TWENTIETH REPORT
OF
THE MICHIGAN ACADEMY OF SCIENCE

PREPARED UNDER THE DIRECTION OF THE COUNCIL

BY
G. H. COONS
CHAIRMAN, BOARD OF EDITORS

BY AUTHORITY

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1918

PUBLISHED
NOVEMBER 22, 1919.

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LETTER OF TRANSMITTAL.

TO HON. ALBERT E. SLEEPER, *Governor of the State of Michigan:*

SIR—I have the honor to submit herewith the XX Annual Report of the Michigan Academy of Science for publication, in accordance with Section 14 of Act No. 44 of the Public Acts of the Legislature of 1899.

Respectfully,
I. D. SCOTT,
Secretary.

Ann Arbor, Michigan, June, 1918.

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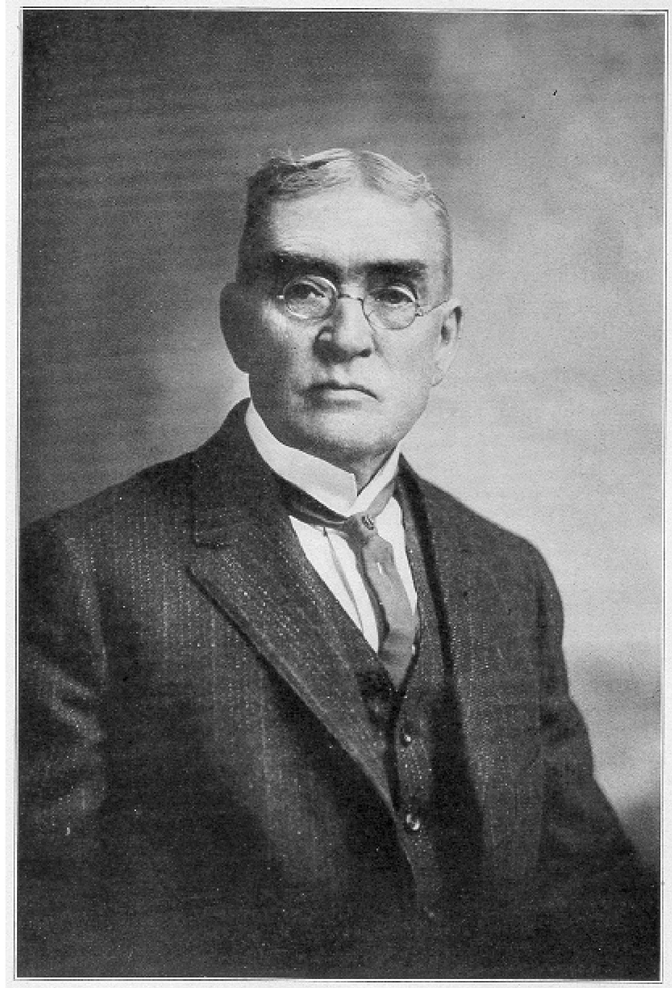


[Plate I. Charles Keene Dodge.]

CHARLES KEENE DODGE.
1844-1918.

The science of botany in Michigan suffered an irreparable loss in the death of Charles Keene Dodge on March 22, 1918. A most enthusiastic field worker and an able and painstaking systematist, it is due largely to him that so much is known of our vegetation; and his pleasing personality made his life a real inspiration to his fellow naturalists.

Mr. Dodge was born on April 26, 1844, on a farm near Jackson, Michigan. He received the usual country schooling, then prepared for college at the Ann Arbor Union School, from which he graduated in 1866. The same year he entered the University of Michigan, graduating four years later from the classical course. At that time not much botanical work was given in the University, but he was able to take a six weeks course under Alexander Winchell, then professor of geology. Although always keenly interested in the out-of-door world, it is due no doubt to Professor Winchell's influence that Dodge became so attracted to plant life.

After his graduation from the University he taught for two years at Rockland, Ontonagon County, and two more years at Hancock, Houghton County. In the latter place he read law for a year and was admitted to the bar in 1875, when he moved to Port Huron to practise his profession. Here all of his spare time was spent in the identification of the plants of Lambton County, Ontario, and of St. Clair County. In 1893 he gave up his practise and entered the United States Customs Service at Port Huron, and with greater leisure was able to do more systematic field work, to start a permanent herbarium and to prepare some of his work for publication. In 1908 he became associated with the Michigan Biological Survey for which he has spent a part of every subsequent summer in active field work in various parts of the state. He became an Associate in Botany in the Museum of Zoology, University of Michigan, in 1912, and remained a valued member of the staff until his death.

The following papers of Mr. Dodge have been published and there are several more in manuscript.

Flora of St. Clair County. Ann. Rept. Mich. Horticultural Soc., 1899.

Observations on the Crataegi in the Vicinity of Port Huron. Ann. Rept. Mich. Acad. Sci., 1907, 123-125.

A Botanical Trip to Thunder Bay Island. Ibid., 1908, 40-42.

Results of the Mershon Expedition to the Charity Inlands, Lake Huron, Ibid., 1911, 173-191,

Catalog of Plants, in the Biological Survey of the Sand Dune Region on the South Shore of Saginaw Bay, Michigan. Mich. Geol. and Biol. Surv., Pub. 4, Biol. Series 2, 1911, 65-121.

The Flowering Plants, Ferns and Fern Allies Growing Without Cultivation in Lambton County, Ontario. Ibid., 1914, 132-201.

Annotated List of Flowering Plants and Ferns of Point Pelee, Ontario, and Neighboring District. Canada Department of Mines, Ottawa, 1914.

Contributions to the Botany of Michigan. Misc. Publications, Mus. of Zool., Univ. of Mich., No. 4, 1918, 1-4.

ALEXANDER G. RUTHVEN,
BRYANT WALKER,
FREDERICK C. NEWCOMBE.

20th Mich. Acad. Sci. Rept. 1918.

ADDRESS OF THE PRESIDENT OF THE MICHIGAN ACADEMY OF SCIENCE.

DELIVERED THURSDAY, MARCH 28.

AUDITORIUM, NATURAL SCIENCE BUILDING.

NEW WINE IN OLD BOTTLES.

LEROY H. HARVEY.

The theme which I have chosen is a favorite one having a frequency almost as great as exaugurals. However, it seems to possess an almost unique significance at this juncture in our national life and so I venture to invite your consideration with me of the relation and function of science to our future effort in Americanization.

At the dedication of the Pasteur Institute in Paris in 1888, that significant time in French national life, Pasteur in his closing remarks said: "If I might be allowed, Mr. President, to conclude by a philosophical remark inspired by your presence in this House of Work, I should say that two contrary laws seem to be wrestling with each other nowadays; the one a law of blood and death, ever imaging new means of destruction, and forcing nations to be constantly ready for the battlefield—the other a law of peace, work and health, ever evolving new means of delivering man from the scourges which beset him." Pasteur's philosophical meditations have burst into a terrible reality—a reality whose problems are involving the best thought and sinew of our nation.

Never before in the development of our country has the scientific ability of the nation been so thoroughly cataloged and subjected to critical analysis and utilization as today. Thru the National Council of Defense "American Men of Science" are drafted under centralized direction and with a single end in view—the perpetuation of our political, educational arid moral ideals—a true union of science not only in the interest of national welfare but international equity as well. How dominating a part scientific applications are wielding in this titanic struggle is common knowledge, for "he who runs may read." The temporary destructive aspects crowd the horizon of our interests and possibly our desires. . Yet these very efforts are leading upward and tho we travel thru a slough of despond, in the end we will emerge with ideals higher and banners triumphant and mankind will be richer for the anguish of these years. Witness: the martial applications of medical and sanitary science which have been scarcely short of miraculous and the spectacular achievements in the field of commercialized scientific processes which bid fair to place America in a position of national economic security.

Science now sits at the right hand of public approbation as the Prime Minister of national unity and continuity. The rising spirit of Americanism demands the tangible measured in human achievement for the welfare of the state. The nation is now paying its homage to the bulwarks of its organization—its men of science, the apostles of realism. American Science is rising to the zenith of societal evaluation. We herein witness the dawning of a golden educational opportunity.

> "There is a tide in the affairs of men,
> Which taken at the flood, leads on to fortune.
> On such a full sea are we now afloat,
> And we must take the current while it serves,
> Or lose our venture."

But opportunity confronts us with an equal responsibility. "Soldiers of Common Good! Rebuilders of Civilization! Moulders of the Destiny of the World! Your great task is ready." Shall we assume it?

"The aim of modern science is to discover, if it can, the ultimate realities in terms of which all forms of nature may be stated." Thus as scientists we are interested in the advancement of knowledge, in progressively pushing farther into the unknown, in the better synthesis of facts already acquired, in the formulation of underlying principles, in the contribution of principle or fact which shall possess technological value and which shall contribute to the emancipation of the body, to the "peace, work and health of the world." But in this most of us play a dual role. Not only are we scientists but we are teachers of science as well. Most of us hold positions whose justification rests securely only upon this latter activity. In fact the general public today supports science thru taxation for what it is, not for what it may become however short sighted and unintelligent this may be. It must be clearly apparent that the function of science is one thing; the function of science in education quite another. It is to this latter phase that I now ask your especial attention.

As teachers of science, our efforts reflect clarity and objectiveness in just the proportion in which we realize the role of science in education, secondary and collegiate. I believe that you will agree in the premise that in undergraduate instruction the main emphasis should be placed not on the making of scientists, but in building for rational citizenship. Not that I for a moment hold that the two are of necessity incompatible. Altho, graduate work has for its particular function the training for research, I would nevertheless urge the desirability of research work in the preparation of a teacher. However, we cannot lose sight of the fact that in Michigan in 1915 only 22.66 per cent of our population was found in our public educational institutions. Of these 88.99 per cent were in the Elementary Grades, 8.74 per cent in Secondary Schools and 2.27 per cent in our Higher Educational Institutions. Of the 8.74 per cent of secondary students only about 67 per cent appear to have had a course in science,[1] i. e. only about 1 per cent of our total population is annually under science instruction in our High Schools. In our Colleges and University the condition is scarcely more satisfactory. It is therefore evident that the colleges and University are playing an almost negligible role in the science education of the state. How effective the indirect effort of our Institutions of Higher Education will be; how effectively our standard bearers will be able to "carry on" depends mainly upon our full realization of the function of science in secondary education and the shaping of the content and conduct of courses specifically to this end. It is our great privilege to train the ambassadors of science to the people.

As teachers of science, our duty lies along two main avenues of endeavor. In the first place, it is our distinction to transmit those facts and generalizations of science of social import to the youth of today, the social heirs of all the ages. We must always be fully conscious that one claim of science in education rests upon its sociological contribution of utilitarian facts. Awareness of this will inevitably react selectively upon content. Fundamental as is this point of view it seems not infrequently to be deplorably lost to sight.

We make but few scientists but we have the opportunity of indirectly moulding an intelligent citizenship. It is obligatory upon each of us to see that the endless stream passing thru our lecture halls comprehends the relation of our chosen field to societal evolution and human welfare and its correlation with other realms of human knowledge. The deeds of Pasteur are as pertinent in social advancement as those of Napoleon. Youth cries for the humanizing of science, for its direct relation to Community and National life. Science led the children of man out from the wilderness of savagery. The scientific knowledge which permeates a race and passes into general social utilization provides us with a trustworthy index of its social status. Science applications have one by one shattered the shackles of ignorance and superstition thus emancipating physical man from the bondages of his savage environment. Watt, Fulton, Morse, Bell and Marconi have severed the shackles of time and space. Disease and suffering have found amelioration in the labors of Jenner, Pasteur, Ross, Reed, Lister, Simpson and Morton. Scientific agriculture with food preservation and conservation not only places our civilization in a position to feed its own but to wield the turning power in this international conflict for social and political justice. Conservation of all natural resources, physical and vital, insures the continuity of statehood. And Mendel's law illuminates the path avoiding racial deterioration.

On the one hand then, science instruction finds justification in the technological value of its contribution to the state. We may also note, pari passu, that the unique role of the humanities in education, viz., the development of appreciation, can doubtless in large measure be met by humanized science. Science discoveries and inventions provide a ready and rational basis for lessons in community and national life. Vitalize science as well as civics. A historical touch with the lives and works of such great scientists as Aristotle, Gallileo, Bruno, Lavoisier, Huxley, Pasteur, Lyell, Darwin, Franklin, Reed, Mendel and a score of others is as potentially cultural as a study of the lives and accomplishments of great warriors, statesmen and economists. The study of the historical development of the germ theory of disease, the doctrine of evolution, cosmic hypothesis or uniformitarianism are as certain to ignite the fires of ambition and social determination, to generate aesthetic sensation and ethical action as a study of Old English Prose or Modern Drama. I cast no reflection nor place any undervaluation on any branch of human knowledge. I would only urge that the study of science and the lives of its makers are of as great social and ethical value and possess equal educational importance in leading to a comprehension and appreciation of our modern social complex and one's social obligation as the content of any other field of human achievement.

Out of the travail of war was born the Royal Society, Milton's Academies and the Ecole Polytechnique. Not only new institutions but new educational ideals and policies have thus taken origin. Under the organizing genius of Napoleon I came "the division of France into academies, the founding of lycees, the reestablishment of the great Ecole Normale, and the organization of the Imperial University with new science courses and new provincial faculties at Rennes, Lille and elsewhere." Do we stand on the verge of another great educational readjustment and reconstruction? The hand writing is to be plainly seen upon the wall. Need we astrologers or soothsayers? The times need a Daniel and he "shall be clothed with scarlet, and have a chain of gold about his neck, and shall be the third ruler in the kingdom." Shall educational reconstruction arise from the insistent demands of the mores or shall we as the guardians of scientific knowledge assume the role of prophets and lead the way?

Yet, the educational obligation of the teacher of science is not discharged even when he has fully accomplished the ideals which have just been outlined. Overwhelmingly important have been the facts and applications of science in the evolution and present maintenance of the modern social organism. Yet we must ever fully appreciate that they are but results—conquest over Nature. Conquests of mind—mind emancipated from the bondages of desire and dogma, of prejudice and passion, of greed and ignorance, of mysticism and logical necessity. Conquests of the unfettered mind rigorously guarded by the canons of scientific procedure.

It was in this emancipation of the mind that the foundations for the emancipation of the body and societal evolution were securely laid. In savagery man's control of Nature was due to luck and accidental discovery; in modern civilization, however, it seems quite certain that further amelioration of man's lot will largely come only as the result of rigorous scientific endeavor. In the words of John Dewey: "the future of civilization depends upon the widening spread and deepening hold of the scientific habit of mind." A habit of mind whose sole desire is the extension of the boundaries of human knowledge. We must not forget that it was Faraday who made transcontinental conversation possible, Langley who enunciated the principles which led to aerial navigation. Marconi's wireless had its origin in the researches of Clerk, Maxwell and Hertz, and Newton's prism gave us the alphabet of the stars. "The history of science shows that the greatest advances have always been made by men who undertook their inquiries into Nature without thought of proximate or ultimate application or pecuniary reward." When "men began to observe and interrogate Nature for the sake of learning her ways, and without concentrating their attention on the expectation of useful applications of such knowledge" then came forth fundamental facts and underlying principles. Material advancement lies solely in the extension and application of such facts and principles. All honor to the apostles of Utility! But "real progress comes from the pursuit of knowledge for its own sake." It is scientific research which creates. May the time hasten when the creative searcher will be cherished by society above all others. Today the public applauds indiscriminately, if not unjustly, the more spectacular utilitarian application. "Lest we forget": the rungs of the ladder of societal advancement were not forged simply in arduous self-sacrificing endeavor but in endeavor hedged by barriers to mental fallibility and unscientific generalization.

Origins fade into the mist of antiquity, but when man first began to appeal directly to Nature for truth rather than to authority—when meditation succumbed to observation, the initial step in the "emancipation of the human race from the trammels of traditional doctrine" was taken. From the banks of the Nile and the Valleys of the Euphrates and Tigris come records of scientific observations made forty centuries ago. Some seventeen centuries later the "Founder of Biology" gave observation and classification of facts a permanent place in thot. However, the Aristotelian school which dominated thot for more than two thousand years took no cognizance of verification thru experimentation. Scientific Method which had thus been so happily started flickered weakly thru the periods of Hellenic and Roman culture; was dimmed by Barbarian and opinionative influence during those long wearying centuries of the Dark-Ages to be finally extinguished thru appeal to authority and the renunciation of the senses.

Next appears the "greatest apparition of the Middle Ages," Roger Bacon, who in the bold appeal which he made in his Opus Majus (1276) to experiment and observation of Nature, "stood out as the champion of unfettered inquiry in a period of scientific stagnation." For his temerity "he suffered persecution, banishment and imprisonment." In the brilliant work of Galileo (1564-1642) and the fearless declarations of Giordano Bruno (1550-1600) Bacon's canons lived on fanned into flame by the murders of the Inquisition. The faithful and untiring labors of Gilbert (1540-1603), Tycho Brahe (1546-1600), Kepler (1571-1630) and Harvey (1578-1657) were brilliant in their successful demonstration of Roger Bacon's claim that "authority has no value unless its reason be shown" and that "armed with experiment and calculation, science must not be content with facts, though these may have their utility; it seeks truth; it wants to find out the laws, the causes—*canones, universales regulae.*" While the works of these investigators had confounded orthodox philosophy it remained for that philosophical opportunist Francis Bacon in his Novum Organum (1620) to promulgate the creed of the Inductive Philosophy. As the "John-the-Baptist" of experimental inquiry he gathered the results of earlier and contemporaneous labors and prepared the way for the new philosophy. The work of Descartes (1637) and Locke (1690) contributed philosophical impetus to the Doctrine. But above all, it was the labors of quietly and carefully working scientists thru a long period of years which sowed the seed of mental emancipation—now grown to that fruitful attitude of mind which in humility and diligent research labors for "justification, not by fact, but by verification," not by appeal to authority, but by appeal to Nature.

In the light of its origin we may now inquire if Inductive Philosophy is indeed so simple that we may assume that the youth of our land will fall heir to it as to their wisdom teeth; that we need make no conscientious effort in their behalf? Are we to pin our faith to mental recapitulation and expect that every youth, because he perchance basks in the sunshine of a course in science, will in due time epitomize the travail of mental emancipation? Would that we might! As a matter of fact, such recapitulation seems totally unsupported by the evidence at hand, and the whole superstructure of educational recapitulation stands tottering under the weight of negative evidence. "The tragedy of science —the slaying of a beautiful hypothesis by an ugly fact." It would then appear that if we desire a wide-spread scientific attitude of mind—golden gift of our social heritage—as a result of our science instruction we needs must take the matter aggressively in hand and studiously train our youth in this safe and trustworthy method—this intellectual device for ascertaining the truths of Nature. But even here we cannot rest for the Doctrine of Formal Discipline has, in the light of psychological research, been dissipated into thin and misty phraseology. Transference of training comes thru utilization. So we must see that the citizens of tomorrow are today compelled to effectively apply scientific procedure in the study and solution of the every day problems of life.

They must be brought to conscious realization that inductive investigation is not a recondite and abtruse formalism of the scientific laboratory but the common sense method of the street. We must inculcate in them a fanaticism for truth and lead them into the mental exhilaration of its acquisition thru direct participation safeguarded by conscious possession of the canons of scientific method. In this connection may I recall to your minds the fact that the utilitarian value of science already has wide spread recognition, but in this ever increasing appreciation of its technological achievements there stalks a national educational danger, for far more significant in education and so in a constructive democratization is its method. It is its unique and exclusive potential capacity to inculcate an habitual attitude of mind which constitutes the essential and fundamental contribution of science to the education of mankind.

