"A writer in public print has attributed this undercutting in large part to the flowing of the tail water from the water wheels in the power house along the toe of the dam toward the channel, as shown in Fig. 11. This theory is not sustained by the facts.

"This dam was built on the rock bed of an ancient channel of a great river. Both ancient shores are of rock and nearly vertical to the height of the dam. When the dam was constructed the modern river occupied less than half the ancient river channel, and the remainder of the channel, covering somewhat more than its easterly half, was occupied by an alluvial deposit forty to sixty feet in depth. A narrow cut was made through this deposit to the east shore for placing the foundations of the dam in that part of the ancient channel. The tail water from the power house flowed out through this cut on bed rock to the modern west channel, as shown in Fig. 11, and had the toe of the dam for its right shore and the earth deposit for the other shore.

"In examining the theory of the bed rock cutting by the tail water alone we observe that the quantity of tail water flow was ordinarily about 250 cubic feet per second, and in the narrowest part of the channel had a velocity of about two feet per second. In the wide section of this channel, at point of scour, the tail water alone had a mean velocity less than three-tenths feet per second. The theory of scour and undercutting of the rock by the tail water flowing at these low velocities is absurdly erroneous.

"The undercutting was probably not done by the scour of extreme floods. It was anticipated that the cutting by floods would be at a distance from the toe of the dam. Figure 11 shows that floods passed over a space in front of the toe of the dam and did their cutting of the alluvial deposit below the line of the lower end of the power house, about 200 feet from the toe of the dam.

"When a flood glides down any sloping face on the lower side of a dam its current is discharged in solid stream under the back water below the

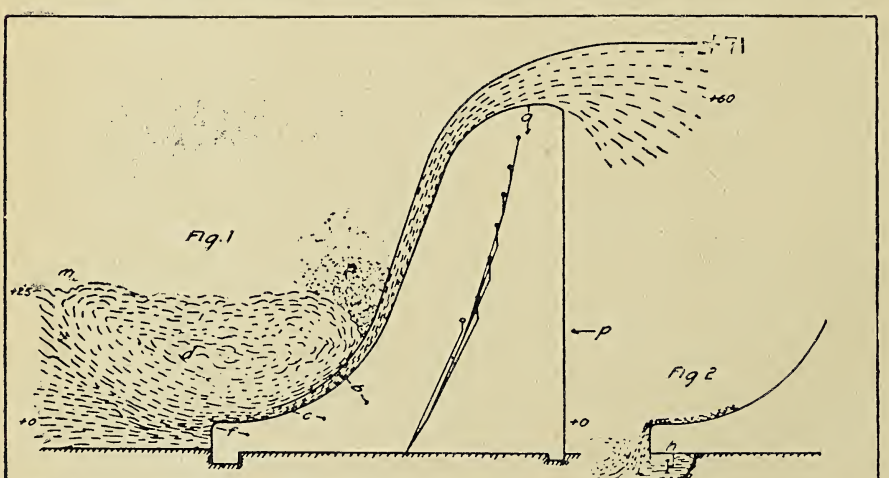


FIGURE 13.
Fanning's Illustration of Flow Over Dam (Plate 1).

dam somewhat as shown in Plate 1 (Fig. 1) [Plate 1 refers to Fig. 13]. When logs pass over a sloping dam with the flood they first appear at the surface of the ebulition at some distance below the dam, as at m in Plate 1, and then return along the surface toward the dam. The greater the flood depth on the crest the further from the toe of the dam do the logs appear and the more swiftly the logs return with the surface current toward the dam.

"*Breakwater.*—In a case such as is shown in Plate 1 (Fig. 1) the breakwater comes in contact with only the toe of the dam. With eleven feet depth on the crest, sixty feet fall and twenty-five feet of backwater, the discharge velocity past b, c. f. is great. The water at d then flows back over the swift undercurrent with a velocity due to the free head of backwater next the dam, but at its surface level cannot reach the dam. These effects of flow, which may be observed at many dams, seem to have been overlooked by most writers on the subject. It is illustrated in part by Fig. 14, in which the valley between the down flowing stream and the returning current is filled with spray.

"Fig. 1, on the left of Plate 1, is a reproduction of a sketch relating to these matters explained by the writer to members of the Board of Public Works at Austin, in June, 1892, when he first visited the works. The foundations of the dam were then in place and the superstructure in progress.

"In computing the stability of a masonry dam, the weight of water resultants from a to b, Fig. 1, Plate 1, have usually been neglected. So, also, have the reactions of the tail water against the dam througout the flowing jet and also the weight reactions at b, c and the weight of the water at d, which in this case are sufficient to materially enhance the factor of safety.

"*Fall at the Toe.*—Referring again to the undercutting at the toe of the dam, which occurred at a point about three hundred feet from the easterly abutment, we call attention to the appearance of the low and moderate flows at the fall over the toe of the dam, as shown in Figs. 11 and 15 (a view taken of dam from east instead of west as printed under illustration). This fall should but slowly cut hard limestone, but might cut such soft stone as was said to have been found at the point mentioned. At the right of Plate 1 (in Fig. 2) is a sketch suggesting the possible effect of such fall on a soft rock or adobe stratum. A fall of one foot to surface of backwater gives a velocity of about 8 feet per second, and of two feet a velocity of about 11.34 feet per second, and of two and one-half feet, as observed, a velocity of about 12.68 feet per second, each independent of the velocity acquired down the slope.

"The failure of the dam was attributable to a local weakness in the rock on which it rested. It is probable that the friable or soft stratum under the part of the dam which first moved, and which was not removed and replaced, became so saturated with water that upward pressure from the pond was transferred to the underside of the dam in sufficient amount to neutralize a considerable part of the weight pressure of the masonry resting upon that soft rock and, furthermore, that this saturated stratum became like a lubricant on which that part of the dam had but moderate resistance against sliding.

"The parted sections constituted nearly one-half the length of the dam. It is probable that the section of the dam resting on the formation on which it had not sufficient frictional resistance was held as a part of a beam until a vertical cross-crack came at the central part of the soft section at B (Fig. 12), and also that then the two parts adjacent to B were held briefly as cantilevers until they cracked at C and A, after which they slid, moving slightly fastest at B, the point of first crack, until they rested eighty feet forward of their original positions. The erosion in front of the toe of the dam was not so wide but that the two parted sections of the dam slid over the erosion without tilting and stood erect in their new position, as shown in Fig. 10.

"In such constructions it is usual to countersink the toe of the dam flush into the bed rock, giving it an abutment, which makes sliding impossible.

"*Power House Foundations.*—The injury to the power house was a remarkable and unprecedented accident.

"The foundations remain now uninjured, as is indicated in Fig. 11. The basement windows were placed above the forty foot backwater level, and the river wall was trussed to resist the inward pressure of forty feet of backwater. The wave of water from the broken dam rose above the windows and broke them in and then flooded the basement where the turbines were located. As the flood receded the basement held this water, as a tank, up to the forty foot level. When the backwater outside had next day (twelve hours after break in dam) fallen below the level of the basement floor the enclosed water pressed a part of the basement wall outward and permitted a part of the floors and roof to fall.

"*Site of Power House.*—Someone has stated that the power house was in more danger from the flow over the dam than it would have been if located one hundred feet further down stream. Its position as constructed was adopted as the one of greatest safety and stability, and also in part because the extension of the abutment and steel penstocks one hundred feet further would have added $20,000 to their cost. The relative location of the dam and power house are approximately shown in Fig. 16. In this sketch GF is the face of the east abutment, but with exaggerated curve. This easy curve of the abutment was proportioned with care to deflect the flood current in a predetermined direction so that it could not scour along the face of the power house foundation except as a return eddy. The return eddy flowing up stream would be weakest near

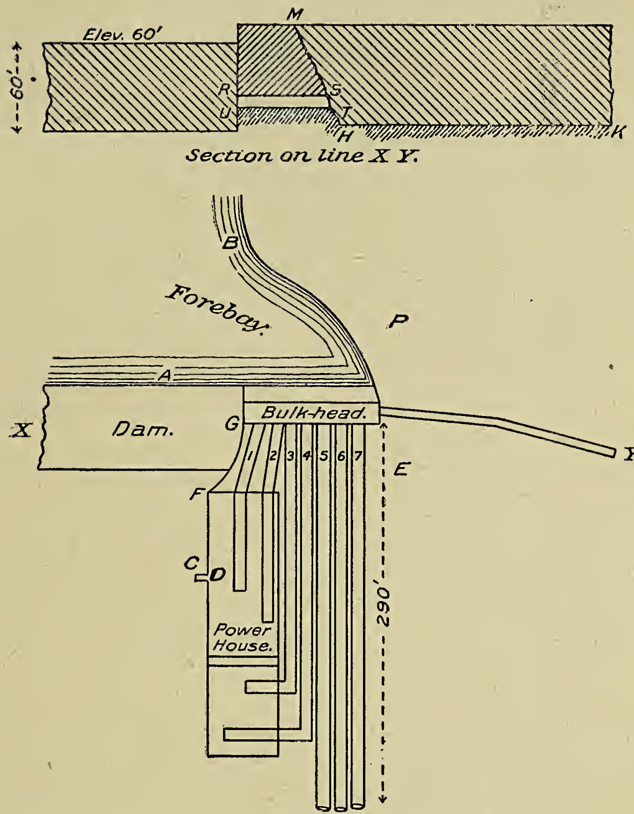


FIGURE 16.
Plan of Power House and Penstocks.

the dam, so that part of the foundation nearest the dam was safest of all from scour by flood. The foundations of the power house were uninjured by the rush of waters dashed against the building."

The question of rebuilding the dam is not considered in these pages for the reason that it will require expert examination of the whole question. The most paramount factor aside from the financial features will be the character of foundation.

Since writing the above, Mr. Wilbur F. Foster, of Nashville, Tenn., upon invitation of the committee appointed by the Water and Light Commission to consider ways and means of rebuilding the dam, has submitted the following report:

NASHVILLE, TENN., March 19, 1902.

Hon. Emmet White, Mayor, and Members of the Water and Light Commission, Austin, Texas.

GENTLEMEN: By invitation of Mr. D. H. Caswell, chairman of one division of the citizens' committee, appointed by the city council for certain purposes, and in compliance with his request "to offer such suggestions as might be timely, and furnish a statement as to the probable cost of replacing that portion of the dam across the Colorado river which was destroyed by flood in April, 1900, and securing from further injury that portion which now remains standing and uninjured," I have visited the site of the said dam, made such examinations and measurements as were practicable without great expense, and respectfully submit the conclusions to which I have been led thereby.

Any estimate of this kind, in the absence of definite plans and specifications which are to be complied with, is at best uncertain and unsatisfactory; and in this case it has been assumed that those which controlled the original construction would be followed in the renewal, in order to preserve uniformity of appearance of the entire dam when completed; but with such modifications to secure stability, and for the sake of economy, as are herein suggested for your consideration.

The report herewith submitted is from the standpoint of a builder, guided by some experience in construction of similar work in other localities, and from information obtained in your city as to various details of cost, and will, therefore, ignore technical questions as to cause and manner of failure, etc., which have been so ably and exhaustively discussed by well informed and intelligent observers who have given much time to the study of the facts. Only the conditions as they now exist will be considered.

The engineering problems involved demand the most painstaking, careful investigation, and these you will doubtless submit to some member of that profession in whom you have entire confidence, and whose advice, plans and specifications, when once adopted, as well as his instructions with regards to details during the progress of the work, you will rigidly abide by. I may be pardoned for suggesting that some of the questions thus to be most carefully studied in the light of the unfortunate experience you have had are:

(1) Whether it will not be better to abandon entirely the present location, and in rebuilding adopt one by which you will avoid the "faults" or unreliable strata in the geological formation which seems to have been the prime cause of the trouble you have had, both with the foundation of the dam and the construction of your bulk head masonry and power house. Of course, a large amount of material will be available by salvage from the old dam when removed, and from the debris from the portion destroyed.

The surveys, soundings and careful investigations already made by the eminent professional gentlemen who have been connected with your work heretofore will greatly facilitate the decision of this point.

(2) Whether, in view of the observed action of the overflow in time of flood, a modification of the profile or cross-section of your dam is not advisable, wherever it may be built, the up-stream face to be battered

or offsetted in lieu of vertical, and the down-stream face to have flatter slope, thus increasing the weight of the mass and giving a larger frictional area upon the base.

(3) A careful consideration of the merits of the fossiliferous limestone, which is abundant in the vicinity of the dam, as a building material. It does not seem reasonable that stone which has withstood the action of the elements for untold ages should be condemned as altogether worthless. In view in the excessive cost of granite, both in quarry cost and transportation, as given to me in Austin, I believe that the limestone of the vicinity should be used in the up-stream face, at least to a point fourteen feet below the crest of the dam, and quite possibly on a portion of the down-stream face also, and that it will be reliable for strength and durability in that portion.

Assuming that these and other details will hereafter be decided by your engineer, I will endeavor to answer, as briefly as possible, the inquiry of Mr. Caswell, guided by my personal examination of the locality and by my best judgment as to the cost of the various items.

It might be assumed by some that inasmuch as the total length of the dam between abutments is 1091 feet, and its total cost was about $611,000.00; and as about ninety-one feet at the east end and 500 at the west end remain standing, that the interval 500 feet could be replaced for its pro rata of the total, or about $300,000.00. This supposition will be found erroneous for several reasons.

(1) The shattered condition of the ninety-one feet now standing at the east end makes its removal and reconstruction a necessity, and inasmuch as this is at a place where a very troublesome leak occurred after completion of the dam, it is probable that the foundation itself ought to be excavated to greater depth.