Xenophanes wrote: "Men make gods in their own image" and convincingly claim that it was this portrayal of anthropomorphic deities by Homer and Hesiod that led directly to the fatal moral corruption of their time. Nations succumb to ideas authoratively promulgated. Most conspicuous example of this in the the history of the world is doubtless the present Paranoia Teutonica, in which the very facts and ideals of science have been for several decades studiously perverted, falsities[2] forcibly inculcated into the beliefs and actions of this nation, reaching its climax in that infamous repudiation upon the part of the "ninety-three intellectuals" of all for which their lives and labors had stood before the world. This national mania is tragically and unwarrantedly letting the most virile blood of civilization and immolating its ideals as "military expediency." This militaristic mania will stand forever condemned in the eyes of future civilization. Yet, may we not thru its soulless, honorless and ruthless program catch a vision of a national educational possibility? If one nation can thru education cause its people to turn from the God of Civilization and prostrate themselves before the Moloch Kulture may we not turn the eyes of our youth toward the God Veritas and nationalize in our educational system the canons of her devotees.

Fellow teachers! Soldiers of truth! Builders of the Foundations of civilization! Prophets of rationalism! The educational opportunity of a century immediately confront us. Shall we shoulder the task and "carry on"?

20th Mich. Acad. Sci. Rept., 1918.

[1]Annual Report, U. S. Commissioner of Education, 2:15, 12, 1917.

[2]"Germany's mission in history is to rejuvenate the exhausted members of Europe by a diffusion of Germanic blood,"
--*Fatherland School Manual for Children, 1913*.

GEOLOGY AND GEOGRAPHY

FEATURES OF THE COUNTRY AROUND CAMP CUSTER.

BY FRANK LEVERETT.

(Abstract)

Camp Custer stands on a high plain of outwash gravel on the south side of the Kalamazoo valley, west of the city of Battle Creek, at an altitude about 100 feet above the river. It is in a position commanding a view eastward far beyond the city of Battle Creek and westward to the high range of hills of the Kalamazoo moraine west of the city of Kalamazoo. The site is one with good underdrainage for water percolates rapidly downward nearly to the level of Kalamazoo River to reach the permanent ground water table. The water supply is drawn from wells in the Marshall sandstone on the north bank of Kalamazoo River.

The Cantonment stands at the junction of the Saginaw and Lake Michigan ice lobes, and its relation to the two lobes is very clearly shown by the trend of the moraines of the Tekonsha morainic system. The rifle range in the south part of the Cantonment is on a prominent morainic spur where the ice lobes came together, the hills being piled up to a height of 150 feet above the plain at the Cantonment. The Saginaw part of the morainic system leads southeastward from the Cantonment past Tekonsha, after which the morainic system is named. The Lake Michigan part leads southwestward along the south bluff of Kalamazoo River. An outwash plain, known as Climax Prairie, starts at the junction of these ice lobes and extends southwestward past Climax and Scott. Another great outwash plain farther east fills the space between this moraininc system and the St. Joseph River valley, down which its water found escape.

The outwash plain on which the Cantonment stands is a dependency of the Battle Creek moraine, a relatively weak moraine, scarcely a mile in average width, which lies along the south bluff of Kalamazoo River from the Cantonment eastward. It is present in the north part of the Cantonment on the brow of the south bluff of the river, and also across the valley for several miles between Urbandale and Augusta. Farther west it is largely cut away by the Kalamazoo River. The water discharging from the Battle Creek moraine flowed westward past the Cantonment site, as shown by the dip of the beds of gravel exposed in excavations on and near the Cantonment. Beginning a short distance east of the city of Battle Creek, however, the drainage from the ice seems to have passed southward to the St. Joseph River.

A few miles south of the Cantonment, in southeastern Kalamazoo County, is a plain of clayey till on which drumlinoidal hills were developed which have a trend in the direction of movement of the Saginaw ice lobe, from northeast to southwest. A similar plain is found south of St. Joseph River in Branch County. These hills are not shaped into forms so smooth and symmetrical as the typical drumlins of the New England States, New York, and Wisconsin, but they show a similar relation to the flow of the ice. The till plain on which they occur extends southwestward to the Sturgis moraine, the southernmost moraine of the Saginaw lobe, within the limits of the southern peninsula of Michigan.

North of Kalamazoo River is a great outwash plain of gravel and sand from 3 to 10 miles wide formed as a dependency of the Kalamazoo morainic system. That morainic system, which is 6 to 8 miles wide, traverses the north part of the Galesburg and Battle Creek quandrangles. In the northeast corner of the Battle Creek Quadrangle a till plain occupies several square miles north of Bellevue on the inner border of the Kalamazoo morainic system. Its smooth surface and relatively heavy soil is in striking contrast with the rugged surface and loose textured material of the morainic system. Lakes abound in the gravel plain both north and south of Kalamazoo River, the largest being Gun Lake, with an area of about 4 square miles. There are also large basins with peaty or marshy beds where lakes have been tilled, or drained by the cutting down of their outlets. The basins in which these lakes and marshes occur appear to have held detached masses of the ice sheet that persisted until the active ice border had been melted back some distance to the north and the outwash gravel plain had been built up around them.

The great valley occupied by Battle Creek from Bellevue down to the city of Battle Creek and by the Kalamazoo River below that city, was excavated by a great glacial river draining a considerable part of the Saginaw lobe and a section of the Huron-Erie lobe at the time the Charlotte morainic system, was forming. It is 1 to 1½ miles or more in width and 40 to 80 feet deep. It is in striking contrast with the small valley excavated by the part of the Kalamazoo River above Battle Creek, a valley only 20 to 40 feet deep and less than one-fourth mile in avarage width. Battle Creek and the part of the Kalamazoo River from Battle Creek down past Kalamazoo are now wandering through a valley many times as large as these streams could have excavated in the time since the last glaciation. Near Plainwell the bluffs disappear and the river enters a plain which was occupied by a lake at the time the Charlotte and Valparaiso morainic systems were forming, which is known as Lake Dowagiac and which extended from the Gun River Plains in Barry County southwestward to South Bend, Indiana, at which point it found discharge into the Kankakee valley and thence through Illinois and Mississippi to the Gulf of Mexico. This lake was drained when, the Lake Michigan ice lobe melted back into the Lake Michigan basin and exposed a low line for the discharge of the river along its present course from Ostego to Lake Michigan.

Ann Arbor, Michigan.

20th Mich. Acad. Sci. Rept., 1918.

DRAINAGE FEATURES AND UPLIFT OF SHORE LINES IN ELSIE AND PERRINTON QUADRANGLES.

BY FRANK LEVERETT.

(Abstract)

These quadrangles take in the head of the Grand River outlet and part of the area of the glacial lakes Saginaw, Arkona, and Warren. The topographic maps with 5-foot contour interval bring out very clearly the channels made by the Imlay Outlet in the south part of the quadrangles, and the position and altitude of the shore lines formed by Lakes Saginaw, Arkona, and Warren. It is found that the altitude of each of the Saginaw and Arkona beaches increases from SSW-NNE at a rate of about 20 inches per mile, but that the Lake Warren beach is at a uniform altitude in its course across these quadrangles, the altitude being about 680 feet. The uplift or tilting of the earlier beaches must therefore have been completed before the time of Lake Warren. Studies further north, however, show that the Warren beach passes into an area that was uplifted after it was formed, but the amount of the uplift is much less than that of the higher beaches. Earlier studies of the beaches of the glacial lakes on the east slope of the Thumb, reported in Monograph 53, U. S. Geological Survey, show that the Warren beach there remains horizontal farther north than the higher beaches, and that within its area of uplift there is a less rapid rise than in the higher beaches. It is also shown in Monograph 53 that the tilting of Lake Algonquin shore lines does not extend so far south as that of Lake Warren.

Ann Arbor, Michigan.

20th Mich. Acad. Sci. Rept., 1918.

ON THE MANNER OF OCCURRENCE OF POTASSIUM NITRATE IN OREGON.

BY THOMAS NATTRESS.

The Quaternary Lake Lahontan, which once filled the basin of Central and Southern Oregon, North Western Nevada, and the extreme North Eastern part of California did not have, at any period of its history, an outlet to the sea. Therefore, unlike its neighbor in Utah, the similar Quaternary Lake Bonneville, which had such outlet throughout its history, Lake Lahontan did not deposit NaCl, but those salts only which were obtainable from the weathering surfaces round about it.

Always comparatively shallow, the center of a vast drainage basin of which the present 400,000 acre Harney Lake Valley affords an index of the Oregon portion of it, precipitation of both salts and rock material was continuous and heavy. There were successive periods of complete desiccation in the course of which all the salts carried by the waters of the great lake were deposited and were buried in, or otherwise absorbed by, the marls and clays that were cotemporaneously laid down. Consequently the deposit of salts below the surface of the adjacent plains will no doubt be found to be as rich as in the bluff faces of the whole faulted monoclinal area, and should be richer in whatever salts they may carry, for the reason that there has been no exposure to the ages of weathering and leaching to which the bluff surfaces sampled have been subjected.

The samples taken for analysis carry K_2O, a trace of NH_3, a trace of Sodium Nitrate, and Potassium Nitrate (KNO_3).

Samples forwarded by interested parties showed all the way from 4.64 to 21.47% KNO_3. Independent sampling, done with some attempt at fairness to the bulk contents of the rock strata, showed an average of from 4% to 6% KNO_3.

Mr. Harry Wilson who is quoted in Washington geological reports as an authority, interviewed up in this Harney country, made the statement that 4% would repay handling.

Extinct volcanos, plugged with basalt or with obsidian, stand round about the fringe of the ancient lake area, and the Cascade range bounds the western uplift of the monocline. These may have contributed toward the salts deposit, but weathering of the native rocks of the greater drainage area must be admitted to be the principal source of the supply and the explanation of the uniformity that prevails in the deposit.

Resourceful nature furnished the laboratory: a thin earth-crust—as evidenced by the extinct volcanos and by the extant hot springs; a great gathering basin with no outlet for the waters accumulated; and desiccation. In other words, heat and the component salts, and Potassium Nitrate resulting.

The characteristic crystals are observable in clusters and patches, protected from weathering by any slight projection, on the bluff-face; on the sheer walls of a crevice; in small cavities; and in caves in the softer rock beds. A very favorable index of the probable values is presented in this fact: shafts carried back into the rock in places where the bluff-face showings are unpromising have shown up fairly rich contents of Potassium Nitrate.

Chalk River, Ontario, 20th March, 1918.

20th Mich, Acad. Sci. Rept., 1918,

AN INTERESTING ILLUSTRATION OF A PROCESS OF DESTRUCTION OF A GLACIATED SURFACE.

BY GEORGE M. EHLERS.

It is the purpose of this paper to record a most interesting illustration of a process of destruction of a glaciated surface of dolomite on the shore of Lake Michigan near Seul Choix Point, about fifteen miles east of Manistique, Michigan.

The surface rocks on the peninsula of which Seul Choix Point is the extremity are the Manistique, below, a thin-bedded, buff dolomite and the massive Engadine dolomite, above, which is white to bluish-white. The Engadine is cut by several sets of joints. Two main systems meet at an angle of about forty-five degrees; the less important ones cross at smaller angles.

Most of the peninsula is underlain by the Manistique, areas of Engadine dolomite occurring only on its southwest and northeast sides (Figure 1). This areal distribution is due to the erosion of the latter formation from the top of a low anticline, having a crestline parallel to the northwest-southeast axis of the peninsula.

Some unique topographic features are presented on the area of Engadine dolomite bordering the southwest shore of the peninsula between points *a* and *k*, Figure 2. Perpendicular, northeastward-facing surfaces of dolomite, three to ten feet in height, occur on the northeast sides of a number of small, aligned peninsulas at this locality. These low cliffs extend for a short distance inland, parallel to the northwest-southeast axis of the peninsulas (see Figure 2). The cliffs on the northeast sides of the two peninsulas nearest points *c* and *g*, Figure 2, are parts of a nearly continuous escarpment, bordering the southwest side of a narrow depression extending between the heads of bays *b* and *h*. From the tops of all cliffs the rock surfaces slope southwestward. The surface of the dolomite, along the shore between points *i* and *k*, also slope in this direction.

These inclined surfaces of dolomite, which were worn smooth and polished by the last glacier passing over this region, are being destroyed by the waves and agents of weathering. All stages of the process, from a nearly untouched polished surface to a surface showing an advanced stage of destruction, can be seen.

The surface of the Engadine dolomite along the shore southeast of point *i*, is largely covered with sand, but where exposed, presents every feature of a recently glaciated surface (Plate II*a*).

Where the much jointed Engadine is exposed to the full sweep of the waves, as along the shore between points *c* and *g*, the process of destruction is readily seen. Plate II*b*, a view looking southeast from point *f*, shows a surface which has been roughened by solution of the rock along joints and by dislodgment of blocks of dolomite by wave action. The general contour, however, of the glaciated surface is largely preserved. The surface of the Engadine shown on Plate III, a view looking lakeward from point *d*, is much roughened by the waves, which have also formed a channel in the rock by excavating blocks of dolomite between joints of one of the main fracture systems. Several such channels occur along the shore between points *c* and *f*. At one point, e, Figure 2, the waves have quarried a passage through the northeastward-facing cliff, permitting the water of the lake to flood the low land beyond (see Figure 2).

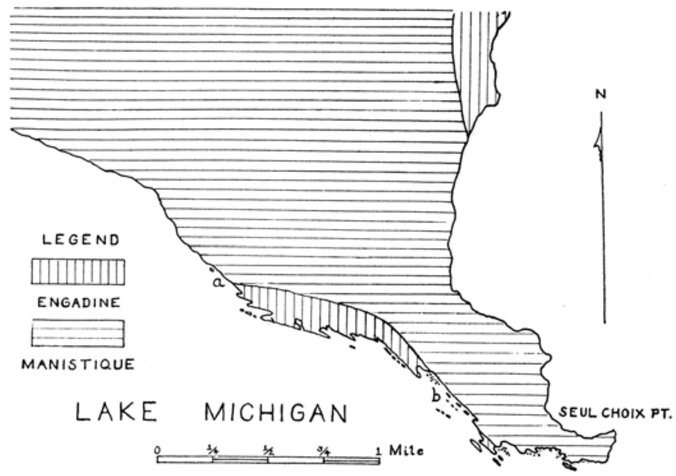


Figure 1. Sketch map of Seul Choix Point Peninsula showing distribution of surface rocks. (U. S. Lake Survey base, with additions.)

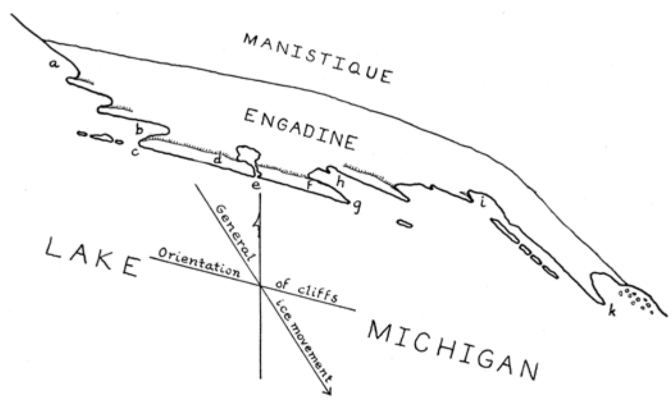


Figure 2. Sketch map of part of the southwest shore of the Seul Choix Point Peninsula between points *a* and *b*, Figure 1 indicating low escarpment and general direction of ice movement. (U. S. Lake Survey base, with additions.)

Surfaces, showing every stage in the process of destruction of a glaciated surface by waves and solution, acting upon a much jointed dolomite, may be seen in the course of a few minutes walk along the shore from points *j* to *d*.

The formation of the vertical surfaces of the northeastward—facing cliffs and the effect of the orientation of the cliffs on the prevailing movement of the glacier are also problems of considerable interest.

All low escarpments and depressions northeast of them were probably formed to large extent by preglacial streams, which more deeply excavated the thinner and perhaps more soluble layers of the southwesterly dipping strata, leaving the more resistent beds as cuestas, parallel to the strike of the strata.

The glacier, when its ice was thin as at the time of retreat, was possibly locally deflected eastward from its prevailing course, S. 25° to 30° E., by these cuestas, the general strike of which makes an angle of forty-five to fifty degrees with the general direction of ice movement (see Figure 2).

Such local deviation is possibly indicated near the head of bay *h*. A low canoe-shaped prominence of dolomite, the northwest-southeast axis of which is parallel to the major axis of bay *h*, makes a V-shaped projection in the shoreline at the head of this bay. The local movement of the ice indicated by this prominence, whose smoothed and polished surface and general form are obviously due to glacial abrasion, was southeastward, parallel to the orientation, S. 70° E., as shown on U. S. Lake Survey charts, of the major axis of the bay. This direction of ice movement is forty to forty-five degrees east of the prevailing course of the glacier; the deflection indicated is due to the escarpment, extending between points *c* and *g*, to which the local ice movement is nearly parallel.

The cuestas may have been more or less rounded by glacial abrasion; a slight rounding of a part of the cliff on the southwest side of bay *h* and of the northeastward-facing surfaces of a few reefs, which continue some of the low escarpments lakeward, suggests this action, though it is possible that postglacial solution may have accomplished the same result.

The present perpendicular escarpments were possibly formed by wave action and processes of weathering upon such rounded cuestas. Waves are the most important of these agencies in modifying the rounded cliffs. The water, hurled into the widened joints at the top of a rounded escarpment by the breaking waves, would exert hydraulic pressure sufficient to remove small blocks of rock, thus forming vertical surfaces. This quarrying action along the joints of a main system nearly parallel to the strike of the escarpment, extending between points *c* and *g*, would be particularly effective in forming a vertical cliff. This process of destruction is suggested by the breaking of the waves at the top of the cliff near point *g* and at the top of the reefs southeast of point *g* and northwest of point *c*. The formation of most of this vertical cliff by this process must have taken place at a higher level of the lake, since the waves of the lake at its present level are unable to reach a height sufficient to destroy the luxuriant vegetation, growing adjacent to and at intervals upon the top of the escarpment. Frost and other agents of weathering would also have contributed much work in the production of a perpendicular surface.

The absence of much talus at the base of the cliff, extending between points *c* and *g*, would seem to be an objection to the process of formation of its vertical surface by waves and agents of weathering. Much of the talus, which would have accumulated as a result of wave action and weathering at a higher level of the lake, may have been removed by current action when the depression northeast of the cliff was flooded. Lake ice, after forming about small masses of rock, may also have carried much material away on being broken up and set in motion by winds at the ends of the winters. Much of the removed talus may lie at the bottom of the depression beneath coverings of sand and swamp vegetation.

In concluding, the writer wishes to thank Professor E. C. Case of the University of Michigan for criticism of this manuscript and for many valuable suggestions in the field.

Ann Arbor, Michigan, March, 1918.