(2) A large mass of the original dam is still standing, just far enough down stream from its original position to be very much in the way of construction of new work, and must be removed.

(3) A very large deposit of earth and silt east of the present channel, also along the toe of the dam on the west side of the channel, must be removed for construction of new work.

(4) An examination by sounding with an iron rod reveals the fact that the bed rock in the channel through which the river is now flowing is an irregular surface, ranging from 8 6-10 to 12 6-10 feet below the assumed low water line, which was the top of the toe of the dam as built. This is the result of seven soundings, and is pretty conclusive proof that not only the foundation stone is gone from this portion of the dam, but that the bed rock itself has been broken up and washed out to a depth in some places of more than six feet. The average of these soundings is 10 8-10 feet, and while it is not certain that this condition extends to the eastern end of the gap, yet it will not be safe

to estimate otherwise, as it is probable that if not washed out, at least that much would have to be removed before rebuilding. This break-up of the bed rock I have assumed to be from a point six feet above the upper face of the dam a line twenty feet below the toe. This, then, will make a pit 483 feet long by ninety-two feet wide by four and eight-tenths feet deep, which must be filled with masonry or concrete before reaching the base of the original dam.

(5) It seems to me imperatively necessary that the toe of the dam its entire length should be protected by an apron of masonry or concrete to prevent undermining. This I have estimated as 1100 feet long, average width twenty feet, average depth three feet.

(6) In my estimate I assumed that the up-stream face wall will be built of limestone to a height fourteen feet below the crest of the dam, and will have a slope or batter of three inches to one foot vertical. This will add 442 feet to the original sectional area of the dam, making it 2642 feet. The upper fourteen feet of the up-stream face, the coping, and the down-stream face all to be of granite as in original plans. All

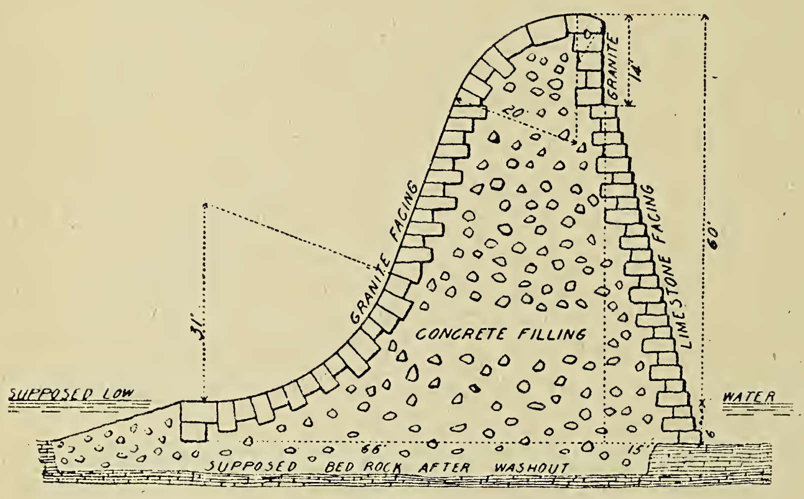


FIGURE 17.
Foster's Suggested Cross-section.

this will be shown more fully by the sketch (Fig. 17) which I herewith enclose, showing suggested profile. It is suggested that the entire filling or interior shall consist of concrete made of American Portland cement.

(7) The cost of the contractor's plant or outfit under conditions like these is quite as great for the construction of a dam 600 feet long as for the original length of 1091 feet.

With the above explanations I submit the following estimate of cost:

Earth excavation, wet and dry, 21,000 cubic yards, 30 cents, $6,300.
Rock excavation, 2000 cubic yards, $1.60, $3,200.

Removal of masonry now standing, 14,000 cubic yards, $1.00, $14,000.

Granite coping course, 1373 cubic yards, $19.00, $26,087.

Granite facing, down-stream, 5535 cubic yards, $11.75, $65,036.25.

Granite facing, up-stream, 684 cubic yards, $11.50, $7,866.

Coursed limestone masonry, up-stream face, 4738 cubic yards, $7.50, $35,535.

Concrete filling, 55,749 cubic yards, $5.50, $306,619.50.

Total, $464,643.75.

Deduct for salvage of granite in old dam and debris, 3025 yards, $7.00, $21,175.

Total net, $443,468.75.

In the above estimate it is assumed that the granite work can be done at the same prices as in the original contract, notwithstanding the increased figures given me when in Austin. It is also assumed that all the work will be laid in American Portland cement mortar of approved quality.

Incidentally, while at the site of the dam, I made a measurement of the flow of the stream, which was said to be at a stage lower than for many years. This measurement, which was of the rudest type, and without any facilities for securing accuracy, indicated a flow of 360 cubic feet per second. I also examined the ground on the west side of the river, and found that by cutting a channel 100 feet wide, with an average depth of about fifty feet, and approximately 1000 feet long from the canyon of Bee creek southwardly to a ravine which empties several hundred feet below the dam, a spill-way might be obtained, which, with ten feet of water on the dam, would pass a volume of water equivalent to a depth of one foot over the crest of the dam. The excavation would be solid rock, would probably cost $150,000, and is only mentioned as my attention was directed to the matter.

In this report, I have made no attempt to determine the extent or estimate the cost of work to be done in reconstruction of the power house. Whether the headgate masonry must be rebuilt; whether the penstocks and turbines should be lowered; whether two or three penstocks will not be sufficient in lieu of six, and whether the river wall of the power house should be more solidly rebuilt, are questions that can be best decided by those who are familiar with all the details, and who know the present condition of the plant and the cost of all the items involved.

One detail, however, should not be overlooked or neglected in any event. The tail race by which water is discharged from the turbines should be so directed that the current will not scour along the toe of the dam, thus endangering its stability, however careful it may be protected.

In conclusion, I would say that the estimate herewith furnished is concurred in by my business partner, Mr. R. T. Creighton, who was present and assisted in all the examinations and measurements.

I wish to express my appreciation of the courtesy shown and valuable information and assistance given by the various officers and employes of your city and other well informed gentlemen whom I met while engaged in this examination.

All of which is respectfully submitted.

W. F. FOSTER.

It will be observed that Mr. Foster concludes from his soundings that not only the foundation stone, but part of the bed rock was also torn up and washed away. It will be remembered that Supt. H. C. Patterson, in a report to the Water and Light Commission in July, 1900, said "that the original foundations were in no way damaged, and in all cases, not less than six feet of the footing courses remained." The writer has made many soundings at the dam, and has, on different occasions, taken issue with the conclusions of Superintendent Patterson as to the foundation. The report of Mr. Foster will perhaps be sufficient to settle this matter once for all.

POWER PLANTS ON THE COLORADO AND TRIBUTARIES.

Locality.	Owner.	Head in feet.	Material.
Knickerbocker	T. Vinson	15	Ditch.
San Angelo	Payne & Jones	18	Ditch.
San Angelo	J. L. Millspaugh, Mgr.	11	Steel—stone.
Point Rock	F. J. P. Ford	4	Stone—wood.
Ratler	J. D. Willis	4	Logs, rock, etc.
Menardville	Gus Noyes	23.5	Ditch.
San Saba	Water Co.	20	Stone.
San Saba	Water Co.	10	Stone.
Bakers			Brush.
Lometa (11 W.)	M. Chadwick	5	Logs—rock.
Bluffton	Tanner Bros.	9	Natural.
Kingsland	J. M. McDaniel	5.5	Wood.
Llano	J. K. Finlay	12	Natural.
Llano	J. K. Finlay	8	Natural.
Llano	Water Co.	9	Wood.
Marble Falls	Water Co.	22	Natural.
Austin	City	62	Stone.

BRAZOS RIVER AND TRIBUTARIES.

The Brazos river rises in the Staked Plains in the counties of Hale and Lamb, and takes a southwesterly course for 100 miles and then turns to the left and takes a general easterly course for 100 miles to Young county, where it again assumes its southeastern course, which it maintains to the Gulf of Mexico, a distance of 350 miles. In its upper stretches, above Young county, it courses through flat plains and maintains an unreliable flow for power purposes. The two branches, the Salt Fork and the North Fork, of the Double Mountain river unite in the eastern part of Stonewall county and 100 miles below they receive the waters of the Clear Fork.

The first power plant that occurs on the Brazos is located on the Clear

Fork in the southern part of Young county, near Eliasville, and is owned and operated by the Donnell Brothers. The dam is situated about the middle of a rounded bend in the river and backs the water about two and one-half miles. The width of the bottom bed of the Clear Fork is about 150 feet. In the irregular bed of the river deep rock holes occur alternating with shoals. Some of these shoals give a fall of as much as six feet in a distance of 300 feet, while others give only an inch or so. There is a fall of perhaps thirty feet from the dam to the mouth of the river, a distance of nine miles. The flow of Clear Fork is quite irregular, often getting bank full, but seldom overflows the banks. The river is not supplied by many springs, and it falls fairly rapidly when rain ceases. It usually falls to a flow of about twenty square feet cross-section on shoals, and when dry weather continues will stop flowing altogether in four months or thereabouts. It has not quit running since 1880. The Eureka dam is built of sandstone slabs 6x2 by six feet long and is 120 feet long and six high. At first the lower face was left vertical, but so much pounding occurred from drift logs that a timber apron was put in with a slope of one to two. This rock bed of the river is about six inches thick, underlaid by hard *blue* clay. The swiftness of the current eroded the bank on north side of river and to prevent the waters going round dam a great quantity of brush and logs were piled in and proved successful in preventing erosion. In very high water the dam in invisible, the current is hardly swifter on crest than elsewhere. For a while the mill was an ordinary crusher mill for wheat and corn, run by an overshot wheel. About 1888 patent roller machinery was added. Although often forced to shut down by low water, the mill has paid well. A cotton gin, of recent construction, is run by steam and doubtless an auxiliary steam plant will be put in for the mill.

About six miles south of Whitney, Texas, B. M. Boyd owns a flour mill, which is operated by the water power obtained from a dam across the Brazos river. The river at this point has a vertical bluff on the north side about fifty or sixty feet in height, and in a gap in this bluff (the bed of an old creek, presumably) and at a safe distance above high water is located the mill. The dam is 300 feet long and is constructed of cedar timber and brushwood, rock and gravel, and rests upon the solid limestone bed of the river. The cross-section is triangular in shape, and it is built up by a foundation layer of logs placed lengthwise of the dam, brush and stone spread over this, then a layer of logs placed crosswise of the dam and brush and stone placed upon this. Then another course of logs is laid lengthwise, and more stone and gravel, etc., until the top is reached. The top surface of the dam slopes backward to the foundation and makes an angle of about twenty degrees within it, and a liberal backing of stone and gravel is deposited upon it within a few feet of the crest, which effectually prevents leakage through the dam. Iron pins are let into the bed rock at the toe of the dam to prevent any sliding. The height is about seven feet, and the width at the base about twenty feet. The junction with the shore on the south side is made by means of a bulkhead or abutment of log cribbing, and on the north side by means of limestone masonry. The power is developed by means of two Leffel turbines, a 44-inch and a 48-inch, each of which develops twenty-five horse power with the seven foot head obtained. It is possible to add at least another three feet to the height of the dam and thus obtain a ten foot head, without backing the river up over its banks, and it is probable that the owner will attempt this and add to his equipment in the near future. The dam was first constructed in 1856, but has been partially washed away and rebuilt several times since then.

On the North Bosque, at Clifton, Bosque county, T. O. Swenson owns and operates a flour and corn mill that derives its power, except in dry times, from the water of the Bosque. The dam is of stone, 195 feet long, ten feet high, and was built in 1867, at a cost of $5000. The water is backed up the river for one mile. The power is generated by two Leffel turbines of thirty and one-half inches diameter, and when running at three-fourths gate opening can develop thirty-five horse power. To guard against dry seasons and low stages of the river, an auxiliary steam plant of thirty horse power has been installed.

The feasibility of constructing a dam across the Brazos at or near Waco has often been discussed. At the suspension bridge the southwest bank is composed of limestone, while the northeast bank is an alluvial deposit. The width between bank crests is a little over 500 feet and a dam to be at all safe would have to be this length or over, with protecting wing walls. The sand is of unusual depth and it would require an excavation through the sand bed nearly twenty feet deep at places to reach bed-rock with a foundation for dam. Then to obtain a head of thirty feet, the dam if constructed near the suspension bridge would have at some places a height of at least fifty feet. A gauge was established near the suspension bridge by the U. S. Geological Survey in September, 1898, and since then measurements of the flow have been taken. The gauge heights are read twice each day, recorded and published. The lowest flow ever reached by the Brazos since measurements have been kept occurred on March 8, 1902. The stream where measured was only twenty-four feet wide, an average depth of seven and one-eighth inches, and had a mean velocity of 1.36 feet per second, giving a discharge of 19.4 cubic feet per second. With a dam thirty feet high, this would produce fifty-three horse powers continuously. This is, however, far less than the ordinary low capacity of the river. Its ordinary low flow at Waco could be safely put at 100 cubic feet per second.

The Leon river rises in Eastland county and flows through the counties of Comanche, Hamilton, Coryell, and Bell before it empties into the Little river, a tributary of the Brazos. A short distance above Belton it receives the waters of Cowhouse creek. The flow of the Leon at Belton is utilized by the electric light plant. The dam was built in 1894, and is somewhat unique in its construction. Its ends butt against the abutments of the highway bridge and its race or forebay extends under the end approach of the bridge adjacent to the west abutment. It is in its plan arched up stream, the radius of its curve being 240 feet, giving it a rise of twelve feet in its span of 150 feet. The frame work was made of cedar posts and it was then covered with pine plank. The main purlin posts that carry the upper face are inclined to the horizontal at an angle of forty-five degrees. These purlin posts are braced from near their top by posts that are inclined to the vertical at about ten degrees, and the purlin posts are again braced by a series of short posts about three feet from the bed rock. Horizontal braces connected these two main supports of the purlin posts. To this frame work is attached the frame work of the apron. A row of short vertical posts, three feet high, extend in a circular curve seven feet below the main dam, and to this the top row of post sleepers are attached and connected to the frame work of the dam. These sleepers slope down stream and form the support for the flooring of the apron. The main cross-section of the dam is like the letter A, the first inclined line of which is inclined at forty-five degrees, the right hand line at about eighty degrees to the horizontal, while the horizontal line is about one-fourth of the height from the bottom. A course of plank was nailed to the up stream posts and then a layer of gravel, dirt, and small stones was spread on this surface, and then the up stream face was again protected by several layers of plank. The down stream face, the apron and the vertical fall below the apron are all protected by plank coverings. The total height is twelve feet, the fall from crest to apron seven feet, the fall of apron one foot, and the final fall from apron three feet. The water is taken from the lake through an arched conduit between the west abutment and the shore. This conduit opens into an open flume eleven feet and eight inches wide and eighty feet long. The flume follows the west bank and is supported on posts that are thoroughly protected from the effects of floods by strong sheathing. The fall at the penstock is eleven feet and the power is transmitted to the dynamos by shafting. The power house is on the high west bank and is equipped, in addition to the water plant, with two tubular boilers whose estimated capacity is one hundred horse power each, and one automatic Russell engine of eighty horse power.

LAMPASAS SPRINGS.

The Sulphur Fork of the Lampasas river rises in the city of Lampasas and is formed by two springs, the Hancock and the Hanna. The Hancock spring is about one mile S. 30 W. from the court house, and its flow, as measured on December 18, 1900, by current meter, was 10.3 second-feet. The measurement was made just below the ford and about 400 feet below the bath house at the spring. The dam of the electric light plant, which is a little over half a mile below the spring, backs the water up to within 200 yards of the spring itself. The flow of the spring, as stated by the citizens, is reliably constant.

The Hanna spring is about one-fourth of a mile N. 20 E. from the court house and almost on the opposite side from the Hancock. It rises in a large pool, sixty feet in diameter, which has been constructed of stone and cement. The water flows out of a pool over an inclined apron and can be diverted to the large bath house nearby. The stream formed by the spring has been diverted from its original channel and is conveyed partly underground for over 200 yards, but at certain places the stream is visible through boxes placed in its course and whose sides project above the surface of the ground. At one of these boxes the flow of the Hanna spring was found to be four second-feet on December 19, 1900. The Hanna spring is strongly impregnated with sulphur.

The waters of the springs are utilized by various power plants. There are three dams across the stream within a mile and a half of Lampasas. The electric light plant is in the suburbs of Lampasas and has a stone dam of eighteen feet in height above foundation bed and fourteen feet above the river bed, and 150 feet long. The water is conveyed by a race nearly 300 yards long to the power house, where a fall of fourteen feet is obtained. The waters above this stone dam are held back during the day and used only at night, but the lake above the dam fills up and the water begins to flow over the dam shortly after midday. A judicious use of flashboards would render more power available. A flow of one cubic foot of water with an efficiency of seventy-five per cent. would give a continuous horse power of one and one-half, or a total of twelve horse power used continuously, or a total of twenty-eight and eight-tenth if used for only ten hours during the day and held back for fourteen. An auxiliary steam engine is used at the power plant to reinforce the water power when heavy demands are made for power.

The second dam belongs to W. T. Donovan & Sons and is about three-fourths of a mile below the stone dam. It is an old-fashioned wooden dam, 120 feet long, and gives a fall of eleven feet. Triangular frame bents are constructed with the inclined braces up stream. To these braces sheeting is nailed, which forms the up stream face of the dam. With a good hydraulic wheel one second-foot of flow should give one horse power at the dam. The power is used here by the Donovan Flour Mill, but the flow of the stream is under the control of the upper dam to such an extent that a gasoline engine is used as an auxiliary power.

The lower dam, about one mile below the Donovan dam, belongs to Bradley Brothers. It is a wooden structure, composed of cedar post frame work, the upper brace of which is inclined at an angle of forty-five degrees, while the lower is nearly vertical. These posts are bolted into the bed of the stream and the upper face is covered with planks. To sustain the water pressure the upper inclined purlin posts are braced with a short brace a few feet above the bottom. The north end of the dam terminates in a substantial masonry bulkhead that serves to prevent cutting around the end in times of high water. The power plant is on the south bank of the river and consists of a mill. The fall is ten feet, and the power is developed by a turbine.

The Salado river rises in the famous Salado springs, in the town of Salado, nine miles south of Belton, Texas. These springs are similar in source, behavior, and character of water to those of San Marcos, Del Rio, etc. The discharge was measured in December, 1901, at the site of the old stone dam in the town and a discharge of thirteen cubic feet per second was found. The stream below the town is often rather deep and resembles in all its characteristics, except magnitude of flow, the San Marcos. At present there are four power plants on the Salado. Two miles above the mouth is located Summer's mill. The dam is built of stone masonry, is 175 feet long and ten feet high. The power is generated by two Leffel turbines, thirty and thirty-two inches in diameter, respectively. The head is ten feet and the gate opening is one-half. In the winter the mill is operated twelve hours per day, and in the summer twenty-four hours per day. A twenty horse power steam engine is kept ready in case of necessity, but it is seldom used.

Six miles above the Summer's mill is located the Stinnett's mill. The three foot dam is one mile above the mill and is used merely to deflect the water into the mill race. The power is generated by a 23-inch McCormick turbine under a head of eighteen feet. The mill has all of the water privilege and it runs the entire year. Between these two mills there are two cotton gins operated by water power. In addition to these plants, there are four possible locations where power plants could be located.

At Jonah, Texas, about ten miles east of Georgetown, is located a flour and corn mill, owned by McDonald & Bruce, and operated partially by the power derived from the San Gabriel river. The dam is about 300 feet long and is constructed of timber frame work with a top sheeting of 2-inch planks. It is triangular in section and is made up of a row of 6″x6″ upright posts, on the down stream face, let into the bed rock of the river a few inches and about twelve feet or fifteen feet apart; a cap of 6″x6″ timber rests upon these posts and supports one end of the stringers, to which the top plank sheeting is spiked. These stringers slope up stream at an angle of about thirty degrees to the horizon, and the other end rests upon the river bed. Two-inch planks are bolted to these to form the up stream face of the dam. A head of nine feet is obtained, and the power is derived from one 36-inch Samson turbine, and it is estimated that fifty horse power can be developed with a full gate opening. A thirty-five horse power steam engine is used in conjunction with the water power when the mill is run to its full capacity and during time of low water. The dam was built in 1890. The machinery is valued at $5000.

About six miles east of Georgetown is located the flour and corn mill of J. F. Towns, on the San Gabriel river. The power is derived from one 26½-inch Leffel turbine and is estimated at thirty-six horse power under the sixteen foot head obtained. The dam is constructed of timber frame work and a top sheeting, similar to the one at Jonah, except that the posts on the down stream face are slightly inclined instead of being vertical, and that there is no cap on the top of these to support the stringers for the sheeting. Each stringer rests on the head of a post and the sheet planks are nailed directly thereon and lengthwise of the dam. The posts are about eight feet apart, and a wooden sill embedded in concrete is placed the full length of the dam at the foot of these posts to strengthen against sliding. The dam is connected to the river banks on both ends by stone abutments. It is about 400 feet long and six feet high, and was first built in 1882. In 1892 it was rebuilt entirely as it stands today. The power house is located about one-fourth of a mile below the dam and a head of sixteen feet is obtained on the turbine. The water is conducted to the power house by a race. The cost of the plant, dam, machinery, etc., was about $8000. At present the river is so low that the mill is not run, but when the water supply is sufficient it is run day and night.

About three miles northeast of Georgetown is located a small corn mill, owned and operated by D. A. Strange. The mill is situated on the banks of Bear creek, but obtains its power from a spring, the water of which is backed up by a dam and forms a pond or small lake above the mill. The dam is built of limestone masonry, is of irregular section, and is about 150 feet long. In plan it is approximately trapezoidal in shape, and the mill is situated in the middle of the section at right angles to the river. The effective head is sixteen feet, and with the 16-inch turbine twenty-two horse power can be obtained. The mill is a very small concern, the machinery old and very seldom used.

SUMMARY OF WATER POWER PLANTS ON BRAZOS AND TRIBUTARIES.

Locality.	Owner.	Head in feet.	Material.
Elisasville	Donnell Bros.	6	Stone.
Towash	B. M. Boyd	7	Wood.
Clifton	T. O. Swenson	10	Stone.
Belton	Smither	11	Wood.
Lampasas	Water Co.	18	Stone.
Lampasas	W. T. Donovan	11	Wood.
Lampasas	Bradley Bros.	10	Wood.
Summers	Summers	10	Stone.
Salado River	Cotton Gin		
Salado River	Cotton Gin		
Salado River	Stinnett	18	
Jonah	McDonald	9	Crib work.
Georgetown (6 miles east)	J. F. Townes	16	Frame work.
Georgetown (3 miles west)	D. A. Strange	16	Masonry.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901.

REPTILES AND BATRACHIANS OF McLENNAN COUNTY, TEXAS.

JOHN K. STRECKER, JR.,
Waco, Texas.

VOLUME IV, PART II, NO. 5.

AUSTIN, TEXAS, U. S. A.:
PUBLISHED BY THE ACADEMY
1902.

THE TEXAS ACADEMY OF SCIENCE.

A PRELIMINARY REPORT ON THE REPTILES AND BATRACHIANS OF McLENNAN COUNTY, TEXAS.

JOHN K. STRECKER, JR.,
Waco, Texas.

INTRODUCTORY.

This paper is more properly a preliminary *list* of the reptilia and batrachia observed and collected in Waco and vicinity by the writer, from August, 1893, to November, 1901, and is the forerunner of a more complete annotated list, with short descriptions of each species, and accounts of their habits as gleaned from personal observation, which will appear in 1902.

The writer has thoroughly explored the western and southern, and has made a number of trips through the northern and eastern, sections of the county.

The list is by no means complete, being especially lacking in Testudinata, only five forms being enumerated, while future investigation will probably bring seven or eight more species to light. Thanks are due to Mr. Julius Hurter, of St. Louis, Mo.; Mr. Clement S. Brimley, of Raleigh, N. C.; and, indirectly, to the National Museum authorities for the identification of specimens; and to Messrs. C. B. Pearre, Jr., Bert L. Combs (now deceased), William Winston and Harry Bahl, for assistance in collecting material.

The reptile fauna of McLennan county is largely composed of the forms peculiar to the Austroriparian and Sonoran faunal regions.

THE LIST.

REPTILIA.

1. *Anolis carolinensis.* Linn.

Carolina Anolis. Green Lizard.

This beautiful lizard occurs in the eastern and extreme southern sections of the county, but is quite rare. I have been unable to find any specimens at Waco.

2. *Holbrookia texana.* Troschel.

Texan Rock Lizard.

This species is abundant in most suitable localities throughout the county. At Cottonwood creek, seven miles west of Waco, it is very numerous, and in October, 1901, I obtained thirty-nine specimens in about four hours.

3. *Holbrookia maculata lacerata.* Cope.

Boll's Lizard.

With the exception of three specimens (U. S. National Mus., Nos. 22147-9) collected near Waco, I have found this lizard in only one locality, i. e., the bluffs of the North Bosque river, near China Springs. Here it is rather common, while *H. texana* is rare.

4. *Sceloporus spinosus.* Weigmann.

Tree Swift. Scaly Lizard.

An abundant species in the wooded districts.

5. *Sceloporus undulatus consobrinus.* Baird and Girard.

Fence Lizard.

Occurs in the northern and eastern sections, but is by no means a common species.

6. *Phrynosoma cornutum.* Harlan.

Horned Lizard.

Common along roadsides and in the grassy flats and fields.

7. *Opheosaurus ventralis.* Linn.

Glass Snake.

Occurs, but is rare.

8. *Cnemidophorus gularis.* Baird and Girard.

Southern Lined Lizard.

An abundant species.

9. *Cnemidophorus sexlineatus.* Linn.
Six-lined Lizard. Swift.

This small species occurs, but it so closely resembles the smaller specimens of *Cnemidophorus gularis,* that without a large series of swifts for examination, it would be difficult to say whether it was common or rare.

10. *Liolepisma laterale.* Say.
Ground Lizard.

A common species in the wooded districts where it lives among logs, masses of decayed wood and fallen leaves.

11. *Eumeces quinquelineatus.* Linn.
Red-head. Blue-tailed Lizard. Skink.

Occurs, but as far as my observations go is quite rare. I have only taken two specimens, and have seen but three others.

12. *Diadophis regalis arnyi.* Kenn.
Arny's Ring-necked Snake.

One specimen. East Waco.

13. *Heterodon platyrhinus.* Latreille.
Spreading Adder.

Apparently not common.

14. *Cyclophis aestivus.* Linn.
Southern Green Snake.

A common species in the wooded districts.

15. *Zamenis constrictor.* Linn.
Racer. Black Snake.

Both the black and yellow forms occur.

16. *Zamenis flagellum.* Shaw.
Coach-whip Snake.