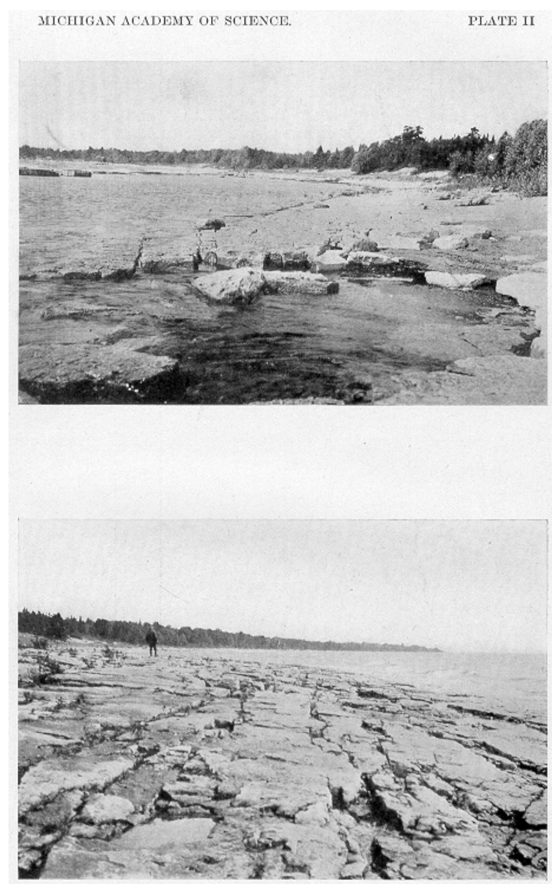
20th Mich. Acad. Sci. Rept., 1918.

EXPLANATION OF PLATES.

Plate II. a. View looking northwest from point *j*, Figure 2, showing glacially smoothed and polished surface along the shore near the center of the photograph.

b. View looking southeast from point *f*, Figure 2, showing a glaciated surface roughened by solution and wave action.

Plate III. View near point *d*, Figure 2, showing a surface very greatly roughened by wave action and solution and a channel excavated by the action of the waves upon a much jointed dolomite.



HAUY'S CONTRIBUTION TO OUR KNOWLEDGE OF ISOMORPHISM.

BY EDWARD H. KRAUS.

University of Michigan, Ann Arbor.

Abbe Rene Just Hauy, commonly recognized as the father of crystallography, was born February 28th, 1743, and died June 3rd, 1822. On the occasion of the 175th anniversary of Hauy's birth, the New York Mineralogical Club held a celebration in recognition of Hauy's contributions to crystallography, and a paper with the above title formed a part of the program.

Hauy is well-known as the discoverer of the fundamental law of the rationality of coefficients. Next in importance to this discovery was his pronouncement that "Every chemical substance possesses a characteristic crystalline form and that substances differing in chemical composition cannot occur in the same form." This pronouncement was made prior to the publication of Mitscherlich's work on the phosphates and arsenates of ammonium and potassium which lead directly to the discovery of the principle of isomorphism. Mitscherlich's earlier ideas of isomorphism involved absolute identity of crystal forms and hence were directly opposite to those of Hauy. There thus arose two schools of thought, for Hauy persisted to the very end in his conviction that his pronouncement was correct. As a result of this difference of opinion, investigation in this field of chemical crystallography was greatly stimulated and the results obtained during the last twenty-five years with refined instruments and material of great purity have shown conclusively that in the main Hauy's opinion was correct, and that in the case of substances other than of those belonging to the cubic system, crystal form is to be considered a function of the chemical composition. Although Hauy made no direct contributions to isomorphism, his influence upon investigations bearing upon this subject was exceedingly strong, and it stimulated many researches.

20th Mich. Acad. Sci. Rept., 1918.

FLOODS IN THE SAGINAW VALLEY, THEIR CAUSES AND EFFECTS.

F. W. FROSTIC, UNIVERSITY OF MICHIGAN.

Location and Area.

The Saginaw Drainage Basin lies like a giant butterfly with expanded wings on the palm, of the southern peninsula of Michigan. The Saginaw River represents the body from which the right wing extends fifty miles to the southeast over the "Thumb" while the left spreads sixty miles northwestward over the central portion of the hand. The basin comprises an area of 6,271 square miles. Parts of twenty counties are included within its boundaries. It is the largest river system in the state, the Grand River system, 5,570 square miles, being next in size.

GLACIAL HISTORY

The reason for the shape and topography of the basin is found in its glacial history. When the Saginaw lobe of the Wisconsin glaciation retreated toward the northeast, the waters from the melting ice were impounded on the northeastward sloping land between the ice front on the north and the Flint moraine on the south. Thus was formed First Lake Saginaw, a narrow crescent extending in a line somewhat parallel to the present shore line of Saginaw Bay. The lake was little more than a large pond but it grew as the ice retreated until during the stage of Lake Warren it occupied an area of probably 3,000 square miles.

The history of the lake is closely bound up with that of the Huron-Erie Basin. It became merged with Lake Arkona and was restored to independence again during the Lake Whittlesey stage. It became successively a part of lakes Wayne, Warren, Lundy, and Algonquin. During these successive stages it requires a change of only a few feet in the level of the lakes to shift the drainage to the Atlantic or to the Gulf. This long glacial history within the boundaries of a comparatively shallow basin has left a complex record of shores, bars, spits, deltas, lake clay and sand deposits, thruout the valley, indicating the many oscillations which took place in the ice front and the varying height of lake levels.

PHYSIOGRAPHY OF THE BASIN

During two halts in the retreat of the ice lobe, two moraines were formed which have had a large effect in determining the conditions of drainage in the valley. These are the Saginaw and the Bay City moraines. Both are in large part water laid and were built while the ice formed the northern barrier of the lake. In character the moraines are low and rounded with an almost imperceptible swell above the level of the surrounding country. At Saginaw the moraine is about four miles wide, reaching an elevation of 610 ft., 25 feet higher than the elevation of the basins north and south of it. The moraines become higher as they receed from the valley.

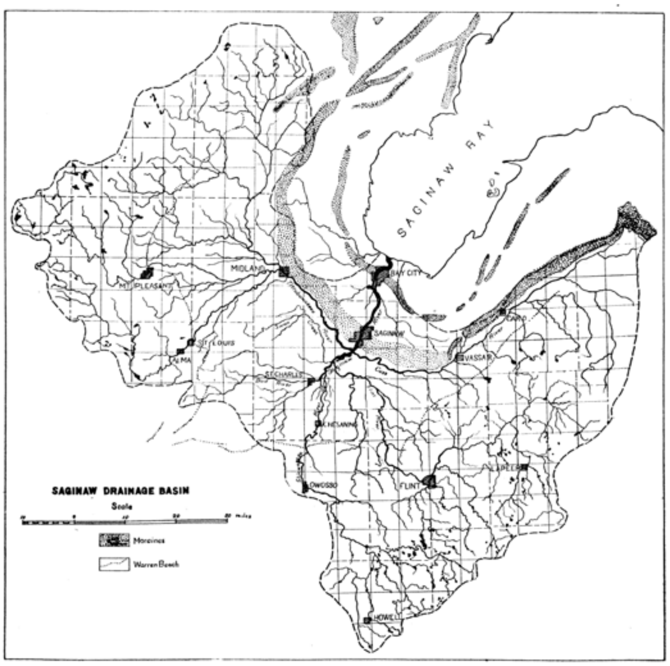


Figure 3. Saginaw Drainage Basin.

The locations of both Saginaw and Bay City are controlled geographically by the intersection of the river and the moraines. The river breaks thru the lowest depression in each morainal ridge. The higher ground offers better protection from floods and the river provides a navigable waterway to Lake Huron.

The Saginaw River proper is a short stream formed by the junction of the Shiawassee and the Bad. The river is sluggish and embayed conditions prevail from the bay to St. Charles, 22 miles up stream on the forks of the Bad River. The approximate length and areas drained by the rivers of the system is shown in the following table.

TABLE 1.

River	Approximate Length in Miles	Drainage Area Square Miles
Tittabawassee	80	2,494
Swan Creek	25	174
Bad	28	312
Shiawassee	80	725
Flint	75	1,429
Cass	75	921
Saginaw	21	216
Total		6,271

The Tittabawassee, the largest river of the system, drains the western wing of the basin. It flows south and southeastward along the edge of the Saginaw moraine and enters the Saginaw River just before that stream, breaks thru the moraine. The Cass River drains the northern part of the eastern wing and in like manner flows along the Saginaw moraine for most of its course before joining the Saginaw near the place where the Tittabawassee enters. Both of these rivers show no branches on the northern side because they flow at the base of the moraine which is low and narrow. The Flint River drains the southeastern part of the basin and enters the Saginaw a few miles below the Cass. The Shiawassee rises in the southern part of the basin and with the Bad River forms the Saginaw River proper. The Bad River carries the water from the southwestern slope, rising in that part of the valley thru which the waters in early glacial times passed to the Grand Outlet. Swan Creek is a short tributary between the Bad River and the Tittabawassee River. The confluence of the six rivers of the system is within a distance of eight miles, above the Saginaw moraine, and in a low part of the basin where the elevation is only 582 feet above sea level, eighty-three feet above the average level of Lake Huron.

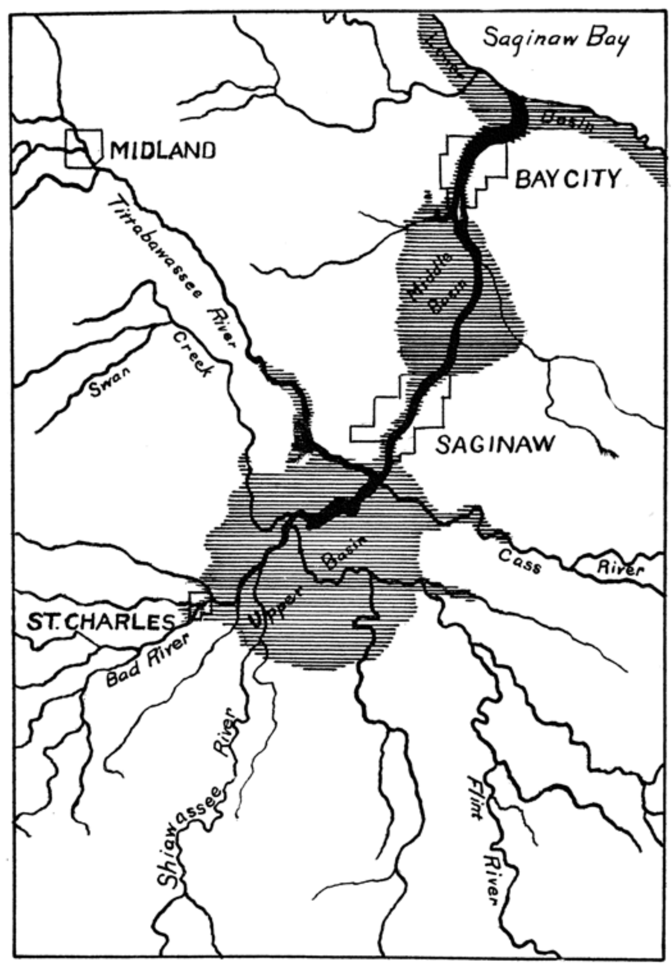


Figure 4. Showing; positions of the Upper, Middle and Lower Basins. The areas shaded show the area covered by the highest flood.

The highest portion of the valley rim is in the northwest where an elevation of approximately 1,000 feet is reached. The source of the Shiawassee is a 920 feet; the Cass, about 800 feet; the Flint, 785 feet; and the Bad, 675 feet. These rivers have a fall of from 5 to 10 feet per mile in their upper courses. Water power, in. small units, is developed in the upper or morainal courses of the streams as at Flint, Chesaning, St. Louis, Alma, and Mt. Pleasant. When the old glacial lake bed is reached the fall decreases to less than one foot per mile from the 595 foot contour to the point of confluence for below this contour line the land is very flat. The divide is lowest at the upper sources of the Bad River on the southwest.

The lowlands of the basin are divided into three smaller basins by the Saginaw and Bay City moraines. The Upper Basin south of the Saginaw moraine is the largest having an area of approximately 94 square miles below the 595 foot contour. The Middle Basin lying between the moraines has an area of about 72 square miles below the 595 foot line. The Lower Basin extends for some distance along the shore of Saginaw Bay in a narrow strip from one to two miles wide below the 585 foot contour. The Lower Basin is interrupted by many narrow sand ridges parallel to the present shore line. The areas of the Upper and Middle basins are shown in Table 2. The number of acres recorded after each contour elevation representes the total acreage below that line; thus, in the Upper Basin there are 3,470 acres of land below the 582 foot line, 8,550 acres below the 583 foot line, etc. In terms of flood acreage, if the water rises to the 582 foot line 3,470 acres are flooded, etc.

TABLE 2

Contour elevation	Upper Basin Area in acres	Middle Basin Area in acres
581	......	11,100
582	3,470	13,340
583	8,550	14,790
584	14,010	16,770
585	20,700	18,200
586	25,360	20,550
587	29,760	23,390
588	34,400	25,710
589	37,780	29,520
590	42,320	34,150
591	48,000	36,750
592	50,550	39,300
593	52,980	41,750
594	55,840	44,100
595	60,380	46,340

The rivers of the system are remarkably free from silt. Had the streams been even moderately loaded with sediment, the low marshy lands would have been built up to a higher level long ago. Of the six tributaries, the Shiawassee appears to carry the largest amount of silt. Its course below the 590 foot contour line is often broken by branching streams and natural levees are quite well developed. The mouth of the stream shows distributaries and one of these distributaries crosses the low swampy land to the Pickerel and joins the Bad River two miles above the main point of confluence.

SOILS

The soils of the basin are varied. A little more than half of the area is composed of lake clay and sandy lake beds. The outer portion of the basin is almost entirely land laid moraines and boulder clay plains. In the lake plain portion of the basin, probably one-half of the soil is sandy at the surface. Most of this sand is light and more or less worked over by the waves of the glacial lakes and since glacial times by wind action. In many places these bars and beaches have been modified into long sand dunes 5 to 20 feet in height and extending disconnectedly across the country for miles. These sandy strips constitute the poorest land of the valley. Extending in a general north to south direction across the slope in the western half of the basin they render many acres back of them too wet for agriculture until these lands have been well drained. Figure 3 illustrates such a sand ridge. It is probably the modified remnant of the Algonquin beach. In the eastern half of the basin the ridge-like character is not so pronounced.

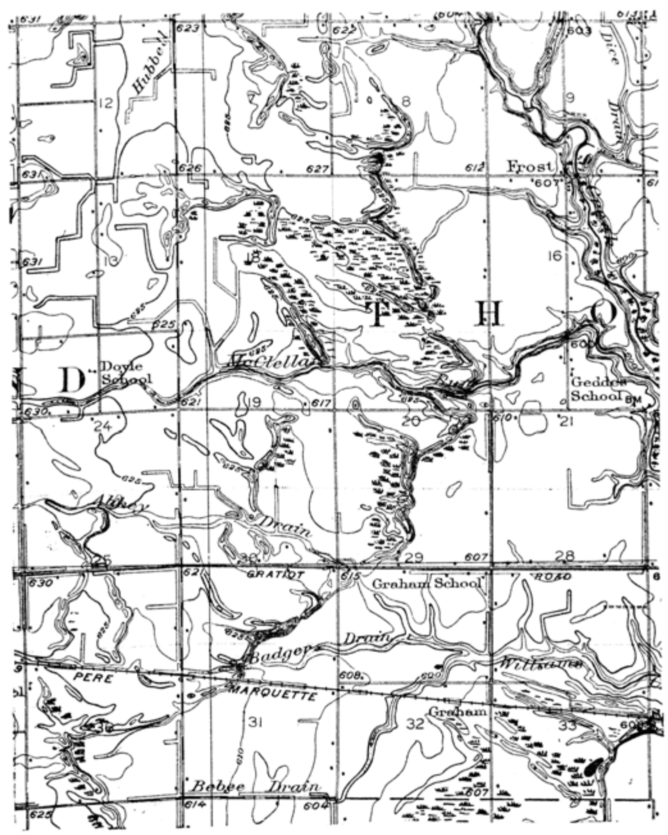


Figure 5. From St. Charles Quadrangle. Scale 1 inch to the mile, contour interval, 5 feet. Showing the effect of sand ridges on drainage. Note the undrained areas west of the ridges and the efforts being made to improve these lands.

FLOOD BASINS AND STREAM DISCHARGE

The upper valleys of the streams have no settling basins which can be used to regulate the flow of the water into the lower valley. The few lakes are located on the outer borders of the basin near the divide. The amount of fall is determined by the height of the water in the bay. According to the U. S. Lake Survey, the average elevation of water in the bay for a period of 56 years is 587.17 feet. The maximum elevation is 584.69 feet, and the minimum 578.5 feet. It is evident that fluctuations in the lake level must exercise considerable influence on the height of the water and the area of overflowed lands in the valley. A maximum high water, such as that during the year 1838, 584.69 feet, would flood approximately 30,000 to 40,000 acres of land by back water. In the same manner a high wind from the northeast continued for a few hours would flood several thousand acres. Such as case occurred on November 22-23, 1917. Such winds if they occurred during flood stages would do much to retard the discharge of flood water into the bay and increase the heights of the floods. The lake levels are generally lower during the months of highest water in the river and this tends to mitigate flood conditions.

The shape and position of the Upper and Middle Basins have much to do with regulating the discharge of flood waters thru the Saginaw River. The expanded lowlands in these areas serve as large catchment basins from which the waters discharge thru the moraines as water thru a funnel, thus prolonging the period of floods. The waters collect in the Upper Basin and discharge thru the narrow neck at Saginaw into the Middle Basin where they expand again and then discharge thru the neck at Bay City into the Lower Basin which widens to the bay. During floods the water may stand 10 feet higher in the Upper Basin than at Bay City. On the other hand these narrow necks serve to retard the inflow of water from the bay during periods of northeast storms which often cause considerable rise in the level of the water in the bay. The rise of water in the Middle and Upper Basin at such times is probably due in large part to the inability of the Saginaw River to discharge its normal amount of water to the bay, since the rise of water in the bay decreases the fall of the river proportionally.

Few data have yet been gathered on the volume discharge of the various rivers of the system. The U. S. Geological Survey has maintained stations at Freeland, Bridgeport, and Flint, mainly for gauge records. The Weather Service has collected gauge records at various stations thruout the valley since 1912. The City Engineer at Saginaw has obtained records at the Saginaw bridges and at Bridgeport. At the present time the U. S. Office of Public Roads and Rural Engineering is collecting extensive data in order to make recommendations regarding flood control. The maximum discharges at the Genessee Street Bridge at Saginaw for four years are given in Table 3.

TABLE 3

Date	Gauge Height	Discharge in second feet
March, 1914	591.6	61,000 estimated
April, 1912	589.96	42,200 measured
May, 1912	590.9	55,000 measured
March, 1916	591.15	66,394 measured
March, 1917	582.8	15,800 measured

The discharge of 15,800 second feet for March, 1917, is probably not far from the normal discharge of the stream at ordinary height. It will be seen from the table that the discharge of the stream for periods of high flood is approximately four times that of ordinary periods. The maximum discharge is considerably higher than that recorded for any other Michigan river.

CLIMATE.

Climatic records in the city of Saginaw may be taken as fairly representative of the basin as a whole. The longest and most complete series of records have been kept here. Table 4 shows the normal precipitation and temperature by months and seasons. The normals are computed on the basis of a 17 year period.

TABLE 4

Month	Mean Temperature	Precipitation in inches
March	31	2.63
April	44	2.69
May	56.3	4.12
		9.44
June	66.3	2.64
July	71	3.70
August	68.6	2.87
		9.21
September	61.3	3.10
October	49.4	2.79
November	36.3	2.29
		8.18
December	26.8	1.92
January	22.5	2.26
February	22.3	2.07
		6.25

It will be seen that there is no very marked variation in the average precipitation of the seasons. The maximum of 9.44 inches in the spring months is only a little greater than that of the winter months, 6.25 inches. On the other hand the minimum precipitation occurring in the winter months, lessens the amount of accumulated snow and ground water and thuse serves to reduce the run-off in the spring. The temperatures of January and February are low enough to produce ice of considerable thickness. This is sometimes a factor in increasing the height of water in the following spring. Under normal conditions of temperature and precipitation probably 30,000 acres are flooded every spring. The floods that are most destructive to property, however, are those which occur under abnormal conditions of temperature and precipitation. Sudden rises of temperature, excessive rainfall or both, appear to be the most important causes. The relation between rainfall and run-off varies widely.