Common. I collected several and saw others at Cottonwood creek this year. Here they feed largely on Rock Lizards.

17. *Coluber spiloides.* Dumeril and Bibron.
Texas Pilot Snake.

This large Coluber is one of our commonest snakes, especially in the timbered sections of the county.

18. *Pityophis sayi.* Cope.
Bull Snake.

Not uncommon in the prairie districts to the west of Waco.

19. *Osceola doliata doliata.* Linn.
Scarlet Snake.

One specimen collected.

20. *Ophibolus calligaster.* Say.
Evan's King Snake.

I collected one specimen of this King Snake (U. S. National Mus., No. 21,486) about a mile west of Waco, and at the same time saw two others, which, however, escaped by crawling into burrows made by small mammals.

21. *Ophibolus getulus sayi.* Holbrook.
Say's King Snake.

A common species.

22. *Rhinochilus lecontei.* Baird and Girard.
Le Conte's Snake.

I have collected but one specimen of this species; but I have seen several others, all in the Bosque country.

23. *Natrix rhombifera.* Hallowell.
Diamond Water Snake.

A common species in the marshes and along the creeks.

24. *Natrix fasciata transversa.* Hallowell.
Hallowell's Water Snake.

Apparently our commonest water snake.

25. *Natrix fasciata erythrogaster.* Shaw.
Red-bellied Water Snake.

One specimen collected near the suspension bridge over the Brazos river at Waco. Identified by Mr. Julius Hurter, the St. Louis herpetologist.

26. *Natrix grahami.* Baird and Girard.
Graham's Water Snake.

One specimen; from Bosque river near Waco.

27. *Storeria dekayi.* Holbrook.
DeKay's Snake.

A common species along the Brazos banks at Waco. I have not met with it elsewhere.

28. *Haldea striatula.* Linn.
Brown Snake.

Very abundant, especially in the wooded districts where I find them principally among masses of decayed wood and dead leaves.

29. *Tropidoclonium lineatum.* Hallowell.
Lined Snake.

A common species.

30. *Eutaenia proxima.* Say.
Say's Garter Snake.
Our commonest Eutaenia.

31. *Eutaenia elegans marciana.* Baird and Girard.
Garter Snake.
One specimen. Grassy flats west of Waco after a heavy rain.

32. *Eutaenia eques collaris.* Jan.
Collared Garter Snake.
Several specimens, all from the river bottoms.

33. *Eutaenia sirtalis dorsalis.* Baird and Girard.
One specimen. I have lately collected a large *Eutaenia* of the *sirtalis* type near Waco, which may also be referable to this species.

34. *Tantilla gracilis.* Baird and Girard.
Graceful Tantilla.
One specimen. Brazos bottom lands.

35. *Elaps fulvius.* Linn.
Coral or Harlequin Snake.
Not uncommon.

36. *Ancistrodon piscivorus.* Lacépède.
Cotton-mouth. Stump-tail Moccasin.
Common.

37. *Ancistrodon contortrix.* Linn.
Copperhead. High-land Moccasin.
Common in all suitable localities.

38. *Crotalus adamanteus atrox.* Baird and Girard.
Texas Diamond-back Rattlesnake.
This species, said to be common years ago, is now very rare.

39. *Crotalus horridus.* Linn.
Banded Rattlesnake.
One large specimen. Shot in the cedar brakes four miles north of Waco.

40. *Pseudemys concinna.* Le Conte.
Neat Turtle.
One specimen. From McGregor near the Coryell county line.

41. *Terrapene ornata.* Agassiz.
Painted Box Tortoise.
Common on the grassy flats from Waco west to McGregor, and in most sections of the county that I have explored.

42. *Chelydra serpentina.* Linn.
Snapping Turtle.
Abundant in the rivers.

43. *Kinosternon louisianae.* Baur.
Louisiana Mud Turtle.
An abundant species, both in marshes and rivers.

44. *Aspidonectes emoryi.* Baur.
Emory's Soft-shell Turtle.
A common inhabitant of the rivers and streams.

BATRACHIA.

45. *Chondrotus microstomus.* Cope.
Small-mouthed Salamander.
Not uncommon.

46. *Amblystoma opacum.* Gravenhorst.
Marbled Salamander.
One specimen from near Hewitt (nine miles west of Waco).

47. *Plethodon glutinosus.* Green. ?
Slimy Salamander.
This salamander, which resembles *P. glutinosus* to all appearances, is said to be common, but I have never been so fortunate as to capture but one, and this specimen escaped from the box it was confined in before I could get a chance to compare it with specimens in my collection. This species is known to the countrymen, who call it the "lizard that leaves a silver streak."

48. *Scaphiopus couchii.* Baird and Girard.
Couch's Spadefoot.
A common species, especially during the spring rains, when it comes forth to breed in temporary pools. I have collected over forty specimens.

49. *Lithodytes latrans.* Cope.
Rock or Barking Frog.
One specimen. Waco.

50. *Bufo americanus americanus.* Le Conte.
American Toad.
Common.

51. *Bufo valliceps.* Wiegmann.
Nebulous Toad.
Not uncommon.

52. *Bufo debilis.* Baird and Girard.
Green Toad.

As far as my observations go, this species is common in but one locality, i. e., the grassy flats to the west of Waco where I have collected about seventy-five specimens.

53. *Hyla carolinensis.* Pennant.
Carolina Tree Frog.

Occurs, but is not common.

54. *Hyla versicolor chrysoscelis.* Cope.
Western Tree Frog.

Common.

55. *Chorophilus triseriatus clarkii.* Baird and Girard.
Clarke's Striped Tree Frog.

An abundant species, especially so in the vicinity of marshes.

56. *Acris gryllus.* Le Conte.
Cricket Frog.

Common.

57. *Engystoma carolinense.* Holbrook.
Toothless Frog.

Common.

58. *Rana pipiens.* Kalm.
Leopard Frog.

Common.

59. *Rana catesbiana.* Shaw.
Bull Frog.

Common.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901.

THE RED SANDSTONE OF THE DIABOLO MOUNTAINS, TEXAS.

CRETACEOUS AND LATER ROCKS OF PRESIDIO AND BREWSTER COUNTIES.

E. T. DUMBLE,
Houston, Texas.

VOLUME IV, PART II, NOS. 6-7.

AUSTIN, TEXAS, U. S. A.:
PUBLISHED BY THE ACADEMY
1902.

THE TEXAS ACADEMY OF SCIENCE.

THE RED SANDSTONE OF THE DIABOLO MOUNTAINS, TEXAS.

E. T. DUMBLE,
Houston, Texas.

In the several reports of the Geological Survey of Texas, mention is made of a red sandstone which occurs in the Diabolo Mountains north of Allamore station on the Texas & Pacific Railway. This appears to be a very massive sandstone of red color with some white particles and of tolerably even grain throughout. It is the rock which encloses the copper vein, a part of which has been known for some years as the Hazel mine. Prof. Streeruwitz in one of his reports on the region states that the sandstone is possibly Devonian, basing the statement, as I understand it, entirely on the petrographic character of the rock (since no fossils have been found in it) and on its relation to the Carboniferous rock in the hills north of the mine.

During a hurried trip to the locality some months ago, I observed a few further facts which seem to me to suggest a much earlier age, and I believe that more detailed investigation will result in the discovery of some very interesting geological conditions connected with this material.

In the first Annual Report of the Survey, in my *résumé* of the systematic geology of the State, I called attention to certain schists and the marbles overlying them, which were found near Eagle Flat, and referred the marbles to the Texan group of Comstock's Llano section, which was supposed to be the equivalent of the Algonkian of the geologists of the United States Survey. The character of the outcrop of these marbles is well shown on plate number XXV of our Second Annual Report.

I observed a red sandstone in connection with these beds, but its relationship was obscured by faulting and was not made out. It appeared to occupy a part of the valley between the higher, mesa-like hill at Eagle Flat, sometimes called the Eagle Flat mountain, and the scarp of the Diabolo mountains to the north, and to be unconformable with the other beds observed.

The formations observed then or later to overlie there were:

(a) A series of brown sands and grits with conglomerates which were referred to the Potsdam. The pebbles of these beds include quartz and other siliceous material, red basaltic rocks, red sandstone (resembling that under discussion), and fragments of material resembling silicified wood such as was found on the west slope of Eagle Flat mountain and identified by Dr. Osann as belonging to the quartz porphyries. Their character is well shown on plate number XXIV of the Second Annual Report. Toward the top, these brown sands and grits gradually change their color to gray and become finer grained, the pebbles being chiefly of quartz. Still higher, the increasing fineness of the grain gives beds of gray and yellow sandstone full of worm borings. This is the horizon from which specimens were sent to Mr. Walcott by Prof. Streeruwitz, and the borings were identified by him as those of *Scolithes linearis*. The culminating beds are flaggy.

(b) Above these beds, and possibly separated from them by another sandy bed, are the limestones of the Silurian; and these are followed by the deposits of the Carboniferous. The reference of these beds to the Silurian and Carboniferous is based upon the fossils found in them by the different explorers of the Boundary Survey, the Pacific Railroad Survey, and W. P. Jenny, and, later, by ourselves in the various mountain ranges of the region. The Carboniferous fossils are abundant at certain horizons of the beds referred to that age, but those of the Silurian are not so plentiful. Enough can be found, however, to determine the age.

In the vicinity of the Hazel mine we have all of these horizons represented. In the mountains lying to the southeast of the camp a long scarp shows a body of Silurian limestone underlain by the Potsdam, which in turn rests unconformably on the Hazel sandstone. Following the scarp westward to the vicinity of the Black Gulch mine, we find a strong fault with a northeast-southwest strike, which brings into view the Texan marbles resting directly upon the Hazel sandstone. This condition continues toward the west until the summit of the ridge is reached, when the Texan marbles or dolomites are overlain by the Potsdam and this by the Silurian. Across the ridge, the exposures show the Texan group resting on the Hazel sandstone and capped by a dark brown sandstone, highly ferruginous, and different from the Potsdam beds. This is followed by a bed of reddish brown basaltic material. This basaltic material is also found in connection with the deposits of copper in various localities, and appears to be closely related to them. The marbles are here underlain by shales and schistose materials containing a dike of the red igneous rock.

The exposures at Tumbledown mountain, which lies south of the Hazel mine, give practically the same section as the lower portion of the hills to the southeast. Beginning at the base, we find the Hazel sandstone overlain by the Texan marbles, heavy bedded to flaggy, cherty or siliceous, and of various colors. Succeeding these is the dark brown sandstone, carrying concretions of iron toward the top, and on this the basaltic rock or lava. A quartzite caps these lavas, and is followed by schists and shales, and then, unconformably upon all, comes in the Silurian sand and lime. The Potsdam seems to be entirely wanting here, unless it be represented by the quartzite and shales, which does not seem to me to be the case. It appears to me that the various sections prove that the entire portion of this section below the Silurian is also pre-Potsdam, as fragments of all these rocks enter into the formation of that conglomerate.

The hills north of the mine show varying conditions. A part of them shows the Hazel sandstone at the base, with a thickness of 500 feet, overlain by seventy-five feet of gray conglomerate which is made up of only partly rounded pebbles and boulders of Hazel sandstone, and red porphyry, rounded quartzites, angular to partly rounded limestone, brown sandstone, quartz, chert, etc., in a brown silico-calcareous matrix. In places, however, there are (between the Hazel sandstone and the gray conglomerate) remnants of an old red conglomerate, which is sometimes as much as eight feet thick. The gray conglomerate is here overlain by the Carboniferous limestone.

A ravine which cuts across these beds follows a fault line, and shows on one side the section given above, while on the other appears what I take to be the Potsdam grits and sands, capped by a gray sandstone, above which are horizontal beds of limestone similar to those opposite. A barometric measurement of this limestone showed its thickness to be 400 feet. At still another locality, this limestone was found resting directly on the Hazel sandstone without any other bed being present. The only fossils found were *Fusulina;* but I think there can be no doubt of its Carboniferous age as its petrographic character and horizontality all correspond with rocks in the same range which carry an abundance of Carboniferous fossils.

We seem then to have this sandstone, if it really be such, at the very base of everything in this section. To occupy the position it does, it must either be a sedimentary deposit laid down prior to these ancient rocks or must be part of an immense boss of igneous material, but of still earlier age than the Potsdam. I think its character precludes this latter idea and believe that it is, as it appears to be, older than the Texan group.

I made an effort to trace it still further west in hopes of finding its relation to the schists and granites which we have, tentatively, referred to the Archæan, but was compelled to give it up before I had completed the examination.

CRETACEOUS AND LATER ROCKS OF PRESIDIO AND BREWSTER COUNTIES.

E. T. DUMBLE,
Houston, Texas.

The developments which have followed the discovery of quicksilver in the Terlingua district of Brewster county, Texas, have brought that region into some prominence, but, so far as I have seen, there has been very little written concerning its geology or that of the area immediately east of it.

The deposits were first brought to my notice during a trip to the Trans-Pecos region in the early part of the year 1894, at which time I secured good specimens of the cinnabar for the museum of the Geological Survey, although I did not have an opportunity to visit the locality. I first announced the discovery of the mineral at one of the regular meetings of the Academy. Later the region was examined by several mining engineers, and Prof. W. P. Blake described the California mine and its surroundings in a paper published in the Transactions of the American Institute of Mining Engineers, entitled "Cinnabar in Texas."* This was, I think, the first scientific publication on the subject, although there had been numerous references to it in the daily papers and in one or two trade journals.