TIME AND TYPES OF FLOODS

There are three main types of floods in the valley, named from the time of their occurrence: 1st, those occuring in the early spring at the time of melting snows and early rains; 2d, late spring floods, locally known as "June Freshets"; and 3d, late fall floods, usually occuring in November. The early spring floods are the most frequent and of greatest significance. The "June Freshets" are due almost entirely to excessive rainfall on water soaked ground. They are particularly destructive to crops planted on the edge of the flooded region. The high floods of May, 1912, are an example of this type. Late fall floods are seldom high and rather infrequent. Heavy fall rains on a water soaked ground are here again the primary cause as in the June Freshets.

Records of the flood stages in the valley show that floods have increased in frequency and in volume in the past few years. Prior to 1900 and beginning with 1873, four floods have been recorded in Saginaw, the dates being, April 14, 1873, April 17, 1876, March 29, 1884, and March 19, 1898. Between 1900 and 1918 the river has passed the flood stage 16 times. The record may not be quite so complete for the early period as for the latter, but making due allowance for this it still remains significant that in the earlier period of 27 years only four floods are recorded, while in the last 18 years sixteen are recorded.

CAUSE OF FLOODS

The physiographic features of the valley, the shape of the basin, and the pattern of the streams as described above give unusually favorable conditions for floods. The most important factors appear to be these.

Reduction of Forests. An examination of the records kept in the valley by the weather bureau and by the local papers showing the annual dates when the Saginaw River became free from ice each year, reveal the fact that prior to the year 1900 the median time when the river was free from ice was March 30. Since 1900 the median time is March 20. By the year 1900, practically all of the important forests in the basin had been cut and the great lumbering industry of the valley ceased. It appears that the removal of the forest shade and the disappearance of the sponge-like forest floor have contributed to a large degree in causing earlier break-ups in spring and to increase the volume of water during the floods. The forest served in retaining the winter snows for a longer period of time, melting taking place more slowly. Most of the forests of the region were pine, which are especially effective in this last respect. The water in this forest period seeped away more slowly and floods were less frequent and disastrous.

Extension of Surface and Tile Drains. With the disappearance of the forest, the lands were put to agricultural uses. This made necessary the construction of a large number of surface drains and later the use of the tile drainage. A very large number of surface drains have been constructed and tile drainage is becoming very largely employed each year in the improvement of farm lands. These factors have undoubtedly contributed in increasing the volume of floods and in shortening the period of high water.

Reclamation Projects. As yet these are not of great significance in the valley. There are two main projects, the Fifield Farm of about 900 acres, north of Saginaw in the Middle Basin, and the Prairie Farm in the upper Basin, east of St. Charles, of about 8,500 acres. The latter project is by far the most extensive. Large retaining walls have been built and pumps have been installed to keep the interior lands dry. The highest ground contour on the farm is 591 feet and more than one-half of the farm area lies below the 585 foot level. Occupying a part of the lowest land in the Upper Basin a considerable body of water is forced to spread elsewhere in time of flood.

Accumulated Winter Snow and Ground Water. A saturated condition of the ground produced by a series of heavy fall rains, followed by a winter of heavy snows in which there has been little melting is almost sure to produce very high water at the time of the break-up in the spring. Under such conditions, rain at the time of the spring thaw falling on an already saturated ground becomes nearly all run-off.

Sudden Rise in Temperature. This is one of the most important factors in producing floods in early spring. In the data of all the early spring floods since 1904 it has been operative to a marked degree. All the great floods appear to have been accompanied with a rise in temperature to about 40 degrees daily mean for a period of three or four days before a rapid rise in the streams.

Excessive Rainfall or the Occurrence of Several Storms in Close Succession. A sudden rise in temperature accompanied by a heavy rain invariably produces floods. Later in the season floods have occurred due to excessive rainfall alone. Rains following each other in close succession soon saturate the ground and the run-off is greatly increased. This condition was responsible for the May flood of 1912.

Deeply Frozen Ground. This increases the run-off during the rainy or warm period preceding a flood. Such a condition is probably present in most early floods. The winter temperatures are normally sufficient to freeze the ground to a considerable depth.

Thickness of River Ice. In winters of excessive cold, followed by a rapid break-up in the spring, the ice in the river breaks up slowly and retards the flow of water. Ice jams are quite common during such times. These increase the height of the water materially. In the flood of March, 1918, an ice jam formed in the Saginaw River below the city and increased the height of the flood water materially. Ice dams have been reported as forming at the confluence of the Tittabawassee and the Saginaw, and the Flint and the Saginaw, in some floods, causing a rapid and excessive rise of water in the Middle Basin. The thickness of ice in the Bay which had not yet broken up at the time of the March flood of 1904.

The ground in the lower part of the basin is clay, and so low that it is almost continually saturated. In this condition there can be little absorption from the flood waters which enter the basin. Floods during the late summer months are unknown owing to the drain of the vegetation on ground water. Rains that in spring months would produce high water, affect the streams but little in the summer. The ground being drier at this time of the year absorbs more water.

Table 5 shows the maximum gauge heights at the Genessee Street Bridge in Saginaw for each year from 1904 to 1918. The number of feet above the flood stage, 586 feet, is also given.

TABLE 5

Record of Flood Stages at the Genessee Street Bridge, Saginaw, 1904-1918.

Date	Gauge Height	Height above flood stage	Days duration
March 29, 1904	591.6	5.6	21
March 27, 1905	587.5	1.5	8
June 13, 1905	586.7	.7	8
January 25, 1906	586.1	.1	2
January 24, 1907	587.3	1.3	7
March 28, 1907	586.1	.1	2
March 17, 1908	589.6	3.16	22
May 17, 1908	586.9	.9	4
April 23, 1909	586.3	.3	2
May 3, 1909	589.3	3.3	8
March 9, 1910	585.5	....	..
February 21, 1911	583.4	....	..
April 8, 1912	589.96	3.96	17
May 24, 1912	590.9	4.9	14
March 17, 1913	588.2	2.2	4
April 6, 1913	587.3	1.3	3
March 20, 1914	583.9	....	..
February 27, 1915	585.7	....	..
March 31, 1916	591.15	5.15	12
March 27, 1917	582.8	....	..
March 25, 1918	591.0	5.0	13

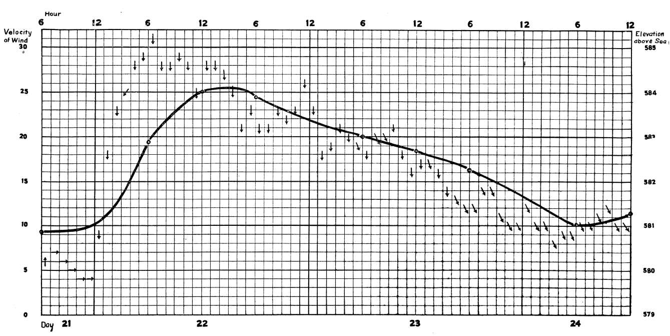


Figure 6. Showing the effect of a northeast storm on the height of the Saginaw River at Saginaw, Nov. 21-24, 1917.

FLOOD OF 1904

This flood is recognized as one of the greatest that the valley has ever experienced. The temperature of the proceeding January was 8 degrees below the mean normal temperature. That of February was 10.5 degrees below normal. The ground previous to the time of flood was frozen deeply and the ice in the winter was very thick. The precipitation for January was below normal (.83 inches). That of February was practically normal. The precipitation was 1.09 inches above normal. It is significant, however, that practically all of the winter precipitation remained on the ground until the time of the spring break-up. During January and February there was only two days when the mean temperatures were above 32 degrees. The mean temperatures of the four days preceding the rapid rise of the streams was as follows:

March 22, 42 degrees.
March 23, 39 degrees
March 24, 41 degrees with .72 inches of rain.
March 25, 53 degrees.

The river reached its highest stage in Saginaw on March 29, when it recorded a height of 591.6 feet, 5.6 feet above the flood stage. It remained above the flood stage for 21 days. Extracts from local papers describe the flood as follows:

"Lowlands are everywhere completely under water and roads are in most cases flowing streams. Bridges, both highway and railroad, are in the same condition. Railroad traffic has been stopped entirely on account of washouts of bridges or sections of track. Factories have been put out of business on account of water rising in their basements sufficiently to put out fires. Stores in the business sections are basement full and in many cases the water is flowing thru them on the ground floors. Many families have been forced to leave their homes. . . . . In the business districts, Saginaw, there is water on the main streets for a distance of two blocks. This cut off street car traffic. Boats can navigate the streets easily. The village of Zilwaukee is in a desperate condition, water being six and seven feet deep in the main streets with a strong current. People are all in upper stories with no means of preparing food or keeping warm. Considerable stock in the country about has perished. The dikes of the Prairie Farm have broken and the whole farm is under water, much stock being lost. The loss will run up into the hundreds of thousands."

FLOODS OF 1912

In this year two floods occurred. The first was preceeded by a winter in which the temperatures were below normal. The month of February was 5.4 degrees below normal while the precipitation was slightly above the normal. The rise in rivers began March 18 with a corresponding rise in mean temperatures to about 40 degrees. The flood was slow in developing but frequent rains and moderately high temperatures brought the crest of the flood at Saginaw on April 8, 3.96 feet above the flood stage. The high water continued for 17 days. The second flood was larger than the first and occurred in May. The rainfall for the month was excessvie, 9.95 inches which was 5.71 inches above normal. The heavy rains began about May 5 and increased in intensity and frequency culminating in a heavy rain on May 20-21. In these two days 3.10 inches of rain fell. The rivers rose rapidly and the crest reached Saginaw on May 24, 4.9 feet above the flood stage. The flood continued for 14 days. The cause of the floods was heavy rain on saturated ground. The weather during the flood was warm. Much vegetation was killed by water standing on the fields. Farms on the edge of the flood zone lost all crops which had been previously planted. An extract from the Detroit Free Press described the condition of flooded zone as follows:

"The damage done by the flood cannot be estimated at this day, but it is known that it will be enormous. To many sections of the farming country it may be beyond repair. Crops have rotted in the ground and the lateness of the season will probably prevent replanting. Hundreds of men are out of employment in the manufacturing plants in the lowlands along the river front owing to forced shut-downs. Carcasses of horses and cattle are common sights floating down the river. The big washout at Paines station prevents traffic to Jackson on the Michigan Central and to Grand Rapids via the Pere Marquette. On the Michigan Central trains are run south from St. Charles to Jackson."

EFFECT OF HIGH NORTHEAST WINDS

During November 22-23, 1917, there was severe storm from the northeast on Saginaw Bay which raised the water at Saginaw to a height of 3.35 feet. At Bay City the lowlands along the shore were flooded, the water rising to a height of 5 feet above the normal lake level. The following extract from Courier-Herald describes the effect of the storm:

"An unprecedented wind storm struck Saginaw Bay early this morning. The waters of the bay and the Saginaw River, which at 10 o'clock this morning had been backed up and had risen nearly six feet, had this morning receded only a foot from this point. Damages that could not be closely estimated but which will amount to upwards of a hundred thousand dollars were caused by the wind and the resultant flood."

"Cottages at Linwood, Tobeco, Kawkawlin, Donahue, Wenona, and Aplin beaches, and at Quanicassae, scores of houseboats and shanties at the mouth of the river and several fish houses in the vicinity of the river mouth were torn from their moorings and driven inland on the bay shore or wrecked in a heap of debris piled against several city bridges. Railroad tracks both to the north and east of the city were washed out and travel has been held up as a result. Five miles of track of the Detroit and Mackinac between Tobeco and Linwood were uprooted by the water and a mile of track of the Detroit, Bay City and Western was destroyed."

It is well known that in periods of low water the height of the Bad river at St. Charles, 22 miles from the mouth of the Saginaw is raised by northerly winds. It seems probable that winds may have been a factor in some of the past floods in either reducing or increasing the height of the water. Figure 6 shows the effect of the high wind on the river levels November 21-23. The elevation of the arrows indicate the mean hourly velocity of the wind and its direction. Arrows fly with the wind. The heavy line indicates the gauge levels on the Genessee Street Bridge at Saginaw.

ECONOMIC CONDITIONS OF LAND IN THE FLOODED AREA

There are approximately 110,000 acres of land in the valley which are subject to severe floods which would otherwise be most desirable lands. About 10,000 acres have been reclaimed and protected by dikes. The remainder of this land lies practically waste or is cropped only under constant threat of overflow. The edge of the flooded zone is occupied by farmers who in most cases are unable to stand the losses which accompany the flooding of these lands by late freshets. The type of houses and farm buildings often found on the border zone speak plainly of the economic losses such farmers suffer. In some places where the farmer has had sufficient resources to use such land as a speculative cropping area he has received large returns when not affected by the flood. In a number of areas, the land is overgrown by small timber which is being cut in the winter for ties, mine props, and other small lumber demands, while the wettest marsh lands, called locally, "The Prairie," is cropped only for the marsh grass which it yields abundantly. This grass is cut during the driest periods and rafted on the river to a place where teams can reach it. The forests of the lowland are composed chiefly of elm, ash, hickory, and red oak. In the lumbering days this material was not thought worth while. Only such great oaks which could be dressed as timbers 18-24 inches square and 40-60 feet in length were thought worth while. The "tall whispering pines" of the higher grounds were the wealth in which the lumberman was most interested and this part of the state produced some of the finest timber of Michigan.

In the early lumbering days, the high water of the spring months, was of considerable economic importance in floating logs down to the saw mill usually located conveniently at the forks of the streams. Small lumber barges sometimes ascended the tributaries for short distances to carry out lumber.

Table 6 shows five contiguous townships extending from west to east across the valley on the northern side of the Middle Basin. Those townships which lie wholly or in part in the flooded zone are printed in italics. The assessed value of real estate is taken from the Proceedings of the Board of Supervisors of Saginaw County, October Session, 1917.

TABLE 6

	Fremont	Swan Creek	James	Spaulding	Bridgeport
Area sq. miles...	36	30	18.84	27.65	36
Total assessed valuation....	$1,001,150	$404,430	$390,450	$604,725	$1,581,025
Average value per acre......	$43.45	$21.06	$32.38	$33.60	$68.62

The effect of the flooded conditions on the value of land is apparent from the above table. In none of those townships are there villages of sufficient size to increase noticeably the value of real estate. For this reason the above townships were selected so as to show more clearly the effect upon the value of farm property.

The low flooded lands in the valley are worth about $10 dollars per acre. The land on the edge of the flooded zone containing partly sandy tracts and partly flooded acreage, about $20 dollars per acre. The clay lands beyond the reach of flood waters are worth from 50 to 150 dollars per acre, depending upon the state of improvement. Lands that have been reclaimed yield very heavy crops under the direction of scientific management. On the Prairie Farm, thousands of acres of mint, beets, and many other crops are raised. The low land soil is very productive when the water is controlled. With proper protection, from, floods the remaining 100,000 acres can be made some of the most productive land in the state.

20th Mich. Acad. Sci. Rept., 1918

PERMO-CARBONIFEROUS TIME VERSUS PERMO-CARBONIFEROUS CONDITIONS

E. C. CASE

This paper attempts to establish the thesis that conditions governing the development of plants and animals are not necessarily synchronous with the passage of geological time. That a change of environment may be established in one part of an area and migrate across that area in a manner not in accord with the established limits of geological periods; that as a consequence similarity of fossils in one part of the area with those in another may not be taken unquestionably as establishing coincidence of deposition.

A concrete example is given from the development of the red deposits in the middle Conemaugh of Pennsylvania and West Virginia and the passage of such conditions westward across the United States until they appear in Kansas, Oklahoma and Texas and in the Basin Province west of the Rocky Mountains at a much higher level, the base of the Permo-Carboniferous or the top of the Pennsylvanian. The red bed rise obliquely across the stratigraphic series from east to west, and the discovery of similar and identical fossils in Kansas, Illinois, Pennsylvania, West Virginia and Prince Edward Island do not serve to correlate these deposits in time but in conditions of the environment.

20th Mich. Acad. Sci. Rept., 1918.

A SOIL CLASSIFICATION FOR MICHIGAN.

C. O. SAUER.

The classification of soils is more than a casual exercise for the systematist. It is the necessary antecedent of the soil survey. Heavy cropping, deforetation, and other acts of exploitation have brought us hard up against the fact that the resource of the land is fast diminishing. Uses must be found for different types of land which will increase their returns and give to them permanent productivity. To this end the agronomist and forester are at work. For this work of conserving and extending the resource of the land the soil survey supplies much needed information. The manner in which the observations of the soil survey are taken and grouped becomes determinative of the degree of its success. The classification of soils is therefore the necessary preliminary of the soil survey. The leading question of this paper is: How may soils be classified so as to bring out established contrasts in production and as well those qualities that may be of future significance in the utilization of the soil?

Workers in many regions are concerning themselves with soil classification, and an extensive literature is developing on the subject. A great diversity of opinion is disclosed, which is illustrative of the complexity of the problem, of the extraordinarily complex functions of the soil as the medium of plant growth. We are still far from a universal soil classification, but certain guiding principles are receiving increasing attention. The least serious problem in soil work is to develop universal correlation of individual soil types. For all immediate needs it is sufficient to have a grouping which will provide for an area subjected to intensive study. Such classifications have been made arid may be examined briefly. They are based on certain scientific principles that give maximum expression to the vegetational adaptations of soils. They involve therefore all environmental factors governing vegetation, in so far as these are not determined by external climate, nor by the competitive relations of life groups other than soil organisms.[1]

No successful classification of soils has been devised which is based directly on productivity. From time immemorial certain soils have been known to be suited to certain crops, as wheat, wine, or fruits. In newer regions, where the farmer has been able to observe the native vegetation, he has learned to judge of soil uses and values by the presence or absence of certain types of wild growth, and by its size and density. It is, however, not generally possible to classify soils by the things that grow upon them. Even in the oldest farming districts the knowledge of the cropping qualities of soils is far from complete. Information conveyed by the native vegetation is becoming less and less available and is also subject to considerable latitude of interpretation. Both types of observation are of great value and should be carried out,[2] but they are supplementary to direct observations on the soil, not alternative. In many cases they will point out soil conditions that would otherwise escape attention. They facilitate therefore the observation of soil qualities, but they must be considered nevertheless as supplying primarily corroborative evidence. The characteristics of the soil itself, not of its products, furnish means of classification that are adequate both from the scientific and from the practical standpoint.

The following types of observations have been employed in systems of classification: (1) The first characteristic fiat suggests itself as possible means of classification is texture. Proverbs, as old as saws on the weather, formulate the farmer's recognition of the individuality of clay, sand, and loam. Texture was made the basis of a much used classification by Thaer at the beginning of the nineteenth century.[3] In the nineties, studies by Whitney on the importance of texture in determining the moisture that soils could furnish to a crop led to the organization of the United States Bureau of Soils and its Soil Survey.[4] (2) Geologists, the world over, have had frequent occasion, in the process of geologic mapping, to observe a close accordance between rock formations and soils. This suggested the grouping of soil according to their rock derivation. (3) Some of these classifications have emphasized the chemical composition of soils and of the rocks from which they were derived. (4) Hilgard and Shaler have given us classifications of soils by origin. Manner of formation has become the basis of the Russian classification of Docuchaiev and his school, who view the soil as a natural body having a "definite genesis and distinct nature of its own and occupying an independent place in the series of formations of the earth's crust"[5]. We have thus physical, chemical, lithologic (less accurately, geologic), and genetic classifications and combinations thereof.

It is generally admitted that all these view-points are significant. Probably no modern soil study would disregard any one of them entirely. Soil classifications vary chiefly (1) in the order of importance that is attached to the several bases of classification, (2) in the distinctness with which the bases are recognized, (3) in the detail in which the system is worked out, and (4) in the degree of positiveness with which the individual soil type is recognized. In general, that classification will be most commendable which establishes the criteria by which soils are distinguished in as much detail as is practicable, but which does not undertake too precise labeling of the individual soil. The Russians give chief attention to the criteria of soil differentiation and assign to each a place in the scheme of subdivision. In our federal survey physical properties were used at the outset almost exclusively as means of classification. "Gradually the scheme of classification expanded under the lash of necessity."[6] In this system, texture is still the only criterion separately and uniformly applied to the grouping of soils, the other factors being considered somewhat vaguely in the sum of their influences. Criteria are employed by it in varying manner and extent, but the soils are differentiated into very definite units, more definite probably than the nature of soils warrants.

The possible bases of classification are not of the same order of magnitude. They can be so employed accordingly as to serve as successive steps in determination. Climate is most fundamental of the causes that differentiate soils and simplest in areal expression. It serves therefore for the establishment of the large soil provinces. The next division will be by the processes through which soils are formed, and the third by their lithologic derivation. It is not by chance that the geologist has had a leading place in the development of soil studies. Soil is primarily a physiographic phenomenon; its characteristics are determined in major part by the physiographic processes that are shaping the surfaces of the earth. In composition, moreover, soil is largely rock waste. Many of the older soil surveys are organized mainly on the basis of lithologic derivation. A more advanced group places first the processes by which they are made. France, Germany, and Japan have carried to great refinement mapping by rock formations, in general, without adequate recognition of the genetic factor. Russia and Great Britain tend to stress the latter. Hall, leading exponent of British thought, says: "The basis upon which any soil survey must be constructed is the origin of the soils."[7] In this country the significance of origin has been recognized most clearly by the Illinois Soil Survey, which bases its major divisions on Leverett's map of the surficial geology of Illinois.[8] Similar systems, combining manner of formation with geologic derivation, are employed in Iowa, Tennessee, Indiana, and New Jersey.[9] No more comprehensive expression of soil qualities has been found than by the determination of the or gin of soils in terms of process of formation and lithologic antecedents. It is in briefest terms a statement of the history of the soil and as such gives the greatest amount of information on physical and chemical constitution, age, surface and drainage, depth, and, in some cases, even humus content. It tells what the soil is by telling how it came to be. It is therefore a vastly more descriptive means of soil classification than the list of mnemonic proper names employed by the Bureau of Soils of the Department of Agriculture. It provides correlation of soils that is sound and readily understood. For the more minute determination, leading to the individual soil type, texture and structure of soil and sub-soil, color, (including humus content), lime content and other significant chemical characteristics are to be considered.

A classification of this sort is embodied in the Progress Report of the Committee on Soil Classification and Mapping of the American Society of Agronomy, summarized as follows (with the retention of original terms):

I. Soil Region, based on humidity and precipitation.

II. Soil Province, based on dynamic agencies.
Weathering
Biological
Gravity
Aqueous (water)
Aeolian (wind)
Glaciation.

III. Soil Group, based on lithology.

IV. Soil Series, based on specific character and conditions.
Color
Drainage
Content of lime carbonate
Relation of soil to sub-soil.

V. Soil Class, based on texture.

The combination of all of these gives the individual soil type. In spite of certain apparent crudities this is a valuable classification and formulates in proper order the leading principles. In its present form it is hardly applicable to field classification, chiefly because the Soil Series embraces a collection of characteristics which can probably not be translated into a series term without recourse to some arbitrary group term, such as the name of a locality in which the series is represented.[10]

The only soil classification thus far introduced into Michigan is that of the U. S. Bureau of Soils, which has made surveys of a number of counties. It places the major part of the state in what is designated the Glacial and Loessial province, including the glaciated and loess-covered areas from New England to the Great Plains and southern Louisiana. In this province it recognizes (1) ice laid deposits and (2) water-laid material, intimately associated with the ice-laid material, "deposited during the advance and retreat of the ice in the form of outwash plains,"[11] and (3) loess or loess-like deposits. A second province, less widely represented, is the Glacial Lake and River Terrace Province, which includes glacial lake beds and deposits "left within the glaciated area by the streams that flowed from the ice."[12] A third province embraces true valley bottoms, and is designated the River Flood Plains Province. Several objections may be urged against these major divisions. (1) It would be hard to find a more trivial line of contrast between soils or one more difficult to establish than the one serving as dividing line between the first and second provinces, namely, the line of demarkation between outwash plains and valley trains. Yet by explicit statement, the one falls into one great soil province, the second into another. (2) It is not at all clear what is meant by the term province. Does it denote a major soil group, or is it a geographic term? One definition says it "is an area having the same general physiographic expression, in which the soils have been produced by the same forces or groups of forces and throughout which each rock or soil material yields to equal forces equal results."[13] The last clause is superfluous as it is true apparently of all soils,—the rest of the definition is ambiguous but seems to postulate both areal unity and genetic unity. It is rare that the two will correspond exactly and that soil group and geographic area can be used as interchangeable terms. In the Glacial and Loessial Province are classed tracts of muck, peat, and dunesand, as is also the case in Glacial Lake and River Terrace Province. It would appear then that the term is used in a geographic rather than in a genetic sense. Such a limitation appears implied in. the statement that soil provinces "are differentiated on the basis of geographic features rather than on that soil character."[13] On this basis one could readily form a Sand Dune Province for Michigan, because there is a compact belt of dunes. No such province has been formed, but soils are mapped under the River Flood Plains Province, which is not an areal, but a soil group concept, as Michigan flood-plains consist of numberless small, discontinuous shreds of land. Nor is the situation much better with the Glacial Lake and River Terrace Province. We find this term used, not to outline a definite area, but to embrace all such deposits wherever found and whatever their size. A province can denote a geographic division or it can be a loose term for a large soil group, but it cannot be both things at the same time. The manner in which the term is employed does not show this distinction of ideas. (3) Any proper areal division of Michigan surface conditions must establish the individuality of the Lake Superior Highlands, with their pronounced relief and thin and discontinuous soils on hard rock. This area, in which glacial erosion dominates, it not set apart in the present classification from the adjacent plains, in which glacial deposition controls topography and soils.

The provinces of the Bureau of Soils are divided into soil series, defined as soil groups "having the same range in color, the same character of subsoil, particularly as regards color and structure, broadly the same type of relief and drainage, and a common or similar origin."[14] The series is made up of soil types, differentiated by texture. The individual soil type carries the name of the series and of the textural class to which it belongs, as Carrington loam. Against this procedure it may be urged that the series lumps an indefinite group of criteria under an arbitrary term, which is not and cannot be descriptive. The factors used in determing the series are stated in correlative form, only in the general handbook of soils.[15] The reader of an individual report, in a measure, must take the identity of the series on faith. The application of the criteria is by no means uniform, and in numerous cases is scanty, especially as to the genetic factor. The Superior Series, Glacial Lake and River Terrace Province, for instance, is determined as follows: "drainage well established, red to reddish soil, pinkish red, silty clay subsoil"[16] The criteria, it has been objected, "are not always clearly recognized and the grouping of types is often not upon parallel lines or lines of equal significance."[17] The idea seems to prevail that there are definite groups of soils, as the product of varying and even indefinite sets of factors, that the student learns to recognize these groups as definite bodies of soil by experience rather than by analysis of factors, and that the group so recognized stands for definite and nearly uniform characteristics. This is hardly the case. The Miami series includes glacial material of considerable diversity of age, origin, derivation, and cropping qualities. The Bureau of Soils classification accordingly appears too assertive of the specific identity of soils, too inadequately formulated in the bases of classification, and involved in inconsistency in its largest division, the soil province.

As alternative to the establishment of hard and fast soil types, Michigan soils may be classed according to a system similar to that formulated by the committee of the American Society of Agronomy. Simplicity of physiographic conditions makes the task simpler in Michigan than in any of the neighboring states. Climatic contrasts do not result in soil contrasts within the state. Origin supplies the general key to Michigan soils. A soil survey in Michigan could build directly on Leverett's Map of the Surface Formations, as did Hopkins on the similar map of Illinois.[18] The whole state has been glaciated and over most of it surface conditions are determined directly by glacial history. Streams have begun here and there to cut valleys and build flood-plains and thus to modify the glacial surface. Along parts of the lake shores dune belts have formed. In glacial depressions the accumulation of bog and swamp vegetation may form a distinct type of soil. In places these minor factors have resulted in the alteration of the ice-made surface and of its materials. No other genetic factors come into play. The land may not need to be distinguished according to its previous timbered or prairie condition as in states farther west. Only a single ice sheet is involved, the latest. All soils are young therefore, and observations on leaching and changes in color due to oxidation are unnecessary. The general classification accordingly may be very simple, consisting of divisions according to glacial, glacial-aqueous, alluvial, aeolian, and bog and swamp origin. Of these groups glacial derivatives will include all but a very small fraction of the soils. The major problem of a Michigan soil survey is the detailed determination of the surficial geology, the mapping on a large scale of drift features and materials. These genetic groups may be subdivided on the basis of lithologic derivation of the material. In the case of glacial soils this determination will be necessary in many cases; in the other groups less commonly. Soil groups are thus determined entirely by these two sets of factors, genetic and lithologic.

The further subdivision, ending in the individual soil type, will consider in order: texture and structure of soil, texture and structure of subsoil, and color or humus content. (1) The field determination of texture and structure is based on the appearance and 'feel' of the soil. For laboratory analysis of texture attention may be called to the Atterberg system, adopted as the International Agrogeological standard. It differs from the Bureau of Soils textural divisions as follows:

Fraction	Bureau of Soils minimum diameter	Atterberg minimum diameter
1	2 mm	20 mm
2	1	2
3	.5	.2
4	.25	.02
5	.10	.002
6	.05	
7	.005	

The five Atterberg divisions appear to supply a sufficient determination of sizes of soil particles for Michigan conditions, and to be preferable in the determination of upper and lower limits of size. The upper limit of clay, at .002 mm., is drawn at what Hall and Russell consider the only non-arbitrary line of mechanical separation, the specific properties of clay not being shown by particles of larger diameter.[19] The stony fraction, above 20 mm., is suggestive of the glaciated lands of Scandinavia in which the system was formulated. As Great Britain, Germany, and Scandanavia have found merit in the plan, and as they have soil conditions corresponding rather well to those of Michigan, the Atterberg textural classification will bear careful consideration. (2) The nature of subsoil materials must be recorded, if they are not merely the more compact, unweathered equivalents of the surface soil, readily recognizable as such. Hopkins, in the Illinois soil survey, distinguishes between significant changes in subsoil conditions at depths of less than 40 inches and at greater depth. 'Thus, loam on tight clay' would indicate the tight clay at a depth of less than 40 inches. In the other case, the term used would be 'loam over tight clay.' In Michigan, with its extremely variable glacial materials, a similar determination will be useful. The greater amount of moisture in the soil as compared with Illinois, results in shallower penetration by plants and in lesser significance of the deeper subsoil. Changes in subsoil should therefore be observed at lesser depths. For Michigan a line of division at 36 or even 30 inches would be adequate. (3) Color contrasts in Michigan soils represent differences in rock materials and its organic content and character, but are not due to any important extent to mineral oxidation. It is ordinarily sufficient therefore to employ terms that will express the amount of organic matter and the state of its decomposition.

On the basis outlined in the previous paragraphs, a soil classification for Michigan may be formulated as follows:

Origin.	Lithologic Derivation.	Texture and Structure of Soil.	Nature of Subsoil or Substratum.	Color.
A. Glacial (deposits by glacial ice, unsorted)	1. No one dominant rock material.	.1. Sand.	.01. Gravel.	a. Buff. (low organic content)
10. Ground moraine.	2. Sandstone material dominant.	.2. Sandy loam.	.02. Sand.	b. Brown. (medium organic content)
20. Terminal moraine.	3. Limestone material dominant.	.3. Loam.	.03. Silt.	c. Black. (high organic content)
30. Water-laid moraine.	4. Shale material dominant.	.4. Silt Loam.	.04. Clay.	d. Gray. (poor aeration)
40. Drumlin.	5. Granitic material dominant.	5. Clay loam.	.05. Stiff clay. (Hard-pan.)	
B. Glacial-aqueous (sorted materials intimately associated with the glacial deposits and of the same age; in the main deposited by glacial waters).	6. Dark (basic) igneous rocks dominant.	.6. Clay.	.06. Bed-rock.	
10. Esker.		.7. Stiff clay. (Puddled).	.07. Cemented bed.	
20. Kame.		a. Stony.	.08. Marl.	
30. Outwash plain (including sandy drift of smooth surface not otherwise classified).		b. Bowldery.	.09. Peat.	
40. Valley train, or glacial river terrace.		c. Pebbly or gravelly.	Preceded by 'on' if at depth of less than 3 feet, by 'over' if at greater depth.	
50. Glacial delta.				
60. Glacial lake bed.				
70. Glacial beach and bar.				
C. Alluvial (modern flood-plain deposits).				
D. Aeolian (wind-blown material).				
10. Active dunes (soil incomplete).				
20. Fixed dunes (vegetation established).				
E. Organic (soil made up predominantly of remains of vegetation.				
10. Muck (organic material largely decomposed).				
20. Peat.				

KEY TO SOIL CLASSIFICATION.

The classification is applied as follows: Group, ground moraine soils, limestone derivation; individual soil, brown, pebbly loam on clay. The genetic group name at most cannot be less significant than such a term as Miami or Carrington. Glacial terms convey a definite and adequate meaning to a very considerable body of people. Leverett's maps of surface formations are very widely used and appreciated throughout the state. To the intelligent Michigan farmer, it is safe to say, the genetic classification supplies a significant grouping. The manner of naming the individual soil is simple and gives a good deal of useful information about the soil by the very act of naming it. Although definite principles are followed in this sytem of classification, it does not commit itself to the specific identity of soils, as is the case in classifications which supply them with proper names. Only in rare cases, where a distinctive and well-known soil is identified, may a proper name be used to call attention to its identity and importance.

For purposes of reference a device similar to the decimal system of the Illinois survey may be introduced. The soil mentioned above can be expressed as A13.3b4b, by combining the appropriate symbols given above in the key in the order employed in the key.

In the mapping of soils, (1) conditions of poor drainage, (2) steep slopes, and (3) areas of rock outcrop should also be represented. This additional information is supplementary to the soil classification, not a part of it.

As the result of soil and economic studies the state should be subdivided ultimately into regions of similar surfaces, soils, and general economic character. These divisions, however, are to be considered rather as georaphic provinces than as soil provinces.

Finally, it may be stated that a soil survey is absolutely dependent on its scheme of classification. The two are one, and the results of one soil survey cannot be interpreted in terms of more than one classification.

University of Michigan.

[1]General studies of the principles of soil classification may be found in Fippin. The Practical Classification of Soils, Proc. Am. Soc. Agron., Ill, 76; Coffey, The Development of Soil Survey Work, Ibid., 115; Hall and Russell, Jour. Ag. Sc. IV, 183; Lyon, Fippin and Buckman, Soils, Chap. XXXI.

[2]Sauer, Proposal of an Agric. Surv., 19th Rep. Mich. Acad, Sc., 81, 84-5.

[3]Mitscherlich, Bodenkunde (2d Ed.), 288-292.

[4]Coffey, loc. cit., 122.

[5]Coffey, loc, cit., 127; Tulaikoff, Jour. Agric. Sc., Ill, 80.

[6]Fippin, loc. cit., 80.

[7]Hall, A. D., The Soil (2d Ed.), 290.

[8]Illinois Agric. Expt. Sta. Bull. 123.

[9]Coffey, loc. cit., 123-4; Tenn. Agric. Expt. Sta. Bull. 78, 83-4; Ind. Dept. Geol., 32d Ann. Rep., 17; N. J. Bd. Agric., 36th Ann. Rep., 162.

[10]Jour. Am. Soc. Agron., VI, 284.

[11]U. S. D. Agric., Bur. Soils, Bull. 96, 109.

[12]Ibid., 109.

[13]Ibid., 165.

[14]Ibid., 8.

[15]Bur. Soils, Bull. 96.

[16]Ibid., Fig.5.

[17]Flippin, Proc. Am. Soc. Agron., Ill, 81.

[18]Michigan Geological and Biological Survey, 1911.

[19]loc. cit., 198-201.

THE PECULIAR WEATHERING PROCESSES OF DESERT REGIONS WITH ILLUSTRATIONS FROM EGYPT AND THE SOUDAN.

BY WILLIAM HERBERT HOBBS.

The Break-down of the Desert Rocks—Exfoliation.

A false perspective has often been acquired by geologists when considering the origin of deserts, because the essential contrast of weathering conditions within arid and humid regions has not been fully appreciated. Of the two broad classes of weathering processes, the chemical ones generally described under the head of decomposition, are largely dependent upon the presence of the common solvent in nature—percolating water. In order that chemical reaction may take place, an intimacy of contact of the diverse substances is required which demands a fineness of subdivision such as is only reached through solution. For this reason decompositional processes are in nature almost entirely restricted to those districts where rainfall is abundant; their place in arid lands being taken by the mechanical processes of disintegration, as well as by certain reactions which are limited to the outermost skin of the rock masses.

The scaling off of surface shells from rock masses as a consequence of diurnal changes of temperature—*exfoliation*—has been somewhat fully treated by those geologists who have concerned themselves especially with desert conditions, and is now well recognized to be a characteristic weathering process for the arid countries.

This process has been so often described that we need not here do more than call attention to certain excellent illustrations that appear to be none too well known. Such examples are found in the granite of the Wadi Leith on the Sinai Peninsula[1] and at the summit of Jebels Nugrus and Atut in Southeastern Egypt.[2]

20th Mich. Acad. Sci. Rept., 1918.

[1]W. F. Hume, The Topography and Geology of the Peninsula of Sinai (Southeastern portion), Survey Dept. Egypt, Cairo, 1906, p. 84, PI. XI.

[2]John Ball, The Geography and Geology of Southeastern Egypt, ibid, 1912, pp. 165-166 and 171-172, pls. VII and IX.

Segmented Rock Columns Resulting from Joint Structures.

Whenever the rock is intersected by a system of joint planes, there is a strong tendency toward the development of spheroidal blocks usually separated from each other and resembling a more or less regular pile of boulders sometimes in vertical series of segmented columns. Unlike that type of spheroidal weathering which results from decomposition, the action is here restricted to the exposed surface, which surface is fresh and hard. Such structures are illustrated by large areas of granite bordering the Nile near the first cataract and extending far into the Soudan[3] (plate IV) and by rounded fragments in a wadi bed near Khartoum.

[3]John Ball, A Description of the first or Aswan Cataract of the Nile, Survey Dept., Egypt, Cairo, 1907, p. 72, fig. 4.

Crumbling Disintegration.