My first examination of the place was made in company with Prof. W. F. Cummins, in August, 1897, and our trip extended as far eastward as the base of the Chisos Mountains. Some of the observations made will probably be of interest to others who may have occasion to make examinations there or elsewhere in the region, as we were so fortunate as to hit upon some excellent exposures.

Starting from Marfa, we drove by way of Alamitos to Alamo de Caesario. Securing pack animals and a guide at the ranch, we traveled east and southeast, by way of the Bishop mine, about twenty-eight miles; than southwest to the California mine. From this point our route was eastward until we reached the coal outcrop on the east of Terlingua creek and then southwestward to some new quicksilver prospects of Bishop and McGuirk, south of the mine. From this point we returned to Alamo de Caesario by way of Fresno creek.

*Vol. XXV, p. 68.

ROCKS.

The sedimentary rocks of the region comprise deposits of Cretaceous age overlain by a volcanic complex, probably Tertiary, but possibly continuing on into Quaternary time, and these are cut by eruptives and interbedded with them.

CRETACEOUS.

We found representatives of all the members of the Cretaceous system of the West Texas section from the Fredericksburg to the Exogyra Ponderosa marls, inclusive, and, although these beds present some differences from those of western areas as well as from their more eastern extensions, a sufficient number of characteristic fossils were obtained to fully identify everything above the Fredericksburg. The uncertainty as to the exact division between the Fredericksburg and the Washita that we have found elsewhere in West Texas and Mexico exists here also, but I have placed the line, provisionally, at that point where definite Washita forms prevail. At this point there is here a decided difference in the two limestones also, so that it makes a well-marked horizon.

Fredericksburg.

Deposits of the Fredericksburg limestone are well exposed some four or five miles east of Alamo de Caesario, where they form a line of hills which trend nearly north and south. The rocks are dark-colored, massive limestones with beds of Gryphæa. Towards the summit of the hills, beds with different forms of Caprina, etc., are found. The limestones here have also the siliceous character which marks them at other places. This line of hills is the axis of a fold involving both lower and upper Cretaceous sediments. The dip of the beds on the west of the hills is toward the west, while on the east the inclination is eastward.

In one of the canyons in this range of hills we found materials underlying the Fredericksburg rocks which we supposed to belong to the Comanche Peak group, but a sufficient number of fossils were not found for full identification.

Good exposures of the Fredericksburg are numerous in the region lying south and southeast of this and an escarpment running north and south for several miles is formed almost entirely of these rocks.

At the California mine these heavy bedded and massive, dark-colored limestones contain large numbers of a small gryphæa with a short beak similar to that observed in rocks of the same age in Coahuila. They also have the cavernous weathering of the Fredericksburg, and locally contain much chert. In general appearance and weathering they are entirely different from the overlying limestone containing Washita fossils. They are more highly metamorphosed and are strongly rugose, their exposed surfaces having an extreme roughness which is not found in any of the later beds. The difference between these heavy bedded, dark-colored and highly corraded rocks and the light-colored, red-banded, thin or irregularly bedded limestone of the Washita with *Ammonites leonensis* is well shown between the California mine and the hill one and one-half miles to the northwest.

Washita.

The principal difference noted in the Washita from that usually presented by it was in its thickness. The limestone is of its usual light yellowish color and has the biscuity weathering seen at other places. Its thickness, however, does not appear to exceed 100 feet, and at the California mine it is not more than 60 feet in thickness. Here, however, metamorphism has altered it in places, giving colors from gray to white, with ferruginous bandings and sharp angular fractures. The stress to which it has been subjected and the infiltration of ferruginous material have given it a curious concentric banding of yellow lines as described by Prof. Blake. In many places geodes of oxide of iron form the centers of the banded blocks. Where still farther metamorphosed, as at Bishop and McGuirk's prospect, the Washita is a granular limestone with nests and pockets of black calcite. The mercury occurs here in connection with these pockets of calcite.

Arietina.

The principal peculiarity of this bed is the scarcity of its characteristic fossil, the *Exogya arietina.* The fossils which characterize it here are those of its culminating horizon, such as *Nodosaria texana,* Con., *Gryphæa pitcheri,* Arietina variety, *E. drakei,* Cragin, Pectens, Echinoderms, etc.

At the California mine the rocks comprise clayey and siliceous shales, dark at the base and containing pyrites and gypsum in abundance. Higher up they are more siliceous and carry quantities of the foraminifer *Nodasaria texana.* They culminate in a band of clay carrying *Exogya drakei* and other forms mentioned. Portions of the beds are highly ferruginated and present an ochreous appearance. Numerous small openings have been made on these as prospect holes for precious metals.

Vola.

This limestone has a variable thickness, ranging from fifty to one hundred feet, and over a large area it forms a distinct bench above the Arietina clay. It is easily recognizable from its peculiar evenness of fracture and its creamy color.

Eagle Ford.

This division presents a basal series of lime shales and flags, succeeded by a considerable thickness of clays. The basal portion is identical with the deposits described as the Val Verde flags,* and carries a rich fauna of Eagle Ford species, of which Inocerami appear to be the most numerous.

The lime shales have a thickness of 250 feet in the vicinity of Alamo de Caesario, while the great thickness of the clays is east of Terlingua creek and amounts to several hundred feet.

Austin Chalk.

The materials here referred to this horizon, because of the occurrence in them of such typical fossils as *Radiolites austinensis* and the crenulate variety of *Exogyra costata,* comprise a series of black and yellow clays immediately overlying the black clays of the Eagle Ford without any marked change in material or conditions of deposition, there being seemingly a gradual passage from the deposits with one series of fossils to the beds containing the other. Its thickness is about 100 feet.

Overlying these yellow or brown clays there are 40 feet of brown sandy shale and sandstone containing numbers of a large oyster. Lying upon this is a deposit of brown clay with a bed of coal at its base, followed by a shale and beds of carbonate of iron. These beds have a thickness of 100 feet and are covered by 80 feet of sandy clay shales which carry a little lime and gradually pass into sandstone. The entire thickness from the base of the materials assigned to the chalk to the sandstone cap is 360 to 400 feet.

TERTIARY.

No attempt will be made to subdivide the materials here referred to as Tertiary, and later into divisions or series, since nothing was found which would form any basis for such a division.

By far the greater part of these materials are, apparently, of eruptive origin, although in places the volcanic conglomerates contain pebbles and boulders of limestone and siliceous rocks. Materials of this kind were observed along the entire route from a point a short distance south of Marfa to Alamo de Caesario, and they extend for some distance to the south and east of that locality. The deposits seem to be composed largely of volcanic mud or tuff, but are interbedded with conglomerates, agglomerates, and lava beds. The tuffs and agglomerates are usually light-colored and frequently porphyritic. They are generally thin bedded. In the limestone boulders which occur in the conglomerate we find fossils of both the Carboniferous and Cretaceous periods. For a distance of twenty miles south of Marfa the surface shows a considerable quantity of agate and chalcedony which has doubtless been derived from

*Bul. Geol. Soc. Am., Vol. III, p. 221.

the weathering of the underlying materials, but beyond that point very little material of this character was observed.

The hills along the route to Alamitos appear to be composed entirely of the tuffs and accompanying lavas, and in none of the exposures seen at San Jacinto Peak did we find anything else.

Similar materials were observed at Water Gate Pass and forming the escarpment on the western side of Green Valley. Here we found beds of grit overlain by conglomerate and this by a rhyolitic bed, followed by later flows of lava of various colors, the whole rising to a height of more than 400 feet above the valley. These beds are also well developed on Fresno creek, where they overlie the Cretaceous, and the provisional name Fresno beds is given them for descriptive purposes until such time as they may be more definitely placed.

In the vicinity of the ranch house at Alamo de Caesario the dark-colored (andesitic?) lavas are cut by porphyries. At the water hole one-half mile east of the ranch house erosion has exposed the base of one of the lava flows and the markings show plainly that the direction of its flow was from northeast to southwest.

Still further down the creek the grit which has been mentioned as the base of the Green Valley escarpment was found to be underlain by a highly crystalline limestone and shales, the whole forming a series of about 100 feet in thickness. The beds are not entirely regular, as the limestone occurs at times interbedded in the shale, while at others a grit or conglomerate may underlie or overlie it. One exposure showed this complex overlying a great volcanic breccia in which the boulders of lava are as much as 8 to 10 feet in diameter. Three miles east of Alamo de Caesario this breccia, which has a thickness of 100 feet, overlies a body of obsidian, which in turn rests directly upon the lime flags of the Eagle Ford shale.

The beds lying east of the Alamo de Caesario therefore appear to be the oldest of the Tertiary, and those to the northwest would be later. The only means, however, of differentiation would be in the composition of some of the materials and their connection with the different structural lines which prevail.

This series of Tertiary deposits is more nearly allied to those of the western portion of the United States and of Mexico than to those on the east. The same character of volcanic complexes occur here, though less in extent, that are found in Arizona and further north and west, and in Sonora and other parts of Mexico; deposits which are known east of the Trans-Pecos, for the most part, simply as thin beds of volcanic ash interbedded with certain materials of the later Cretaceous and others of the Tertiary period, the age of which is not later than Lower Claiborne, and in the Oakville beds, which are certainly Miocene.

These deposits as a whole greatly resemble those observed by the writer in Arizona and Sonora and described by him as the Trincheras and Nogales series. Our study of the locality under discussion, however, was too incomplete to warrant any statement regarding them, save that already made of their position and extent.

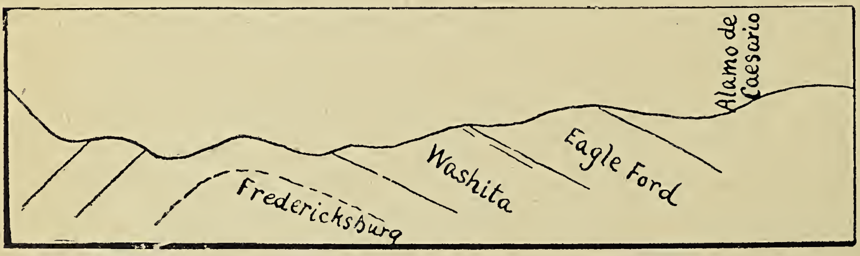
STRUCTURE.

The conditions observed indicate that subsequent to the deposition of the Upper Cretaceous series the deposits were elevated and a period of degredation followed, during which, in the western part of the area, all of the sediments above the line shales of the Eagle Ford were entirely removed. Toward the east the amount of erosion is less and less until finally we have the Cretaceous series almost entire. I think it probable that the uplift which changed the area from one of sedimentation to one of erosion was that which produced the east-west system of fractures.

Succeeding this period of erosion came its resubmergence, preceded, accompanied, and possibly succeeded by volcanic action. Beds of conglomerate were formed in places and covered by deposits of volcanic mud or ash, with or without admixture of pebbles from land areas, and at times alternating with conglomerates derived almost entirely from such source. The eruptives and lava flows which accompanied this were those of the northwest-southeast trend and they continued through a very long period.

The movement which succeeded this was that which gave the lines of faulting having approximately a north-south course, and to which is due the anticlinal of the Lower Cretaceous hills east of Alamo de Caesario.

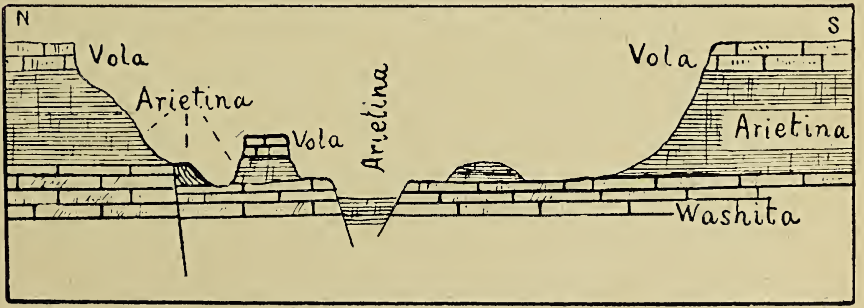
The final disturbance, so far as our observations go, is that of the northeast-southwest strike which is accompanied by the numerous porphyritic dykes and extrusions.



The above section shows the relations of the Cretaceous deposits between the Alamo de Caesario and a point seven miles east, near the Bishop mine. Our first impression was that the occurrence of the Eagle Ford shales, as noticed in some of the valleys, was probably due to unconformity of deposition, but it proved to be on account of block faulting which was especially well shown at other localities.

One of such manifestation, to which, on account of its especially notable character, we gave the name of the Ross ampitheater, occurs near Terlingua creek some twelve miles south of the end of the section given above. This ampitheater is about half a mile in diameter and approximately circular in outline. The enclosing walls are of the massive limestones of the Fredericksburg which form an almost perpendicular escarpment around the entire area, the only egress being through two or three narrow gorges. The dip of the Fredericksburg seems to be quaquaversal and away from the ampitheater. Near the center of the circle there rises a small hill of the Exogyra arietina marl capped by the creamy limestone of the Vola, its top, however, much lower than that of the limestone walls which surround it.

At no place was this character of faulting more clearly exhibited than at the California mine, where the conditions obtain which are shown in the following section.



The faulting here is that of the east-west strike, or that which seems to be the earliest disturbance recorded in these beds. As will be seen, the throw is not very great. In fact, the greatest throw in the entire area, so far as we saw them, was that of the Ross ampitheater which brought the Vola somewhat below the top of the Fredericksburg—probably not more than 250 feet. The width of the blocks as shown at the California mine is also small, being only from 10 to 40 feet. The structure is clearly exhibited by the numerous gulches which cut the beds.