Whereas a dense and fairly homogeneous rock suffers disintegration chiefly by developing convex surfaces and subsequently peeling off concentric surface layers like those of an onion, a coarse-grained heterogeneous rock composed of minerals which possess notably different specific heats and often markedly different colors, often breaks down by a crumbling of the rock due to inequalities of heat expansion. A rock which is notably schistose, sheeted or laminated in structure, soon betrays its make-up by its ribbed surface configuration due both to disintegration and to the searching action of the sand blast. Such structures are particularly well illustrated in the papers by Ball.[1] Dikes of igneous rock also result in deep channelings and eventually in canyons which may be features of large importance.[2]

The joint system if well developed in rocks may constitute the chief factor in determining the features of the relief. Here again we encounter an additional parallel between the inhospitable deserts of the frigid zones and the rock deserts of tropical regions. In the one case it is the frost, and in the other the sun's heat that rends the rock along its surfaces of least resistance, followed up in the latter case by sand blast erosion. Cold and hot regions alike lack the mantle of vegetation which in other regions both protects the rock and hides it from view. Perhaps the most striking illustration of the control of desert erosion through the joint system has been supplied by de Martonne,[3] the position of the filled joints showing at the surface of the ground as deeply eroded channels. A somewhat remarkable later product of such action is furnished by Obrutchev in which squared towers rise out of a plain as the unreduced residuals of the erosion—really desert Monadnocks.[4] A general control of erosional agencies through a system of fracture (in part joints and in parts faults) as brought out in the orientation of valley systems, is a rather common feature of geological papers which treat of desert regions. There is likewise observed a somewhat noteworthy correspondence between the controlling fracture directions and the two sets of rectangular fracture series which approach the cardinal and the bisecting intermediate directions.[5] Such correspondence is often clearly revealed upon the topographic maps whenever these possess sufficient accuracy of detail to warrant a conclusion (plate VIIIb). The monographs by Hume, Ball, and Barron of the Egyptian Survey, to mention no others, indicate how generally valley directions within the desert betray such control.[6]

[1]Ball, Geography and Geology of Southeastern Egypt, p. 166, pl. VII. Also, A Description of the First or Aswan Cataract of the Nile, Cairo, 1907, p. 72, fig. 5.

[2]Ball, Ibid, p. 83, fig. 9; p. 88, fig. 12; and p. 93, fig. 16.

[3]Emm. de Martonne, Traité de Géographic Physique, pl 33, B.

[4]Vladimir Obrutchev, Eolovyi Gorod (In Russian), Zemlevdnia, 1911, figs. 1, 3, 5, 6-9, 11, 12.

[5]Repeating patterns in the relief and in the structure of the land, Bull. Geol. Soc. Am., Vol. 22, 1911, pp. 123-176, pls. 7-13.

[6]Vide Hume, The Topography and Geology of the Peninsula of Sinai (Southeastern portion), pp. 29-42.

Diffission.

More important than exfoliation as a disintegrating process within deserts, though this is little appreciated as yet by geologists, is that to which Walther has applied the ambiguous term “insolation" and which the writer has ventured to call "diffission"[1] (splitting through). From observations made especially in Egypt and in the Anglo-Egyptian Soudan the writer is of the opinion that this process takes precedence over exfoliation in the break-down of the desert rocks whether large or small. Walther in the latest edition of Das Gesetz der *Wüstenbildung* has supplied many striking instances of this splitting action and has clearly shown that fractures of great monolithic monuments generally ascribed either to falling or to the work of vandals, are in reality to be explained by the strains set up within the heated rock when chilled by a dash of rain. A notable instance is that of one of the statutes of Rameses the Great cut in Nubian sandstone at the entrance to the Rock Temple of Abu Simbel (Plate Vb). Another instance but in which the rock is granite, was photographed by the writer near the Shabluka Hills north of Khartoum (Plate Va).

An examination of the flint concretions which are spread in such profusion over large areas of the Libyan hamada is in this respect most instructive. Rarely, indeed, does one encounter a complete concretion such as is shown in plate Via, for nearly all have been split and chipped as a result of diffission (plate Vlb).

[1]Earth Features and Their Meaning, p. 204.

Origin of Facetted Desert Stones (Dreikanten).

It has been common to explain the origin of the facetted pebbles which are so frequently picked up from the desert floor through continued wind erosion, for which their polished surface has been assumed to give warrant. Of the many variations of this and other hypotheses for the origin of these stones, I have noted but two[2] which accounted for the facets by any other process than sand erosion, and even these did not treat specially of the cause of the fracture surfaces. Yet the writer is confident that in many, and probably in most cases, the fractures are to be explained by diffission. In plate VIIa there is seen at the right a pebble which has been split by this process so as to present three edges meeting in a polyhedral angle, and at the left two "Dreikanten" from the same region of the Soudan. Insofar as such stones are of homogeneous and isotropic properties the stresses about a point in the interior of the mass developed from expansion should in general tend to yield fractures along three planes with approximation to interfacial angles of ninety degrees. This results from the general properties of the ellipsoid of stress within such a homogeneous material as flint or dense limestone, so that trihedral angles so characteristic of "Dreikanten" should be the rule. The old assumption that winds have brought the sand blast at different times from three different directions, or that the repeated kick of a camel or of a wandering hyena has changed the attitude of the stone toward winds of constant direction, lie wholly outside the realm of probability. Two recent ingenious but scarcely convincing explanations of these desert stones have been offered by Barron[1] and Wade.[2]

[2]Albert Helm, Ueber Kantengesehiebe aus dem Norddeutschen Diluvium, Vierteljahrsschrift d. naturf. Gesellsch. in Zürich, vol. 32, 1887, pp. 383-385. Further, Dr. Wilhelm Graf. v. Leiningen, Ueber Kantengerölle aus der Umgegend von Nürnberg, Mit, d. geogr, Gesellsch. in München, vol. 3, heft 2, 1908, pp. 1-19.

[1]T. Barron, The Topography and Geology of the District between Cairo and Suez, Cairo, 1907, pp. 116-117.

[2]A. Wade, On the Formation of Dreikante in Desert Regions, Geol. Mag., Dec. 5, vol. 7, 1910, pp. 394-398, pls. 31-32.

Case-hardening of Rock Surfaces.

The protective rinds which are produced out of the surface layers of desert rocks under arid conditions, are now well known and have been somewhat fully described by Walther in his various papers.[3] Such skins of hardened rock he has ascribed to "dry weathering," that is, salts are drawn out from the interior of the rock by capillary processes, and cause chemical changes in the surface portions of the rock and also in the attached dust so as to form a hard surface layer. Obviously essential to this process is the low heat conductivity of the rock which limits the zone of high temperature to a depth usually of a fraction of an inch only. A rather general characteristic of the rinds in addition to their protective quality in respect to the prevailing sand blast erosion, is a yellow, brown, red or even black color, but usually a darker color tone than characterizes the rock as a whole. In general, also, a notable polish is observable due to the omnipresent sand-blast which encounters in the new surface layer a material susceptible of taking on a polish of some degree of perfection.

Inasmuch as this natural "case-hardening" or Harveyizing process is restricted to those rock surfaces which come under the direct rays of the sun, the possibilities of shadow weathering arise, and wherever the rock does not acquire the protective armor, under the continued action of the sand-blast are sculptured the peculiar shapes known as "faucet rocks," also likened to couchant animals. To this lack of armor upon the shaded side of the rock mass, which there lays it open to easy attack by the sand-blast, must be added those peculiar local strains which are set up from inequalities of expansion within that shifting zone where sunlight and shadow meet, and which result in locally increased rending and exfoliation.

Linck, who has studied the desert rinds within the East African deserts,[4] ascribes an important role in their formation to the dew, which even in the most arid region occasionally falls. He says:

> "Since the dew has but a brief existence, it is essential that it have a greater capacity for reaction with the rock than is the case in temperate climates, in order in this brief time of its existence to exert a solvent and extracting activity upon the underlying rock or the dust which covers it. This special capacity appears to me to be based upon the presence of carbonic acid, which like many other ingredient gases of the atmospheric air or like its mechanically mixed salts, is present in greater proportion in dew than in rain."

The possibility of a quicker oxidation is furnished also by the electrolytes ammonium nitrate and sodium chloride, always present in desert air. According to Linck the steps of the process are: (1) impregnation of the rock surface layer with dew, (2) solution and decomposition of the existing minerals at the high rock temperatures, (3) oxidation of this solution with the aid of the salt constituents of the air dissolved in water, and, (4) drying out by the sun and crystallization of the new formed compounds. The fact that protective rinds are not found within savannahs or in other humid tropical districts generally, Linck has explained by the rain-water washing from the surface of the rock the products of chemical weathering or carrying them deeper into the rock. Whatever rind might be formed in the dry season would, he believed, be removed in the rainy season. He claims to have produced in the laboratory protective rinds quite similar to the natural desert rinds through moistening the rock surface with a solution of iron chloride, manganese chloride and common salt and repeatedly raising the temperature slowly to the boiling point of water; a process which is much improved if ammonium, nitrate be added. "I have thus produced," he says, "rinds upon flint, upon quartz, upon gneiss and upon sandstone which are not to be distinguished from the natural ones."

If Linck's explanation be correct, and he seems to have made an excellent case, the production of a rind may have much in common with the processes of "case-hardening" and "Harveyizing" which have been used in the steel industry, and where under the influence of heat slowly applied to the surface a skin of harder metal is produced through chemical changes in which the ingredients of an encompassing layer react with those of the mass itself. Mawson has applied this term "case-hardening" to the natural rind-producing process.[1] He has ably discussed rinds of this character from the arid regions of Australia, in which, following Walther, the water necessary for the solution of the silicate minerals is supposed to be drawn from the interior of the rock by capillary action under the fierce rays of the sun. The influence of the alkali salts is especially emphasized, these being responsible, as desert geologists are generally aware, for the formation of opaline silica and gypsum, so that these substances have the value almost of fossils in determining the climate of former geological periods.

[3]See particularly the 1912 edition of *Das Gesetz der Wustenbildung*, pp. 139-153.

[4]G. Linck, Ueber die dunkel Rinden der Gesteine der Wiisten, Jenaische Zeitsch. Naturw., vol. 35, 1900, pp. 1-8.

[1]Douglas Mawson, Geological Investigations in the Broken Hill area, Mem. Roy. Soc. New South Wales, vol. 2, pt. 4, 1912, pp. 225-227.

Caliche.

A close parallel is drawn by Mawson between the chemical processes which form protective rinds upon the desert rocks and the *caliche* which forms within the alkali soils.[2] In this Broken Hill area the Caliche may extend for a number of feet below the surface of the ground.

A variation of the process by which magnesium and calcium carbonates are separated out within desert rocks is furnished by the peculiar konkur limestone which has been deposited within the widened joint spaces of the Nubian Sandstone on the banks of the White Nile near the fort at Omdurman. This locality is situated a short distance only above the junction of the White with the Blue Nile (plate VIIIa.) The formation of the material appears to be connected with the changes in level of the Nile waters arid their consequent penetration into the rock crevices upon the banks.

During floods in the Blue Nile the White Nile is dammed to form a great lake extending far above Khartoum. The waters of the Blue Nile are heavily charged with magnesium and calcium carbonates, and these diffuse with the waters of the White Nile which carry a large percentage of sodium carbonate due to decomposition of the abundant organic matter taken up in the Sudd region.[1] It is this sodium carbonate in the waters of the White Nile which keeps the sediment in suspension and gives to it its characteristic whitish color. So striking is the contrast of the two arms of the Nile at their junction that in crossing by ferry at low water from Khartoum on the Blue Nile to Omdurman on the White Nile, one passes through a sharp line of demarcation from the ribbon of clear blue water into one which is grey and milky. According to Mr. G. W. Grabham, geologist of the Survey Department at Khartoum, to whom the writer is indebted for much valuable assistance while in the vicinity, the subsidence of the Blue Nile allows the water which has penetrated the cracks in the rocks upon the bank to seep back into the river, and being now highly charged with common salt, this well-known electrolyte brings about a noticeable and remarkably sudden clarification of the river waters. As regards the formation of the konkur limestone within the crevices of the Nubian Sandstone, it is highly probable that the mingling of the waters of the two rivers at flood time near their junction causes the sodium carbonate derived from the waters of the White Nile to throw down in the crevices the magnesium and calcium carbonates derived from the waters of the Blue Nile.

[2]l. c. pp. 225-227.

[1]Wm. Bean, Chemical Composition of the Nile Waters, Second Rept. Wellcome Research Laboratories at the Gordon Memorial College, Khartoum, 1906, pp. 206-214, figs. 92-94. Also, Chemical Composition of Nile Waters, Ibid, Third Rept., 1908, pp. 386-395.

The Black Cataract Rinds of Assouan.

Between low and high water levels the surface of the granite rocks near the great Assouan Cataract become covered by an exceedingly thin glistening black coating (plate 4a) which has been investigated by Lucas[2] and found to consist mainly of manganese dioxide together with ferric oxide, lime, silica, and magnesia, and with traces of potash and of sulphuric and phosphoric acids. Under similar conditions other cataract rinds though of notably different compositions, have been produced at other tropical cataracts where, however, the waters are dashed into foam.[3]

[2]A. Lucas, The Blackened Rocks of the Nile Cataracts. Survey Dept. Egypt, Cairo. 1905.

[3]Das Gesetz dei Wüstenbildung, p. 143.

EXPLANATION OF PLATES.

Plate IV. a. Spheroidal disintegration of granite in banks of Nile above the First Cataract.

b. Porphyry blocks rounded by exfoliation, bed of wadi, Shabluka Hills, near Khartoum.

Plate V. a. Granite block broken apart by diffission near Shabluka Hills, Soudan.

b. Statue of Rameses the Great in Nubian Sandstone split by diffission. Entrance to Rock Temple of Abu Simbel, near Wady Haifa, Upper Egypt.

Plate VI. a. Complete concretion.

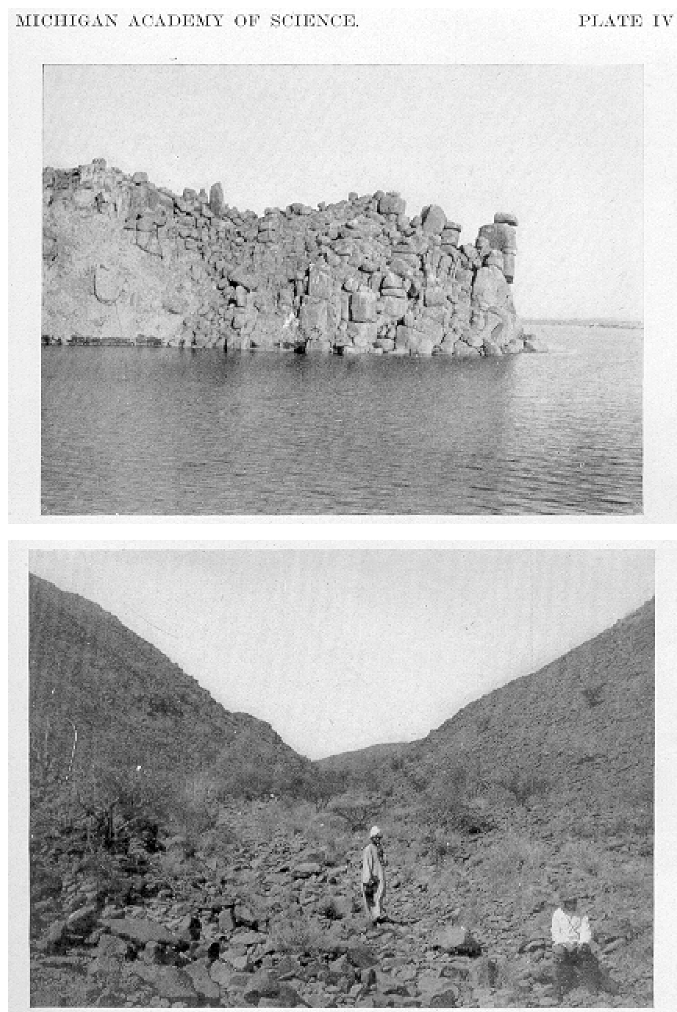
b. Concretion split by diffission.

Plate VII. a. Pebble split by diffission and Dreikanten.

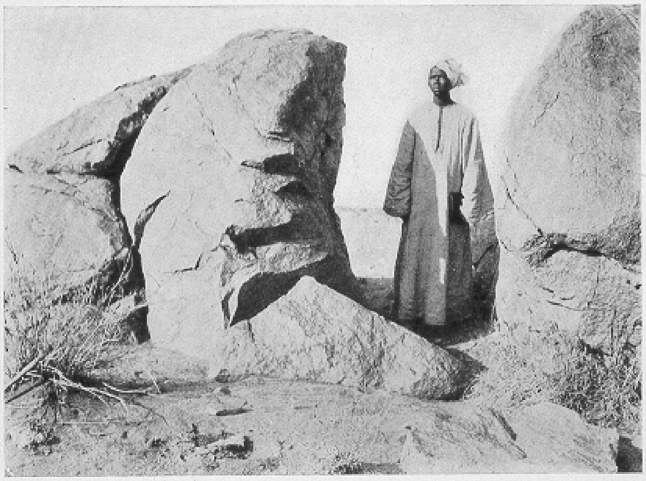
b. Pebbles with black coating from Assuan Cataract.

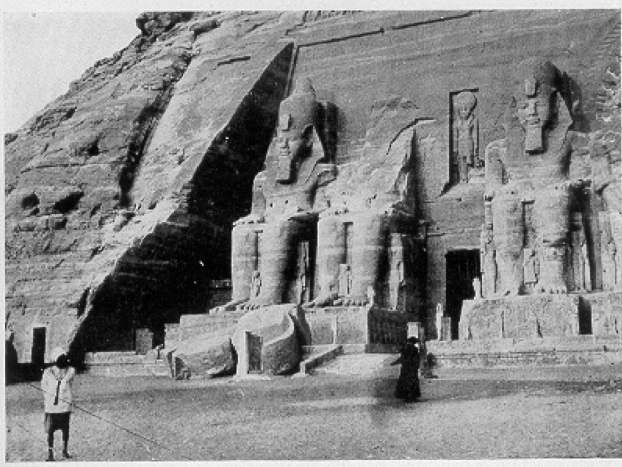
Plate VIII. a. Konkur limestone within widened joint spaces of the Nubian Sandstone.

b. Map of the Moquattam Hill near Cairo, Egypt, from map by the Survey Department.

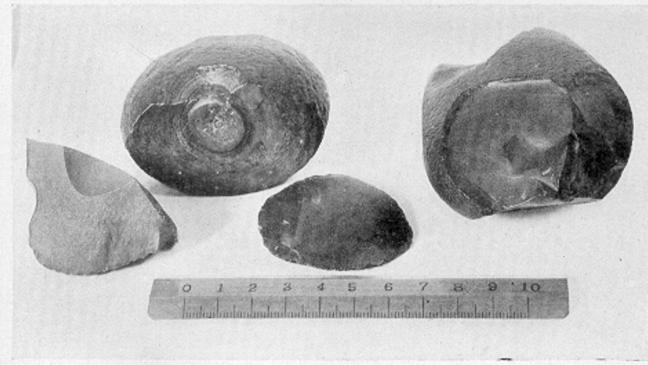


MICHIGAN ACADEMY OF SCIENCE. PLATE V

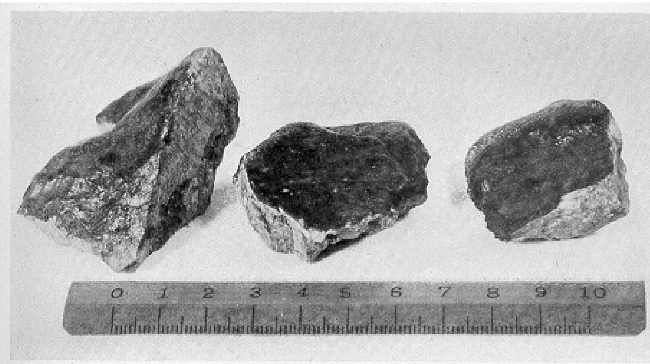




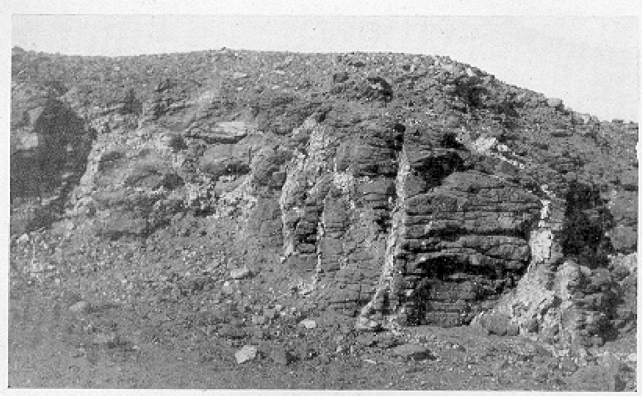
MICHIGAN ACADEMY OF SCIENCE. PLATE VI

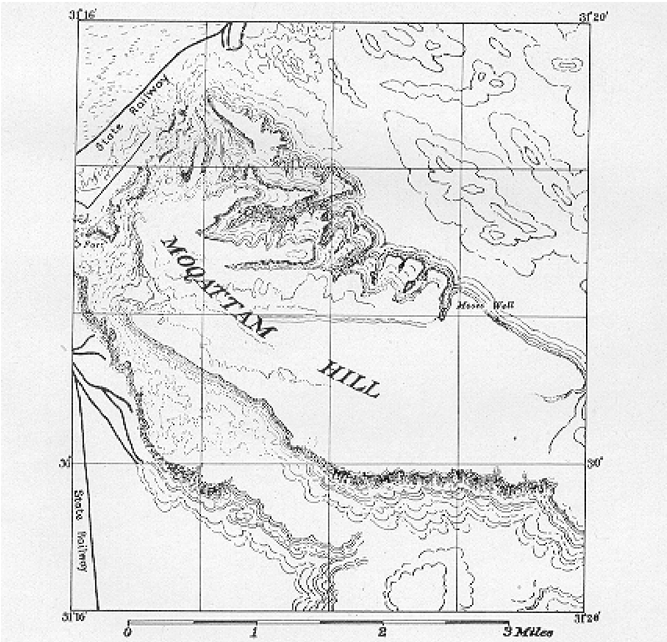


MICHIGAN ACADEMY OF SCIENCE. PLATE VII



MICHIGAN ACADEMY OF SCIENCE. PLATE VIII





BOTANY.

SALT RATIOS IN SOIL CULTURES.

BY R. P. HIBBARD.

Studies of the soil solution have engrossed the attention of many investitors for a number of years. This medium, from which the plant gathers some of its sustenance has been studied entirely apart from the solid particles, which are admitted to modify plant growth under natural conditions. It is only by a study of the solution itself that we can hope to see a way clear to the proper understanding of the soil solution in situ in the soil. Physiological studies in the soil solution with crop plants as indicators have allowed us to draw some definite conclusions. Quartz sand culture studies on the same general plan as used in water culture allow us to draw the same general conclusions. Since the surface area of the quartz particle is quite small due to the largeness of the particles, there is no more change in the concentration of the culture solution added at regular intervals to the jars of quartz sand, than there naturally follows, when the solutions are removed in the water culture series. We have here a repetition of our water cultures method with the exception of a much drier medium, and the presence of an abundance of solid particles. In a natural soil containing small particles with immense surface areas, such as soil colloids, there occurs the phenomenon of adsorption, to say nothing of the presence of other physical and chemical phenomena, so that consequently soil cultures constitute complex culture media and crop production is dependent upon a number of factors. In soil solution studies it has been found that a certain ratio from a large series of ratios affords the best growth of the plants used as indicators. The soil itself when treated with the various combinations produces an optimum yield with a certain definite ratio. The principle of physiological balance for soils is as applicable here as in the case of water cultures. Whatever the changes may be which are brought about by the presence of solid particles, they are believed to be for the most part changes in degree rather than in kind.

In a previous number of this publication under the caption of "Physiological Balances in the Soil Solutions," the author briefly reported his findings in regard to salt ratios in the soil solutions, apart from the soil. This soil solution had been obtained by the new oil pressure method, a method which to date is the best method of obtaining large quantities of solution for water culture studies. It has also been shown that by this method of extraction a solution is obtained which is more nearly the concentration of that of the natural soil waters than that obtained by any other method. Two widely different types of soils were selected for this study, extracted and the solutions then used as the solvents in making up the three stock solutions from which later thirty-six different solution cultures were prepared. These thirty-six culture solutions constituted a series in which there appeared all the possible combinations or ratios of the three salts varying from each other in ten per cent increments.

The results showed that the best or optimum ratio of salts for the growth of wheat seedlings in the solution extracted from an infertile soil was 7-1-2 meaning that of the total concentration, seven-tenths was derived from the first salt, KH_2PO_4, one-tenth from the second salt, $Ca(NO_3)_2$, and two-tenths from the third salt, $MgSO_4$. This was a different ratio of salts from what was found to be the optimum ratio in a distilled water series. This indicated the possibility of a deficiency of a particular salt in the soil solution. The optimum culture in the distilled water series was 5-2-3 meaning that five-tenths of the total concentration was derived from KH_2PO_4, two-tenths from $Ca(NO_3)_2$ and three-tenths from $MgSO_4$.

Tenths of total concentration derived from the 3 different salts in the different solvents.

Solvent	KH_2PO_4	$Ca(NO_3)_2$	$MgSO_4$
Distilled water	5	2	3
Soil solution	7	1	2

A glance at the above table shows that in the soil solution a high partial concentration of KH_2PO_4 was necessary to provide for the best growth. Apparently the soil lacked K_2O and P_2O_5 and this conclusion was substantiated when the dry salt was applied to the original soil. The result was an increase in the yield.

When another soil solution, a solution that had been extracted from a fertile soil, was treated in a similar way as described above an entirely different ratio was found to produce the best growth of wheat. The optimum culture in this case was 2-7-1, meaning that two-tenths of the total concentration was derived from the salt KH_2PO_4, seven-tenths from the salt $Ca(NO_3)_2$, and one-tenth from the salt $MgSO_4$.

Tenths of total concentration derived from the three different salts in the different solvents.

Solvent	KH_2PO_4	$Ca(NO_3)_2$	$MgSO_4$
Distilled water	5	2	3
Soil solution	2	7	1

The table above shows very strikingly that the soil solution lacked $Ca(NO_3)_2$, and when the dry salt was applied to the original soil the result showed an increase in yield which would indicate that the conclusion was well substantiated.

From a consideration of the above it seems very probable that such a method of study would indicate the needs of a soil and provide a means for increasing crop production. At the present time there appears to be no reliable laboratory method for investigating the fertility of a soil or for determining its fertilizer needs. The only suggestion given now is to grow the crops for a series of years under different treatments. It seems that the method used above or some modification of the same could be used for such studies.

A report of the work just briefly outlined above will appear shortly as bulletin Number 40 of the Michigan Experiment Station.

A study of the soil solution is second only to an investigation of the soil itself. If by use of this method one can learn the soil's needs, the laborious process of extracting the soil solution can be eliminated. The data collected in this study will be briefly reported here. The soil was treated with the thirty-six combinations of salts with the idea of demonstrating whether there was a best or optimum ratio of salts.

The wheat seedlings for this experiment were raised in the selected soil placed in one gallon glazed crocks. The solutions were applied to the soil by means of the Livingston auto-irrigators. There were thirty-six different culture solutions plus a distilled water solution used as a control. The total osmotic concentration of the thirty-six solutions was 2.50, a concentration somewhat higher than that used in distilled water or quartz sand series because of adsorption phenomena present in most soils and lacking in quartz sand. By previous test it was learned that when the water supply was at 11 inches below the auto-irrigators in the crocks this particular fertile soil was kept at its optimum moisture content. In the case of the sandy soil the water supply was 7 inches from the auto-irrigators. One, therefore, needed only to see that the solution in the flasks below were kept full up to the mark. To prevent evaporation other than that through the plant the soil was covered with a wax seal and all imperfections in the glazed jars were painted with paraffine.

All the cultures made good growth even that one which was supplied with only distilled water. After a selected period of growth the crop was harvested and the dry weights taken as the criterion of yield.

In the first experiment a sandy loam was used. This soil is considered fertile and has always produced a luxuriant growth of vegetation. The optimum growth of wheat was made in culture 4-4-3 which means that four-tenths of the total concentration was derived from the salt KH_2PO_4, three-tenths from $Ca(NO_3)_2$, and three-tenths from $MgSO_4$. This was true when considering the yield of tops alone or the yield of the whole plant. When the root yield was considered the best ratio was 5-3-2. This shows as in the case of water cultures that the roots and tops are differently affected.

The second experiment was performed with a sandy soil whose producing power was very poor. The ratio which gave the best growth in this case was 5-4-1 when the tops or when the yield of the whole plant are considered. When the root yield alone is considered the best ratio is 2-7-1. This shows again how differently the roots and tops act toward the changes in the soil.

From these experiments it is seen that as in water cultures and soil solution, so also in soil cultures there is strong evidence of a physiological balance. Certain ratios are better for plant growth than others and if this principle is followed out in the application of fertilizers to the soil a greater yield or an increased fertility will result which will be of immense practical value. This study also suggests a possible laboratory method for determining the fertilizer needs of a soil, in a quick, reliable, scientific manner, rather than depending on long time experiments and empirical methods. Further extended and detailed experiments will be needed to establish this, however. The present studies on salt ratios in the soil will shortly be published so in this paper a more extended discussion would be out of place.

Michigan Agricultural College Experiment Station.

20th Mich. Acad. Sci. Rept., 1918.

BLUE-GREEN ALGAE AS AGENTS IN THE DEPOSITION OF MARL IN MICHIGAN LAKES.

BY JAS. B. POLLOCK.

The term marl is applied to soils or geological strata of numerous kinds, but in the present paper it refers to the deposits of calcium carbonate in fresh water lakes of post-glacial origin, such as occur in Michigan and neighboring states as well as in .other parts of the world. These marl deposits often run 95% or more pure calcium carbonate, and furnish the raw material for the cement industry in this region. The origin of these deposits has been a matter of uncertainty. One group of investigators thought them to be the results of chemical precipitation without the agency of living organisms. Another group thought that either animals or plants, or both played a part in the chemical transformations by which the calcium carbonate was precipitated.

Since the publication in 1900-1903 of the papers of C. A. Davis whose work was based on a study of marl in Michigan lakes, the conclusion therein expressed that the alga, Chara, was the chief agent in the deposition of marl, has been accepted quite generally, though not universally. It is given with apparent approval in one of the recent text-books of geology (Grabau, 1913), though Blatchley, (1900), working in the marl deposits of Indiana at about the same time that Davis was studying the Michigan deposits concluded that chemical precipitation alone was responsible for most of the marl. He pointed out that Chara was often wholly absent in lakes containing the purest deposits of marl, or was present in amounts too small to allow the conclusion, that it was the chief agent in the marl formation. He also reported that the marl deposits in which Chara was most abundant were of inferior quality, being too high in organic matter.

Besides Chara, Davis recognized the activity of blue-green algae as possible agents in the precipitation but believed them decidedly inferior to Chara as regards this process. Davis' co-workers on the Michigan Geological Survey, Hale and Lane, were more impressed than Davis by the possible agency of organisms other than Chara in marl deposition. Hale remarks (1908 p. 57) "It is hardly deemed possible that Characeae are the sole cause of the growth of our vast marl beds." "Actively depositing marl is found in the absence of these plants." "It appears the only feasible and true explanation of the origin or exact method of precipitation that minute water organisms absorb the carbon-dioxide from the water in building up their life and leave the calcium carbonate to precipitate upon the twigs, plants or bottom, or any thing available. That the visible water plants serve mainly to precipitate marl I can hardly believe, as it clings to dead twigs as thickly as to live" "it seems possible that other forms of plant life, invisible to the naked eye also assist in the precipitation of the salts."

Lane, commenting on the views of Hale and Davis remarks in a footnote (1903 p. 64): "The main difference between Mr. Hale and Prof. Davis is that the former is more inclined to look to microscopic plants and to the abstraction of carbon-dioxide by plant life generally as inducing the chemical precipitation favored by light and heat." In his own paper (1903 p. 223) Lane concludes: "The Characeae play a conspicuous part, especially in the purer marls. More minute algae may have collectively more importance. In fact microscopic examination seems to indicate this." It is thus seen that while Davis concludes that Chara is the agent in the deposition of marl, his colleagues on the Michigan Survey give the greater credit to the smaller microscopic forms of life. Blatchley and Ashley of the Indiana Geology Department also reject the conclusion that Characeae are the chief agents in marl formation. They believe it is purely a chemical precipitation, but Hale and Lane present very strong evidence that the latter view is not correct (1903 pp. 44-45, 290-217).

Since the publication of Davis' papers the writer had accepted his conclusion as regards Chara and marl formation, until an observation at Ore Lake, Michigan, in September, 1917, showed conditions which were incompatible with Davis' view. The observations were substantially the same as those of Lane and Hale, noted above, but since Davis' view appears to be prevailing among geologists it seems to be desirable to make a new presentation of the facts on the possibility of the predominance of organisms other than Chara in the formation of marl. Incidentally an observation suggested a method of calculating the rate at which marl may be forming.

Ore Lake lies in the southern part of Livingston County, Michigan, about twenty miles from Ann Arbor. This lake is in the form of a broad oval, about three-fourths of a mile in the greatest diameter. A broad shallow bay in the southeast quarter lies adjacent to a swamp, which separates the lake from the Huron River, into which it drains.

For the problem under consideration one significant feature of Ore Lake is the broad strip of shallow water along all the east shore and part of the north and south shores. The bottom of the lake in this shallow region is a very pure marl, the deposition of which is taking place at the present time. In this region of the lake there is either no Chara at all, or so very little that Chara could not possibly be responsible for the great amount of marl now actively precipitating in all the broad reach of shallow water. In the deeper part of the lake Chara is abundant, but the character of the marl is decidedly different. The condition is in agreement with the fact reported by Blatchley (1900 p. 48) that marl is of inferior quality where Chara is abundant, having too high content of organic matter. The condition also agrees with the fact reported by Hale, (1903 p. 58) that deposition of marl is more active in shallow water and lessens as the water deepens. These facts seem to the writer critical ones, and to indicate with a degree of certainty amounting practically to a demonstration that Chara is not concerned at all in, that, part of Ore Lake where marl deposition is most active, and where Chara is present the deposition of marl is not nearly so rapid nor is the marl so pure in quality.

Another significant and critical fact is the presence in the shallow water where deposition is most rapid, of the marl pebbles which have been noticed and described by Davis, Lane, Hale, Blatchley, Murray and others, and which are characterized by the presence of blue-green algae. Murray (1895) was the first to describe such pebbles from Michigan lakes, and he also reported similar structures from Lough Belvidere, Ireland. He described the blue-green alga Schizothrix fasciculata as forming these pebbles. Blatchley and Ashley (1900, Pl. 8) show the external appearance of the pebbles. See also Plate XVII, Fig. 12, this paper. The internal structure is shown in Plate XVII, Figs. 5-9, of this Report. They vary in size from just visible up to several inches in diameter. In shape they are generally globoid to flattened ovoid, but the original shape is determined by the shape of the nucleus about which the deposit started. It may be a grain of sand (silica) or fragment of any plant as a piece of stem, leaf or root, a snail or mussel shell, in fact, any object in the water, alive or dead, may serve as a substratum upon which the marl may be deposited. Hale (1903, p. 57, footnote) mentions the fact that in Higgins Lake, Michigan, the whole bottom of the lake is continuously cemented in a layer of 1-10 of an inch thick, brown above and green below. This bluish-green or brownish color is characteristic of the blue-green algae. In Ore Lake these pebbles are very numerous and crowded in the shallow water, but are less numerous as the water grows deeper, that is, they are most numerous where marl deposition is most rapid. In resistance to crushing they are about equal to rather firm cheese, usually crushing easily in the hand. When broken across they show both a radial and a concentric structure, (see Pl. XVII, Figs. 5-9, this Report). Though composed so largely of calcium carbonate deposited as fine grains over the surface of the pebbles, they are always surprisingly light in weight in proportion to their volume. A pebble thoroughly air dry, kept in the laboratory all winter, weighing .987 gm. displaced .5 cc. of water measured in a burette with reading accurate to less than .1 cc. Another pebble dried at 115-120°C. to constant weight, weighed 1.247 grams, and displaced .75 cc. of water. On dissolving the pebbles in hydrochloric acid the organic residue may have sufficient coherence to retain the approximate size and form of the pebble before solution, even when lifted from the solution by a pair of forceps.

This organic residue consists of the remains of the algae among the threads of which the calcium carbonate was deposited, (See Plate XVII, Fig II). One of the pebbles dried to constant weight at 115-120°C. weighed 2.159 grams. It was dissolved in HCl. The undissolved residue could be lifted with forceps in one mass. It was washed thoroughly in leveral changes of distilled water and dried in a porcelain evaporating dish at 115-120°C. Its weight after drying was .050 grams, equal to 2.78% of the total weight of the original pebble. This was then incinerated until all the organic matter was consumed. The inorganic residue after incineration weighed .008 grams. This equals .44% of total original pebble, and 16% of the portion insoluble in HCl. These results may be summarized thus:

Part of pebble soluble in HC1, (Calcium carbonate chiefly)	97.22%
Part of pebble insoluble in HC1	2.78
	100.00
Part of insoluble portion volatile on incineration. Chiefly organic matter	84%
Part of insoluble matter remaining on incineration, inorganic matter	16%
	100
Proportion of whole pebble composed of organic matter or volatile on incineration	2.34%
Proportion of whole pebble remaining as inorganic matter, non-volatile on incineration	.44%
	2.78%

The striking facts are:

1. The very small proportion of insoluble inorganic matter, and the large proportion soluble in HCl, indicating a marl very pure for $CaCO_3$, with little clay or silica.

2. The large amount of organic matter in the residue insoluble in HCl, and the surprising degree of coherence of the mass of it, allowing it to be lifted from the solution practically in one mass, by forceps. The coherence is due to the continuity and interweaving of the filament sheaths of blue-green algae, as microscopic examination shows, (See Plate XVII, Fig. II). A more detailed description of these will be made later in this paper. The bulkiness of these filaments in proportion to their dry weight, composed as they are of gelatinous sheaths accounts in a large measure if not almost wholly for the light weight, or low specific gravity of the pebbles, always so noticeable when dry pebbles are handled. These filaments are the ‘cementing" or binding material that gives coherence to the pebble, and undoubtedly also to the continuous cemented bottom noticed by Hale at Higgins Lake. Pebbles that are continuously submerged never show their $CaCO_3$ granules cemented by a mineral cement, but those exposed to air part of the time at the water line have a smoother surface, cemented by calcium carbonate probably, where water evaporates from time to time on their surfaces. (Compare Figs. 10 and 12, Plate XVII.) The interior of these pebbles never shows any sign of such mineral cement. (Compare Figs. 10 and 9, Plate XVII.) The cementing or binding action of the alga filaments explains the deposits on all kinds of objects in the water, dead or alive. These become the point of attachment for the algae, and their continual growth leads to the continued deposition of marl on such objects. Since these algae filaments are not easily visible to the naked eye such deposits on dead subtrata have frequently been interpreted as of pure mineral deposition though Hale expresses the thought that the microscopic plants play a part and calls attention especially to the

transparent slime associated with such marl deposits. (1903 p. 57.)