The materials involved in the faults are much altered and ferruginated and along the edges the drag has brought portions of the shale to a perpendicular position, although in the center the beds are almost horizontal, unless disturbed by later action. Fragments of Washita limestone are mingled with the shale on the edges of the faults, and the materials are streaked with gypsum, while along and near the sides of the faults quantities of dog-tooth spar occur.

The northwest-southeast fracturing, which followed that of the east-west trend, was not accompanied by faulting in this immediate vicinity, and the joint planes made by it are ferruginated only to a limited extent compared with the others.

The succeeding dynamic action caused a series of fractures of north-south trend, but in this locality the faulting was very slight. Some of the fractures, which are ten feet in width, cut entirely and cleanly through the east-west breaks and leave the contents of such breaks well exposed by the erosion of the softer filling of those of later date. This series of fractures is filled with granular limestone containing stringers of calcite and strongly ferruginated. The fractures show distinct slickensided walls and carry much dog-tooth spar.

At other places in the area the north-south series of fractures in the Fredericksburg limestone frequently show some mineralization, being usually filled with oxide of iron and calcite in the form of dog-tooth spar. At most localities these vein-like streaks are only a few inches in width, but at times they open out to as much as six feet.

The openings described by Prof. Blake were chiefly in the hills lying north of this valley and in them little more than the Washita rocks were involved. The deposits, as suggested by him, are in reality both bedded and in fissures, and the principal mineralization here appears to be along the east-west trend, although one of the larger openings was on one of the northwest-southeast streaks.

An interesting structure study was observed in Fresno creek. The sedimentary rocks exposed belong principally to the Vola and overlying lime shales of the Eagle Ford, capped by a flow of rhyolite (?) of white color and well developed columnar structure.

The lime shales are folded and twisted, dipping in almost every direction, and have a number of intrusive sheets or sills of basalt which have been forced in along the stratification planes and now appear interbedded with them, occasionally cutting across the strata from a lower to a higher plane and less often cutting the shales as dykes. These intrusives are, for the most part, from a few inches to two feet in thickness, and simply blacken the shale for a few inches on either side. In the upper portion a larger mass, some 25 or 30 feet in thickness, lies between the strata and has metamorphosed both the underlying and the overlying rock to a distance equal to its own thickness.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901.

A PRELIMINARY REPORT ON THE AUSTIN CHALK UNDERLYING WACO, TEXAS, AND THE ADJOINING TERRITORY.

JOHN K. PRATHER, B. S.,
Waco, Texas.

VOLUME IV, PART II, NO. 8.

AUSTIN, TEXAS, U. S. A.:
PUBLISHED BY THE ACADEMY
1902.

A bluff of Austin Chalk in a creek near "Lover's Leap," three miles north of Waco, Texas.

A PRELIMINARY REPORT ON THE AUSTIN CHALK UNDERLYING WACO, TEXAS, AND THE ADJOINING TERRITORY.

JOHN K. PRATHER, B. S.,
Waco, Texas.

Prof. Robt. T. Hill, of the United States Geological Survey, gives the following divisions of the Upper Cretaceous: (1) Navarro formation; (2) Taylor formation; (3) Austin chalk; (4) Eagle Ford shale; (5) Woodbine or Dakota formation.

As early as 1845, Dr. Ferdinand von Roemer spent some time in studying the Cretaceous formations of Texas, and nearly all the fossils from the Austin chalk with which we are familiar were studied and described by him. Among those best known are the following invertebrates: Hemiaster texanus, Roemer; Ammonites (Mortoniceras) texanus, Roemer; Terrebratella guadalupæ, Roemer; Ammonites dentato carinatus, Roemer; Radiolites austinensis, Roemer; Scaphites (species not determined); Gryphæa aucella, Roemer; many nautiloids; Inoceramus deformis, Meek and Hayden; Inoceramus undulato-plicatus, Roemer; Spondylus gaudalupæ(?), Roemer; Pectens; Baculites asper (?) Morton—but of a much larger size than is usual in that species; Inoceramus confertim annulatus, Roemer; Inoceramus exogyroides, Meek and Hayden. Concerning the last-named species, Dr. T. W. Stanton says: "I had not seen this species before from Texas, although I believe it has been reported from the State. It was originally described from the Missouri river, near Fort Benton, Montana." Among the vertebrates are found the remains of such animals as Clidastes, Squalidonts, Cestracionts, and many others.

A paleontologist will find this a very fruitful field for investigation. The main difficulty to be encountered in the study of the fossils is that so many are either casts or are so fragile that they break in pieces in getting them out. Many of the invertebrates are so large that they are both hard to collect and difficult to transport.

The Austin chalk is the most characteristic of the Cretaceous formations. It is a massive stratified limestone with white and blue layers of different thicknesses. Sometimes the white and blue layers alternate, in other places there is a horizon of white followed by one of blue. Good lime can be made from it, but the Edwards limestone is better suited for lime-making and for building stone. The strata vary in thickness from 4 inches to 8 feet, but are rarely less than 1 foot, and are generally 1½ and 2 feet thick. The separating material, where found, is marl.

The topographic features of the Austin chalk are "much milder" than the Comanche Peak and other Lower Cretaceous horizons. The rock is also much softer and less crystalline. The fossils are different and the fossil horizons are not so distinct. The Austin chalk, generally speaking, is of great uniformity throughout its extent, but there are pockets of clay or marl of considerable size scattered through it, and some places are found where the rock is very hard, as if it had been exposed to heat. The rock is seen in hard lumps of a yellow, pink, and black color, and some of these pieces are as hard to break with a hammer as some of the hardest volcanic rocks. The rock, around these hard places, being softer, weathers out, and the hard parts are left covering the surface. Such places are only of limited extent, and occur at intervals. On disintegrating the limestone forms a black soil from 2 to 40 feet thick. Both oil and asphalt have been found in the Austin chalk of this county, but it has not yet been demonstrated that they are in paying quantities.

There are many faults in this formation, and in some localities the rocks are seen inclined in several directions.

One of the characteristics of the Austin chalk is the presence of large veins of calcite. They usually occur running north and south along fault lines, and are from ½ to 4 inches wide, and can sometimes be traced across the country for 3 or 4 miles. These calcite veins are also seen in the marl at the base of the Austin chalk, but they are not so large nor of such great extent. There are many nodules of iron pyrite scattered through the limestone, and in some places where they have weathered out they cover the surface of the ground. The chalk is also found in various stages of disintegration. It breaks up into fragments and cracks and seams are seen running through it in every direction. Often the whole surface of a hill is covered with loose pieces, some very finely divided. The frost seriously affects the chalk, causing it to disintegrate very rapidly. The white limestone layers are, when first exposed, softer than the blue limestone layers, and are not so compact, but the white stands exposure much better than the blue, for the latter, on being exposed to atmospheric agencies, is soon reduced to powder. The white rock is soft and chalky, and turns yellow on weathering. The blue layers turn a lighter blue. Both are very compart, and will hold water when used for the walls of a cistern. The blue rock holds the water better than the white, and makes as good a cistern as if cement had been used. On account of its poor transmitting qualities, the surface wells dug in the Austin chalk do not afford as much water as those dug in the other Cretaceous formations.

The thickness of the Austin chalk, as given by Prof. Robert T. Hill and Mr. Taff, is 500 feet. The best exposure in this county is found at Lover's Leap, on the Bosque, north of Waco. Here it is found exposed, without the marl, in a bluff 150 feet high. This section is as follows:

Blue limestone in bands of hard and soft parts, usually $1\frac{1}{2}$ and 2 feet thick, and containing cracks and joints every 3 or 4 feet	30	feet.
White limestone	$1\frac{1}{2}$	feet.
Blue limestone	2	feet.
White limestone	$2\frac{1}{4}$	feet.
Blue limestone	2	feet.
White limestone	3	feet.
Blue limestone	2	feet.
White limestone	$1\frac{1}{2}$	feet.
Blue limestone	1	foot.
White limestone	5	feet.
Blue limestone	$\frac{2}{3}$	foot.
White limestone	$2\frac{1}{2}$	feet.
Blue limestone	3	feet.
White limestone	5	feet.
Blue limestone	1	foot.
White limestone	$2\frac{1}{2}$	feet.
Blue limestone	1	foot.
White limestone	2	feet.
Blue limestone	2	feet.
White limestone	$1\frac{1}{2}$	feet.
Blue limestone	2	feet.
White limestone	5	feet.
Blue limestone	2	feet.
White limestone	4	feet.
Blue limestone	$\frac{1}{2}$	foot.
White limestone	$2\frac{1}{2}$	feet.
Blue limestone	1	foot.
White limestone	$2\frac{1}{2}$	feet.
Blue limestone	3	feet.
White limestone	2	feet.
Blue limestone	$\frac{1}{2}$	foot.
White limestone	$1\frac{1}{2}$	feet.
Blue limestone	$\frac{1}{2}$	foot.
White limestone	2	feet.
Blue limestone	2	feet.
White limestone	$1\frac{1}{2}$	feet.
White limestone with alternate layers of blue, 6 inches to 1 foot thick	46	feet.
Total thickness	$149\frac{11}{12}$	feet.

These white limestone layers are from $1\frac{1}{2}$ to 5 feet, but are usually 2 feet thick. The layers are almost horizontal.

Sections on a branch in South Pasture at Bosque Farm, 4 miles west of Waco, Texas, on the Waco and Crawford road:

I.

White limestone	5 feet.
Clay	1 foot.
White limestone	6 feet.
Clay	1 foot.
White limestone (very compact).........	10 feet.

II.

White limestone	15 feet.
Blue limestone	1 foot.
White limestone	5 feet.
Blue limestone	6 feet.

III.

White limestone	5 feet.
Blue limestone	5 feet.

IV.

White limestone	6 feet.
Blue limestone	4 feet.
White limestone	1 foot.
Blue limestone	6 feet.

V.

White limestone	1 foot.
Blue limestone	4 feet.
White limestone	1 foot.
Blue limestone	4 feet.

VI.

White limestone	30 feet.
Blue limestone, the rock contains many nodules of iron pyrite and a number of delicate fossils	6 feet.

VII.

Disintegrated limestone, brown to pink in color	45 feet.
White limestone more or less disintegrated	15 feet.
Disintegrated limestone of a clayey nature (yellow color), with small pieces of limestone scattered through it	35 feet.

Hard bands are present where the limestone is but slightly disintegrated.

In two cisterns dug in the Austin chalk at Bosque Farm, we have the following sections:

I.

White limestone, in layers	6 feet.
Blue limestone	15 feet.

II.

White limestone	9 feet.
Blue limestone	12 feet.

From a well on Bosque Farm, bored to a depth of 300 feet, the following section of the Austin chalk was obtained:

(1)	Soil	3 feet.
(2)	White limestone	26 feet.
(3)	Blue limestone	5 feet.
(4)	Dark brown limestone	9 feet.
(5)	White limestone	25 feet.
(6)	Light brown limestone	14 feet.
(7)	Brown limestone	15 feet.
(8)	Gray limestone	14 feet.
(9)	Blue limestone	20 feet.
(10)	Gray limestone	23 feet.
	Total	154 feet.

The drill also went through 152 feet of Eagle Ford shale, and was still in this formation when it stopped. The hill on which the well was drilled is 300 feet higher than the contact of the Austin chalk and Eagle Ford shale at Waco, on Waco creek, just below the bridge on Eleventh Street. Here the contact is as distinct and as clearly defined as if it had been drawn with a pencil. In an artesian well bored near Padgitt's Park by Mr. P. J. Fishback (of which a log was kept), the following section is given:

(1)	Soil dark, changing to a light calcareous loam	18 feet.
(2)	Soft white limestone (Austin chalk)	110 feet.
(3)	Blue shales (Eagle Ford)	162 feet.

This log is given in full by Prof. Robert T. Hill in his bulletin "On the Occurrence of Artesian and Other Underground Waters in Texas, Eastern New Mexico, and Indian Territory West of the 97th Meridian," page 109.

Neither at Lover's Leap nor in the two well borings, nor at the contact with the Eagle Ford shale on Waco creek, do we find the marl which is spoken of by Prof. Hill as "the marl at the base of the Austin chalk." In some measurements taken with an aneroid barometer, I find the limestone above the marl to vary in different sections, as follows: 35 feet, 60 feet, 100 feet, and 150 feet. These measurements were taken at intervals of from 1 to 6 miles apart. At Lover's Leap the whole thickness is not exposed, but judging from other observations here and at the nearest contacts with the Eagle Ford shale, there are not more than 20 feet unexposed. Thus it is seen that the thickness of the white rock (or Austin chalk) without the marl at the base, around Waco, as it now exists, not taking into account that which has been worn away, varies from 35 to 170 feet. The thickness of the marl at the base of the Austin chalk varies from 100 to 250 feet.

In a section of the Austin chalk and the underlying marl, beginning at the top and tracing it down to the contact with the Eagle Ford shale below, I find the thickness to be 200 feet, as follows: 60 feet of limestone, and 140 feet of marl. The marl gives the following section:

Marl	107 feet.
Argillaceous limestone	2 feet.
Marl	4 feet.
Argillaceous limestone	1 foot.
Marl	3 feet.
Argillaceous limestone, in bands	2 feet.
Marl	15 feet.
Argillaceous limestone	6 feet.

(This layer is composed of alternating bands of hard and soft rocks about 4 inches thick, containing Inocerami and Ostreæ). The marl contains small pieces of gypsum, selenite crystals, and nodules of limonite. It is somewhat stratified, and in places turns blue on weathering. It contains numerous fish teeth and vertebræ, and shark's teeth and the remains of a number of large vertebrates; also many Ostreæ and Inocerami. The rock often weathers into thin flakes. The marl is of a clay yellow color. It is sometimes found without the Austin chalk, as, for example, covering about 1 square mile around Speegleville; covering about 6 square miles of territory between Ross and Aquilla Stations, on the Texas Central Ry., and covering about 2 square miles around Bosqueville. While it affords good grazing land and good farm lands, it is inferior to the Austin chalk. It is usually characterized by the growth of mesquite, but elm and red cedar are also found. Just after passing the fish pond (going west), on the Waco and Crawford road, the argillaceous limestone layers of the marl occur, inclined at an angle of 45 degrees. The marl is seen around South Bosque Station in hills (which take the general form of the hills of the Austin chalk, but are more rounded) from 50 to 250 feet high. Potato Ridge is an isolated dome-shaped hill, 100 feet high, composed of this marl.

A section of the Austin chalk and this marl, taken on the road just above South Bosque Station, gives the following:

White limestone (or Austin chalk)	35 feet.
Marl	125 feet.

The best exposures of the marl seen in this county are around South Bosque Station. The marl is here seen covering an area ½ to 1½ miles wide and extending north and south for a distance of 14 miles. In a bluff on South Bosque, ½ mile above Mill's crossing, the bands of the argillaceous limestone of this marl, above the Eagle Ford shale, are 6 to 8 inches, and sometimes more than a foot thick. These bands break up into large flags, some of which may be 7 by 8 feet across. The fossils found in this marl are distinct, but more closely resemble those of the Eagle Ford shale than those found in the Austin chalk. The most common invertebrates found are Ostrea congesta, Conrad, and Inocerami.

Austin chalk occurs in a small isolated area on the east bank of the Brazos river, above the mouth of the Bosque, but the main body (in this county) begins at the mouth of the Bosque, on the south side, and follows the line of the Bosque up to South Bosque Station; thence southeast to within 2 miles of Lorena; thence through Ritchie to the southern part of Waco, about the mouth of Waco creek. This boundary on the south side is very hard to trace accurately on account of the almost imperceptible line of contact between the chalk and the Taylor or Ponderosa marl. It requires close observation and collecting to distinguish between them. The towns of Lorena, Bruceville, and Eddy are on the Taylor marl, which covers a large area in the southern part of this county, extending also over a large part of Falls and Bell counties.

From the description in this paper, and the sections given, it is seen that the marl spoken of by Prof. Hill as "the marl at the base of the Austin chalk" is of considerable importance. In the two well sections and at Waco on Waco creek, the white limestone, or Austin chalk, lies directly upon the Eagle Ford shale, and there is no trace of this marl between the two. In certain localities large areas occur, composed entirely of this marl, and there is no evidence that the Austin chalk once lay above it. It seems to be a separate and distinct formation for the following reasons:

(1) It has characteristic fossils which are not found in the Austin chalk, and

(2) It differs stratigraphically from the Austin chalk. I think this marl should be given a distinct name, and I propose the name of "South Bosque Marl," on account of the fine exposures found around South Bosque Station, McLennan county, Texas.

TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901,

TOGETHER WITH THE PROCEEDINGS FOR

THE SAME YEAR.

VOLUME IV, PART II.

AUSTIN, TEXAS:
PUBLISHED BY THE ACADEMY.
1902.

PROCEEDINGS

OF THE

TEXAS ACADEMY OF SCIENCE

FOR 1901.

[VOL. IV, PART II, NO. 9.]

[THIS NUMBER COMPLETES THE VOLUME.]

THE TEXAS ACADEMY OF SCIENCE.

OFFICERS FOR 1901-1902.

PRESIDENT, PROFESSOR J. C. NAGLE, College Station.
VICE-PRESIDENT, DR. HENRY WINSTON HARPER, Austin.
TREASURER, R. A THOMPSON, C. E., Austin.
SECRETARY, DR. FREDERIC W. SIMONDS, Austin.
LIBRARIAN, DR. WILLIAM L. BRAY, Austin.

Members of the Council.

HON. ARTHUR LEFEVRE.
PROFESSOR T. U. TAYLOR.
DR. WILLIAM M. WHEELER.

PAPERS PRESENTED AT REGULAR MEETINGS.

JANUARY 18, 1901.

"The Relations of Ants to Other Living Forms," Dr. William Morton Wheeler, Professor of Zoology in the University of Texas.

MARCH 23, 1901.

"Texas Forests; their Present Condition and their Future Management," Dr. William L. Bray, Adjunct Professor of Botany in the University of Texas.

APRIL 5, 1901.

"Texas Petroleum," Dr. William B. Phillips, Director of the University of Texas Mineral Survey.

FORMAL MEETING, JUNE 10, 1901.

"Contributions of the Nineteenth Century to Education," W. S. Sutton, M. A., Professor of the Science and Art of Education in the University of Texas.

"Rice Irrigation in Texas," Thomas U. Taylor, M. C. E., Professor of Applied Mathematics in the University of Texas.

"The Texas Railway Stock and Bond Law," R. A. Thompson, C. E., Expert Engineer to the Texas Railroad Commission.

"Texas Minerals and Mineral Localities" (by title), Frederic W. Simonds, Ph. D., Professor of Geology in the University of Texas.

"Notes on the Yellow Oxide of Mercury," E. P. Schoch, M. A., and O. W. Wilcox, School of Chemistry, University of Texas.

OCTOBER 26, 1901.

"The Influence of Applied Science," the Annual Address of the President, J. C. Nagle, M. C. E., Professor of Civil Engineering in the Agricultural and Mechanical College of Texas.

NOVEMBER 22, 1901.

"The Water Power of Texas," Thomas U. Taylor, M. C. E., Professor of Applied Mathematics in the University of Texas.

"An Extract from the Introduction to Roemer's *'Kreidebildungen von Texas,'* " Dr. Frederic W. Simonds and Edmund Wild, of the University of Texas.

Formal Mid-Winter Meeting, Rooms of the Business Men's Club, Waco, Texas.

DECEMBER 26, 1901, AT 8 P. M.

"Petroleum," an illustrated lecture, Dr. Frederic W. Simonds, Professor of Geology in the University of Texas.

DECEMBER 27, 1901, AT 10 A. M.

"The Petroleum of Jefferson County, Texas," H. H. Harrington, M. S., Professor of Chemistry in the Agricultural and Mechanical College of Texas.

"Factors of Progress in Insect Warfare," Frederic W. Malley, M. S., Professor of Entomology in the Agricultural and Mechanical College of Texas.

"Effects of Prolonged Exposure to X-Rays on the Human Body," D. W. Spence, B. S., C. E., Professor of Physics in the Agricultural and Mechanical College.

"The Big Springs of the Edwards Plateau," Thomas U. Taylor, M. C. E., Professor of Applied Mathematics in the University of Texas.

"A Preliminary Report on the Austin Chalk Underlying Waco and the Adjoining Territory," John K. Prather, B. S., Waco.

"A Preliminary Report on the Reptiles and Batrachians of McLennan County, Texas," John K. Strecker, Jr., Waco.

"Dr. Ferdinand von Roemer, Father of the Geology of Texas: His Life and Work," Dr. Frederic W. Simonds, Professor of Geology in the University of Texas.

In Memoriam.

COL. L. L. FOSTER,

PRESIDENT OF THE AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS.

BORN.............November 27, 1851.

DIED..............December 2, 1901.

DR. THOMAS FLAVIN,

EMERITUS DEMONSTRATOR OF ANATOMY,
MEDICAL DEPARTMENT, UNIVERSITY OF TEXAS.

BORN..................May 31, 1850.

DIED..............November 5, 1901.

LIST OF PATRONS, FELLOWS AND MEMBERS.

PATRONS.

Brackenridge, George W., San Antonio.
Halsted, Mrs. George Bruce, Austin.

Patrons, 2.

FELLOWS.

Bailey, Dr. James R., Adjunct Professor of Chemistry, University of Texas, Austin.
Benedict, Dr. H. Y., Adjunct Professor of Mathematics and Astronomy, University of Texas, Austin.
Bray, Dr. William L., Adjunct Professor of Botany, University of Texas, Austin.
Bruce, Dr. W. H., Professor of Mathematics, North Texas State Normal School, Denton, Texas.
Cerna, Dr. David, San Buenaventura, Coahuila, Mexico.
Charlton, O. C., Professor of Science, Baylor University, Waco.
Cline, Dr. I. N., U. S. Weather Bureau, New Orleans, La.
Curtis, George W., Weatherford.
Dumble, E. T., 1306 Main Street, Houston.
Dutton, C. E., Major, Ordnance Corps, U. S. A., Washington, D. C.
Ellis, Dr. A. Caswell, Adjunct Professor of the Science and Art of Education, University of Texas, Austin.
Halley, R. B., Professor of Science, Sam Houston Normal Institute, Huntsville.
Halsted, Dr. George Bruce, Professor of Mathematics, University of Texas, Austin.
Harper, Dr. Henry Winston, Associate Professor of Chemistry, University of Texas, Austin.
Harrington, H. H., Professor of Chemistry, A. and M. College, College Station.
Herff, Dr. Ferdinand, San Antonio.
Hilgartner, Dr. Henry L., Austin.
Hill, Robert T., Geologist, U. S. Geological Survey, Washington, D. C.
Howard, Dr. William R., Professor, Fort Worth University, Fort Worth.
Hyer, Dr. R. S., Regent, Southwestern University, Georgetown.
Keiller, Dr. William, Professor of Anatomy, University of Texas, Galveston.
Lefevre, Hon. Arthur, State Superintendent of Public Instruction, Austin.
Macfarlane, Dr. Alexander, Gowrie Grove, Chatham, Ontario, Canada.
McDaniel, Dr. A. C., 119 Alamo Plaza, San Antonio.
McRae, Dr. A. L., Professor of Physics, School of Mines, University of Missouri, Rolla, Mo.
Malley, F. W., Professor of Entomology, A. and M. College, College Station.
Mather, Dr. William T., Associate Professor of Physics, University of Texas, Austin.
Mezes, Dr. S. E., Professor of Philosophy, University of Texas, Austin.
Montgomery, Dr. Edmund, Hempstead.
Nagle, James C., Professor of Civil Engineering, A. and M. College, College Station.

Ness, H., Professor of Botany, A. and M. College, College Station.
Paine, Dr. J. F. Y., Professor of Obstetrics and Gynecology, University of Texas, Galveston.
Pearce, James E., Principal, Austin High School, Austin.
Puryear, Charles, Professor of Mathematics, A. and M. College, College Station.
Reichmann, Dr. Fritz, Instructor in Physics, Western Reserve University, Cleveland, Ohio.
Schoch, Eugene P., Instructor in Chemistry, University of Texas, Austin.
Simonds, Dr. Frederic W., Professor of Geology, University of Texas, Austin.
Smith, Dr. Allen J., Professor of Pathology, University of Texas, Galveston.
Smith, Dr. M. M., Austin.
Spence, D. W., Professor of Physics, A. and M. College, College Station.
Sutton, William S., Professor of the Science and Art of Education, University of Texas, Austin.
Taylor, Thomas U., Profesor of Applied Mathematics, University of Texas, Austin.
Thompson, Dr. James E., Professor of Surgery, University of Texas, Galveston.
Thompson, Robert A., Expert Engineer, Railroad Commission, Austin.
Townsend, C. H. Tyler, Special Deputy Collector of Customs, El Paso.
Wheeler, Dr. William M., Professor of Zoology, University of Texas, Austin.

Fellows, 46.

MEMBERS.

Acree, S. F., Instructor in Chemistry, University of Utah, Salt Lake City, Utah.
Anderson, W. E., Houston, Texas.
Askew, H. G., Auditor, Railroad Commission, Austin.
Averitt, S. D., Professor of Science, Decatur Baptist College, Decatur.
Baldwin, Zoe L., Eveleth, Minn.
Banks, A. L., Adjunct Professor of Mathematics, A. and M. College, College Station.
Bantel, Edward C. H., Instructor in Engineering, University of Texas, Austin.
Battle, Dr. William James, Professor of Greek, University of Texas, Austin.
Beville, Dr. A. J., Waco.
Black, Dr. H. C., Waco.
Boon, J. D., Professor, John Tarlton College, Stephenville.
Brown, R. L., Attorney at Law, Austin.
Burgess, Dr. John L., Waco.
Burgess, R. F., Attorney at Law, El Paso.
Burgoon, C. E., Assistant Professor of Mechanical Engineering, A. and M. College, College Station.
Callaway, Dr. Morgan, Professor of English, University of Texas, Austin.
Capps, Dr. E. D., Fort Worth.
Carroll, J. J., Waco.
Carson, J. W., Superintendent of Farm, A. and M. College, College Station.
Carter, Dr. W. S., Professor of Physiology and Hygiene, University of Texas, Galveston.
Clark, James B., Proctor, University of Texas, Austin.
Cline, Dr. J. L., U. S. Weather Bureau, Sandusky, Ohio.
Cline, R. R. D., Professor of Pharmacy, University of Texas, Galveston.
Cole, Dr. W. F., Waco.
Connell, J. H., Professor of Agriculture, A. and M. College, College Station.
Cooke, Dr. Henry P., Galveston.
Cooper, Dr. O. H., President of Baylor University, Waco.

Cox, T. S., Superintendent of Public Schools, Hillsboro.
Crow, Dr. C. L., Weatherford.
Darden, W. E., Principal Waco High School, Waco.
Dohmen, Franz J., Solomon Str., 25 a pt., Leipzig, Germany.
Duggan, Dr. Malone, Quarantine Inspector, Eagle Pass.
Duval, E. P. R., Tutor in Pure Mathematics, University of Texas, Austin.
Endress, George A., Assistant Engineer, Monterey Steel Co., Monterey, Mexico.
Ferguson, A. M., Instructor in Botany, University of Texas, Austin.
*Flavin, Dr. Thomas, Demonstrator of Anatomy, University of Texas, Galveston.
*Foster, L. L., President, A. and M. College, College Station.
Freshney, Alfred, Fellow and Storekeeper in Chemistry, University of Texas, Austin.
Garrison, Dr. George P., Professor of History, University of Texas, Austin.
Geisecke, F. E., Professor of Drawing, A. and M. College, College Station.
Halbert, Dr. O. I., Waco.
Harper, Dr. W. A., Austin.
Head, W. Burris, President, Grandview College, Grandview.
Hexter, J. K., Victoria.
Hill, Benj. F., Assistant Geologist, University of Texas Mineral Survey, Austin.
Hill, Dr. H. B., Austin.
Hitt, I. R., Professor, Coronal Institute, San Marcos.
Holman, J. R., Assistant Engineer, T. & N. O. R. R., Houston.
Holmes, W. E., Reef, Arizona.
Hornbeak, S. L., Professor, Trinity University, Tehuacana.
Houston, David Franklin, President-elect, A. and M. College, Dean of Academic Faculty, University of Texas, Austin.
Houston, Otho Sam, President, First National Bank, Stephenville.
Howard, E. E., Bridge Engineer, Alexandria, La., Box 502.
Howe, J. M., Assistant Engineer, H. & T. C. R. R., Houston.
Huberich, Dr. Charles H., Instructor in Political Science and Law, University of Texas, Austin.
Hunnicutt, W. H. P., Land Office, Austin.
Johnson, Dr. J. B., Professor of Mathematics, Baylor University, Waco.
Jones, W. G., Temple.
Kerr, E. W., Assistant Professor of Mechanical Engineering, A. and M. College, College Station.
Long, W. H., Jr., Professor of Biology, North Texas State Normal School, Denton.
Mackensen, B., Teacher of Science, San Antonio High School, San Antonio.
Magnenat, Dr. L. E., Demonstrator of Pathology, University of Texas, Galveston.
Maxcy, John W., Civil Engineer, Houston.
Means, J. H., 215 San Pedro Avenue, San Antonio.
Miller, Thomas D., Gas Works, Dallas.
Mitchell, J. D., Victoria.
Moore, Dr. J. T., Levy Building, Galveston.
McLaughlin, Dr. James W., Professor of Medicine, University of Texas, Galveston.
O'Connor, Jas. L., Architect, Austin.
Palm, Omerod H., Assistant Chemist, University of Texas Mineral Survey, Austin.
Parker, R. D., Assistant Engineer, I. & G. N. R. R., Marlin.

Pittuck, B. C., Agricultural Experimental Station, A. and M. College, College Station.
Poston, W. C., Professor, Weatherford College, Weatherford.
Price, R. H., Professor of Horticulture, A. and M. College, College Station.
Primer, Dr. Sylvester, Associate Professor of Teutonic Languages, University of Texas, Austin.
Prather, John K., Waco.
Prather, Dr. William L., President, University of Texas, Austin.
Raines, C. D., Librarian, Department of Agriculture, Insurance, Statistics and History, Austin.
Reber, Captain Samuel, Signal Corps, U. S. A., care War Department, Washington, D. C.
Reid, Dr. E. Emmett, Professor, Baylor University, Waco.
Reynolds, H. P., Teacher of Science, El Paso High School, El Paso.
Rhea, W. Alex., Attorney at Law, Dallas.
Rice, C. D., Instructor in Mathematics, University of Texas, Austin.
Rucker, Augusta, Instructor in Zoology, University of Texas, Austin.
Sammonds, J. W., County Surveyor, Anderson county, Palestine.
Schmidt, E. F., 508 Travis Street, Houston.
Seltzer, H. K., Bridge Engineer, Box 502, Alexandria, La.
Smith, Felix E., Superintendent of Schools, Victoria.
Smith, Dr. H. S., Austin.
Smith, Noyes D., Austin.
Smith, Robert F., Associate Professor of Mathematics, A. and M. College, College Station.
Smith, Dr. Q. C., Austin.
Sonntag, Dr. A. F., Waco.
Stanfield, S. W., Professor of Science, Coronal Institute, San Marcos.
Strecker, J. K., Jr., Waco.
Stevenson, J. D., Attorney at Law, San Antonio.
Sublette, G. W., City Engineer, 2616 First Avenue, Minneapolis, Minn.
Swearingen, P. H., Attorney at Law, San Antonio.
Tilson, P. S., Associate Professor of Chemistry, A. and M. College, College Station.
Tompkins, Stonewall, care Weld & Neville, Houston.
Warfield, Dr. Clarence, San Antonio.
Weller, William M., care J. S. Cullinan Co., Corsicana.
Wells, Dr. E. H., Professor of Natural Science, Baylor Female College, Belton.
White, E. A., Professor, A. and M. College, College Station.
Whitten, Harriet V., Tutor in Geology, University of Texas, Austin.
Williams, Mason, Attorney at Law, San Antonio.
Wilcox, O. M., Assistant in Chemistry, University of Utah, Salt Lake City, Utah.
Wipprecht, Walter, Bryan.
Worrell, S. H., Assistant Chemist, University of Texas Mineral Survey, Austin.
Wyche, Benjamin, Librarian, University of Texas, Austin.

Members, 109.
Total, 157.

*Deceased.

CONSTITUTION OF THE TEXAS ACADEMY OF SCIENCE (AS AMENDED JUNE 12, 1899, JUNE 10, 1901, AND DECEMBER 27, 1901).

Article I.—Name.

Section 1. This Association shall be called "The Texas Academy of Science."

Article II.—Objects.

Section 1. The objects of the Academy are: To advance the natural and exact sciences both by research and discussion; to promote intercourse between those who are cultivating science in different parts of the State; and especially to investigate and report on any subject of science or industrial art, when called upon by any department of the State government.

Article III.—Membership.

Section 1. The Academy shall consist of Members, Fellows, and Patrons.

Sec. 2. In order to become a member, the applicant must be recommended in writing by two members or Fellows, approved by the Council, and elected by ballot of the Society. In order to be elected, two-thirds of the ballots must be affirmative.

Sec. 3. Fellows shall be elected by the Council from such of the Members as are professionally engaged in science, or have in any way advanced or promoted science.

Sec. 4. Anyone who contributes to the funds of the Academy the sum of five hundred dollars shall be classed as a Patron.

Article IV.—Officers.

Section 1. The officers of the Academy shall consist of a President, a Vice-President, an Honorary Secretary, a Treasurer, and a Librarian. They shall be elected from the Fellows by ballot of the Academy at the June meeting of each year.

Sec. 2. The officers of the Academy, together with the Past Presidents and three Fellows to be elected by the Academy at the June session in each year, shall constitute a Council for the transaction of such business as may be assigned to them by the Constitution and By-Laws of the Academy.

SEC. 3. The President of the Academy, or in case of his absence the Vice-President, shall preside at the meetings of the Academy and of the Council; shall nominate all committees except such as are otherwise specially provided for; shall refer investigations required by the State government to members especially conversant with the subject, and report to the Academy at its next formal meeting; and with the Council shall direct the general business of the Academy.

SEC. 4. The Honorary Secretary shall conduct the correspondence, advise with the President and Council in cases of doubt, and make a report at the formal meeting in June of each year.

It shall be the duty of the Secretary to give notice to the members of the place and time of all meetings, of all nominations for membership, and of all proposed amendments to the Constitution.

The minutes of each meeting shall be duly engrossed before the next meeting, under the direction of the Secretary.

SEC. 5. The Treasurer shall attend to all receipts and disbursements of the Academy, giving such bond and furnishing such vouchers as the Council may require. He shall collect all dues from the members, and keep a set of books showing a full account of receipts and disbursements. He shall present a general report at the June session of each year.

ARTICLE V.—MEETINGS.

SECTION 1. There shall be two formal meetings of the Academy each year, one of which shall be held in June, at Austin, and the other within Christmas week at any place selected by the Council.

SEC. 2. The ordinary meetings of the Academy shall be at Austin during the months of October, November, January, February, March, April, and May, the place and dates to be fixed by the Council.

SEC. 3. The meetings of the Local Sections may be provided for in the "rules for their government."

ARTICLE VI.—PAPERS.

SECTION 1. Intimation of the business of each meeting shall be given to each member by means of a printed card.

SEC. 2. No title of a paper can appear on the card before the paper itself, or an abstract of it, has been approved by the Council or the Secretary.

SEC. 3. The Academy may provide for the publication, under the direction of the Council, of proceedings, memoirs, and reports.

SEC. 4. The advice of the Academy shall be at all times at the disposal of the State government upon any matter of science or art within its scope.

ARTICLE VII.—ASSESSMENTS.

SECTION 1. The admission fee for a Member shall be two dollars, and the admission fee for a Fellow five dollars, or an additional three dollars on promotion to Fellowship.

SEC. 2. The annual assessment shall be one dollar.

ARTICLE VIII.—ALTERATION OF THE CONSTITUTION.

SECTION 1. No part of this Constitution shall be amended or annulled, except after notice given at a formal meeting, and approval by two-thirds of those voting at the succeeding formal meeting.

ARTICLE IX.—LOCAL SECTIONS.

SECTION 1. Local Sections of the Academy may be established by the Council on receipt of a request to do so signed by ten members of the Academy in good standing residing in the territory within which the Local Section is desired.

SEC. 2. Such Sections shall appoint their own officers and committees, and may make any rules for their government not inconsistent with the Constitution and By-Laws of the Academy.

SEC. 3. The place of headquarters and definite territory selected by each Local Section within which its membership must reside will be subject to the approval of the Council.

SEC. 4. Any Local Section may be dissolved by the Council for good and sufficient cause.

BY-LAWS.

CHAPTER 1.—MEMBERSHIP.

1. No person shall be accepted as a Member or Fellow unless he pays his initiation fee and the dues for the year within three months after notification of his election.

2. An arrearage in payment of annual dues shall deprive a Member or Fellow of taking part in the management of the Society and of receiving the publications of the Society. An arrearage for one year shall be construed as a notification of withdrawal.

CHAPTER 2.—ELECTION OF MEMBERS.

1. Nominations for membership may be made at any time in due form to the Honorary Secretary.

2. The form of the nomination of Members shall be as follows:

In accordance with his desire, we respectfully nominate for membership in the Texas Academy of Science—

Full name: ....

Address: ....

Degrees, if any: ....

Occupation: ....

Branch of science engaged in, work already done, and publications, if any ....

Signed by two Members, or Fellows.

The Honorary Secretary will bring the nominations before the Council at its first meeting thereafter, and the Councl will signify its approval or disapproval of each nomination.

The Honorary Secretary shall have lists or cards printed and sent to each Member, giving name of each nominee and such information as may be necessary for intelligent voting.

The Members and Fellows receiving the list will signify their approval or disapproval of each nominee, and return list to the Honorary Secretary.

At the next meeting of the Council, the Honorary Secretary will present the lists and the Council will canvass the returns and declare the results at the next succeeding meeting of the Academy.

CHAPTER 3.—COMMITTEE ON PUBLICATION.

The Council shall appoint a Committee of Publication, consisting of three members, of which the Honorary Secretary shall be chairman ex officio, who shall decide upon the value of articles submitted to them for publication, and in case of doubt be authorized to call upon any member of the Society who is specially familiar with the branch of science treated of for assistance in such determination.

If the paper is accepted, the author must deposit with the Honorary Secretary a sufficient sum to defray publication charges, at a rate not exceeding $2.00 per octavo page, and pay for all cuts or illustrations.

(At present the Academy bears a part of the expenses of publication.)

CHAPTER 4.—ORDER OF BUSINESS.

1. Call to order by Presiding Officer.
2. Statements by President.
3. Report of Council.
4. Report of Treasurer.
5. Election of Officers.
6. Declaration of results of election of Officers.
7. Reports of Committees.
8. Announcements.
9. Unfinished Business.
10. New Business.

At the monthly meetings the order of business shall be:

1. Call to order by the President.
2. Statements by the President.
3. Presentation of memoirs, and discussion.
4. Report of Council.
5. Announcements.

CHAPTER 5.—ELECTION OF OFFICERS AND OTHER MEMBERS OF THE COUNCIL.

(Added April 12, 1895.)

The Honorary Secretary shall send to each member a circular letter including a list of the Fellows, with a request to send in a ballot nominating each officer and other members of the Council. The ballot must be received by the Honorary Secretary by May 15. The Council will select two from the three nominees receiving the highest number of nominations for each position, and prepare a ballot to be sent to each member of the Academy in time to permit his vote being received previous to the June meeting, at which time the votes will be counted.

CHAPTER 6.—PERMANENT MEMBERS.

(Added January 11, 1896.)

Any Member of the Academy may become a "permanent member" on payment of fifty dollars; all "permanent members" to be free from all subsequent assessments.

The money received from this source shall be invested as a permanent fund, the interest of which may be used towards paying for the printing of the transactions of the Academy or for such other purposes as the Council may determine.

CHAPTER 7.—PROXIES.

(Added October 3, 1899.)

A proxy may be used at a meeting of the Council only when necessary to constitute a quorum, and such proxy may be held only by a duly elected member of the Council.

1751