It seems well established now that these, algae pebbles, or a continuous bottom growth of the algae, are associated with marl beds of the highest purity in calcium carbonate, and that the abundance of the pebbles coincides with the degree of purity of the marl beds. They are most numerous in shallow water and become less numerous in deeper water along the surface of the marl beds. Hale has shown that the marl beds are often of the highest purity in shallow water and that the purity for calcium carbonate decreases as the water grows deeper. The vertical distribution of the pebbles in the beds from the surface downward also coincides with the degree of purity of the marl, as Hale has also shown. The marl is purest and the pebbles are most numerous at the surface of the beds (1903, p. 50). The pebbles decrease in frequency and the marl in purity as deeper layers of marl are examined. Blatchley has emphasized the fact that marl associated with Chara is always of low purity for $CaCO_3$, and also mentions the fact that the pebbles are found in some beds to the depth of several feet. In Ore Lake the pebbles were found to be abundant below the surface of the marl to a depth of 18 inches at least. No deeper strata were examined.

One unusual feature at Ore Lake is the presence on the east shore of the lake, at about the present water level, of a stratum of conglomerate marl-stone. This stratum has a small exposure along the shore where wave action or ice action has broken it into irregular blocks. The marl-stone stratum undoubtedly runs out under the muck of the neighboring swamp, and it seems likely that the presence of this overlying layer of muck has helped in the consolidation of the marl into the stone. Photographic reproduction of one of these marl-stone fragments is shown (Plate XVII, Fig. 4). Also certain strata of the lake beach which is composed almost wholly of the marl deposits, have been modified by a deposit of limonite or iron ore, from which the lake takes its name. Both the strata of marl-stone and of iron ore are composed largely of the marl pebbles previously described, (Plate XVI, Figs. 2 and 3), the spaces between the pebbles being filled up with fine material of the same nature. Considering the softness of these pebbles in their original form, and the ease with which any mechanical action would abrade them, it is practically certain that the fine material is from the same source as the pebbles. The marl-stone is just like the loose marl bed in composition, except that it has been consolidated, perhaps by the pressure or other action of overlying muck. In the marl conglomerate the outlines of pebbles can be seen, and, when broken across (as at Plate XVII, Fig. 4, upper left portion) the concentric structure of the original pebble can still be recognized. A comparison of Plate XVI, Fig. 1 and Plate XVII, Fig. 4, will show that the material consolidated into marl-stone is exactly like the loose marl pebbles and marl sand composing the present beach of the lake. The pebbles themselves appear to make up 50% or more of the marl-stone, and also of the consolidated marl deposits. The fine material composing the rest of both is probably of the same origin.

The conclusion is inevitable that the material composing the marl-stone was originally deposited by the same agency which is now actively forming the marl pebbles, namely blue-green algae, and that Chara had little or nothing to do with it in this case. Even in many of the finer fragments filling the space between the larger pebbles the concretionary nature can be recognized, showing that they had the same origin as the larger pebbles.

Whatever agency is forming these pebbles then, is the active agent in the rapid deposition of marl of the highest purity. It is not Chara in Ore Lake.

RATE OF DEPOSITION OF MARL.

The fact has already been noted that marl may be deposited on any object in the water, dead or alive. Among the objects on which marl deposits were observed at Ore Lake were the shells of live clams or fresh-water mussels. Since the clams live in the mud and plow their way through it with only one end of the shell projecting above the mud surface, only this exposed end of the shell will show the deposit on a live clam. On empty clam shells however, the marl deposit covers the shell completely, and these marl-covered shells are not infrequent, and finally become part of the permanent bed of marl.

It occurred to the writer that the thickness of the deposit on a live clam could be used as the basis of determining the rate of deposition, of marl, provided the age to which darns live was definitely known. In answer to the oral inquiry as to the age of clams, Mr. Bryant Walker, of Detroit, the best authority on the Molluscs of this region, informed the writer that they might live to be 8 or 10 years old. He also said he had often seen thick deposits on live clam shells, estimating from memory at one inch or more in, thickness. An even greater thickness has been reported by Mr. Levette from observations made in Indiana lakes in 1875, (quoted by Blatchley, 1900, p. 87). He reports a marl deposit on the posterior end of the shells of live mussels as varying from a half inch to one and one-half inches. The observations at Ore Lake did not reveal deposits of so great thickness as that, but since those of Levette's are on record they may be made the basis of a calculation. It must be remembered that the clams go down into the mud completely in winter arid that this would necessarily remove a considerable part of the deposit of the preceding season. Using the data then of a thickness of 1.5 inches as the deposit on a darn 8 to 10 years old will probably give results well within the possibility of the maximum rate. One and one-half inches in eight years would be at the rate of 1 foot in 64 years. The same deposit in ten years would be at the rate of 1 foot in 80 years. If it should happen that in the winter the clam burrowing in the mud should scour all the marl off its shell and a deposit 1½ inches in thickness formed in one year that would be at the rate of one foot in eight years, which seems considerably too high. It would appear, however, within the possibilities that at the maximum rate of deposition a foot of marl might be deposited within 50 to 100 years.

Tilden (1897 p. 95) reports a lime deposit on the walls of a wooden tank near Minneapolis which increased in. thickness four millimeters each of two successive years it was under observation. This deposit was associated with five species of algae, three of the Cyanophyceae, one of the Chlorophyceae, and one of the Rhodophyceae. This rate of 4 mm. per year would form 1 foot in 76 years, a surprisingly close agreement with the figures based on the deposits on live clams.

THE ALGAE IN THE PEBBLES.

It is of some interest to know what genera of Algae are concerned in the formation of the marl pebbles or continuous layers such as are found in some lakes. Blue-green algae or Cyanophyceae, of several genera have been reported as forming calcareous pebbles. In the text books of Walther (1893-4), Seward (1898), Grabau (1913,) and West (1916,) the literature of the subject is reviewed. Cohn (1862,) found blue-green algae aiding in the deposition of concretionary pebbles in the Carlsbad springs; Weed (1887-8) reported blue-green algae as active in the deposition of calcareous deposits at the Hot Springs of Yellowstone Park; Murray (1895) reported Schizothrix fasciculata in calcareous pebbles from Michigan Lakes and also from. Lough Belvidere, a Lake in Ireland. It was accompanied by Stigonema, Dicothrix, and other genera of the Nostocaceae as well as diatoms. In Bodensee (Lake Constance) Rivularia calcarea is said to deposit a layer of calcium carbonate each year and to cover all foreign bodies on the bottom of the lake (Walther, p. 672). In great Salt Lake and on the Sinai tic shore of the Red Sea Gloeocapsa and Gloeothece are said by Rothpletz to be the active agents in deposition of oolitic sand. (1892 p. 265). Miss Josephine Tilden (1897 pp. 93-104) describes four species of Cyanophyceae associated with a calcareous deposit in a wooden tank at Minneapolis. Three of these were described as new species, *Dicothrix calcarea* Tilden, *Lynghya martensiana calcarea* Tilden, *Lynghya nana* Tilden, and *Schizothrix rupicola* Tilden.

West (1916 p. 35) reports Dicothrix gypsophila, one of the Rivulariaceae, as one of the most active species in building up calcareous deposits; C. A. Davis (1900, 1901, 1903) reported blue-green algae in the marl pebbles of Michigan lakes and submitted specimens to Miss Julia Snow who identified a Zonotrichia (synonym of Rivularia), Davis also quotes Murray to the effect that Schizothrix is present.

All of these genera above named belonging to the Cyanophyceae have been found upon or in the marl pebbles from Ore Lake. Diatoms of several genera and also desimids are present but in relative small numbers, not sufficient to be very effective as agents of marl deposition.

Algae from actively growing pebbles were examined alive, also the filaments left after dissolving out the calcium carbonate in hydrochloric acid were studied. The effect of the acid interferes little or not at all with the microscopic study of the algae. In fact it makes the cell structure in the trichomes of the Cyanophyceae more plain, and the size of the cell more easily measured, nor does it, destroy the chorophyll or the phycocyanin, the green and blue pigments characteristic of this class of algae. Four species of the blue-green algae were found to be more constantly present than any other in the marl pebbles from Ore Lake. The most numerous of all was a species of *Schizothrix* which agrees closely with *Schizothrix fasciculatad* Gomont (1892 p. 299), and with Murray's identification of the species in pebbles from a Michigan lake. Murray reported this species associated with concretionary calcareous pebbles from other parts of the world. It does not agree with Miss Tilden's *Schizothrix rupicola*, since the sheaths are tapering to the tip and not cylindrical, and the cells are smaller in both dimensions, than the cells of Miss Tilden's species.

After Schizothrix the most abundant species is a slender Lyngbya, which agrees fairly well with Miss Tilden's *L. nana*. Another Lyngbya is constantly present but in relatively small numbers of filaments. In size of filaments and cells it agrees closely with *Lyngbya martensiana calcarea* Tilden. Another species present in the pebbles fairly constantly, but not in great numbers of filaments, is one of the Rivulariaceae, perhaps the one Miss Snow identified for C. A. Davis as a Zonotrichia. This latter name is given by Bornet & Flahault (1886, p. 345) as a synonym of Rivularia, and *R. calcaria* has been reported associated with lime deposits in Lake Constance (Walther 1893-4, p. 672). In the Ore Lake pebbles, however, the filaments of the Rivularia-like organism are scattered and mostly separate, rather than arranged in compact manner with filaments radially arranged as is the case is Rivularia. Also some of the filaments in the Ore Lake material showed, more than one trichome in a single sheath, and they are sometimes branched almost dichotomously and these three characters distinguish it as a Dicothrix rather than as a Rivularia (or Zonotrichia). The characters of its filaments and trichomes are near enough to those of *Dicothrix calcarea* Tilden to allow its identification as that species.

A very few filaments of Stigonema were observed, but the species was not determined. Murray had also found a Stigonema and a Dicothrix associated with Schizothrix fasciculata in calcareous pebbles. Several species of Gloeocapsa and Gloeothece as well as some other blue-green algae were observed, but their presence was not at all constant in the marl pebbles, hence it was not considered necessary to identify them as associated with deposition of the marl. However species of both Gloeocapsa and Gloeothece are said to cause deposition of lime as oolitic sand grains in Great Salt Lake and the Red Sea. (Rothpletz 1892).

Besides the algae, very numerous bodies the size and shape of bacteria cells are found among the alga filaments. Undoubtedly many bacteria would find the conditions here favorable for their growth.

In the interior, and therefore older parts of the marl pebbles, the cells in the filaments of all the blue-green, algae have disappeared, and most of the gelatinous sheaths have collapsed so completely that it is impossible to distinguish even the genera to which the filamentous gelatinous sheaths belong. However, some filaments of Schizothrix, Dicothrix and Lyngbya were observed in which the sheaths were partially collapsed, and in part contained recognizable cells. It is certain that all three contribute to the filamentous mass which binds the fine grains of calcium carbonate into coherent but friable pebbles.

A certain proportion of the sheaths however, instead of collapsing when the trichomes with the cell protoplasm disappear, retain their tubular shape, the outer layer of the gelatinous sheath becoming hardened to a sufficient degree to prevent the collapse. As a result of this a certain number of rather heavy walled tubes without visible cell structure are found among the much more numerous collapsed filaments. West (1916 p. 3) asserts that the sheaths of Lyngbya and other blue-green algae are often toughened and chitinized. The chitinization may, therefore, account for the fact that some of the sheaths retain the tubular form in striking contrast to most of the filaments composing the residue of a pebble treated with HCl.

These tubular structures seem to the writer to be highly significant in relation to a certain fossil which has been called Girvanella. By several palaentologists this is supposed to represent a fossil blue-green alga. The tubular structures found in it however, have been a difficulty, and some have said that if the fossil is an algae at all it should be one of the Siphoneae, which are tubular. The fact that in the marl pebbles similar tubular structures certainly belong to blue-green alga, and that several species can produce them, completely does away with the objection that the lack of cellular structure in the tubules is evidence against their origin from Cyanophyceae in Girvanella. Seward (1898, p. 124) reproduces a figure of Girvanella problematica. Taking the magnifi-fication of the figure as given and calculating the diameter of the tubules, they are found to be about 15 microns thick, a size well within that for many blue-green algae, but probably very small for the Siphoneae. Dicothrix calcarea is 9-13.75 microns thick. The further fact that only a small part of the structure of the fossil Girvanella is distinctly tubular is exactly parallel to the structure found in marl pebbles, where most of the organic residue after dissolving the lime of the the pebbles in HCl, is composed of collapsed filaments in which neither tubular nor cellular structure is visible. These facts strengthen very greatly the probability that Girvanella is a fossil blue-green alga or a possible combination of several. These fossil filaments however, could not be identified even to the genus, with any degree of certainty. If this fossil belongs to this class of plants, then blue-green algae are found from Cambrian rocks through Ordovician, Silurian, Carboniferous, Jurassic and other systems (Seward, 1898 d.125-6).

Summary of the facts presented:

1. Active deposition of marl is occurring in the shallow waters of Ore Lake and in many other lakes of Michigan and Indiana.

2. The regions of most active deposition in some lakes are characterized by the presence of marl pebbles in large numbers, varying in size from juts visible to the naked eye up to several inches in diameter, globular to ovoid in shape, or of some other shape. The pebbles have a low specific gravity, and are easily crushed or broken in the hand.

3. These pebbles compose a large proportion, estimated at 50% or more, of those parts of the marl bed where they occur, and the finer material filling the spaces between them is in all probability also derived mostly if not wholly from the pebbles. In some lakes instead of separate pebbles the bottom of the lake is a continuous crust of material similar to that composing the pebbles.

4. At Ore Lake a marl-stone, formed at some previous stage in the deposition of this bed, is also composed of these pebbles to the same extent as the neighboring loose marl, now depositing.

5. Even the thin layers of iron ore (limonite) found at Ore Lake show the marl pebbles cemented to them.

6. No Chara is growing in the shallow water where the marl deposition is most active.

7. Where Chara is growing in this lake, which is in deeper water the marl deposition is evidently less rapid, and other observers have found the marl associated with Chara less pure for $CaCO_3$.

8. The Geological Surveys of both Indiana and Michigan have found these marl pebbles to be characteristic of many lakes in those states, and to be components of the beds where they occur to a depth of several feet, but lessening or disappearing in deeper water or the deeper parts of the marl beds.

9. The same agency which forms the pebbles and sometimes forms a continuous crust over the bottom of some lakes, also covers any object in the water, such as stakes, twigs, other plant fragments, snail shells, clam shells, etc., with a deposit of marl.

10. In the free pebbles or the crusts of marl on other objects, there is constantly growing an association of microscopic plants, giving the pebbles or crusts a bluish-green or a brownish tint.

11. Most constant and most abundant among the plants of this association in the marl pebbles or crusts, are, in the order of their mass-abundance, *Schizo thrix*

fasciculata, Lyngbya nana, L. martensiana calcarea and Dicothrix calcarea, all belonging to the class of algae known as Cyanophyceae or blue-green algae. Other Cyanophyceae frequently present are several species each of Gloeocapsa and Gloeothece. Stignonema was also seen, but rarely.

12. Besides the Cyanophyceae, diatoms and desmids are often present, and the former are of many species, though neither is usually numerous as individuals. These form a very small proportion of the mass of associated plants. Diatom shells are insoluble in acid and since the insoluble part is such a small proportion of the pebbles, it is evident that the diatoms do not form a notable part of the pebbles.

13. The Cyanophyceae abundant in these pebbles and others beside these, have been reported as concerned in the deposition of $CaCO_3$ in many parts of the world, in Europe, Africa and America.

14. No Chara is growing in the shallow water of Ore Lake where the pebbles are most numerous, and marl deposition is most active. This same condition is found in many other lakes of Indiana and Michigan, as reported by their respective Geological Surveys.

15. The proportion of plant material composing the marl pebbles is sufficiently high to cause them to retain approximately the size and shape of the pebble after the $CaCO_3$ is completely dissolved in HCl, and has sufficient coherence to enable it to be lifted out of the water by forceps, and still retain its form. In one pebble, this plant material composed 2.34% of the total weight of the pebble, both dried at 115°C or over to constant weight. It was 84% of the residue insoluble in HCl.

16. In the older parts of the pebbles the gelatinous sheaths of the blue-green algae collapse so completely that most of them show neither tubular nor cellular structure. A small proportion however, are sufficiently firm, perhaps by chitinization, to show as continuous tubes in which no cellular structure is visible. Transition stages were found in which part of a tube showed the cells of Cyanophyceae and such tubular structures were seen to originate from Schizothrix, Lyngbya and Dicothrix. When the cell structure had disappeared only the tubes from Dicothrix could sometimes be recognized by their tapering in the manner characteristic of the filaments of that Genus.

17. Live clams often have a marl deposit on that part of their shells projecting above the mud as they move along the lake bottom. Authentic records indicate that this deposit may be as much as 1.5 inches on a single shell. As clams live to be 8 to 10 years old this gives the data for calculating the rate of deposition of marl.

Conclusions from the facts submitted:

1. The conclusion of Davis that Chara is the chief agent for the deposition of marl cannot be true for all marl beds. Those parts of such beds which are composed largely of concretionary pebbles are deposited in association with several Cyanophyceae and the marl may be deposited in the total absence of Chara.

2. These pebble-marls are characteristic of shallow water, and not of deep water; of the upper strata of some marl beds, and not of the deeper strata of the same beds.

3. The same lake may have marl deposited by Cyanophyceae in shallow water and by Chara in deep water. It is not intended to imply that in some lakes Chara may not be the agent of marl deposition in shallow water as well as in deep water.

4. The Cyanophyceae deposit a purer form of marl than is generally deposited by Chara.

5. The marl may be consolidated into a marl-stone and still show its origin from Cyanophyceae by the conglomerate character and by the radial and concentric structure in the pebbles forming the larger particles in the conglomerate. The structure suggests that seen in some “oolitic" rocks.

6. Cyanophyceae may deposit marl at the rate of one foot in about 75 years. Of course the rate must vary widely in different beds or in different parts of the same bed. This is perhaps near the maximum rate of deposit.

7. The tubular structures found in the marl pebbles are the empty sheaths of Cyanophyceae from which all trace of cell structure has disappeared. This discovery makes it highly probable that the fossil, Girvanella, is properly interpreted as belonging to the Cyanophyceae, though they do not enable it to be identified as a definite genus of that class, since several genera were seen to form such tubes, and probably many others may do so. In size the tubular structures in Girvanella are within the range of size of numerous filamentous Cyanophyceae. With this fossil identified as belonging to the Cyanophyceae, there is authenic evidence for the occurence of this class of algae in the rocks of many ages from the Cambrian onward.

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DESCRIPTION OF PLATES.

PLATE XVI.

Figure 1. A dish of loose marl sand and marl pebbles, such as make up the beach of Ore Lake. All but the smallest particles can be recognized as pebbles or their fragments and the author believes the finer fragments have the same origin.

Figures 2 and 3. Two fragments of marl which has been cemented to a deposit of iron ore, (limonite). The marl pebbles at the surface are colored by the iron and are cemented to a purer layer of iron deposit beneath. This shows the large proportion of pebbles composing the mass, deposited at some former time.

PLATE XVII.

Figure 4. A fragment of marl rock, a conglomerate of pebbles and marl sand, very similar to the loose beach sand and pebbles shown in Figure 1. The upper spongy portion is a freshly fractured surface, the lower, smoother portion is cemented by $CaCO_3$, probably by evaporation of lake water splashed upon it by the waves. This rock was just above the water level in September, at the low summer stage. The figure does not show the extent to which pebbles compose the rock as well as can be seen by the naked eye.

Figures 5-10. Marl pebbles collected on the beach at about water-line, where they have been rolled by the waves and exposed to wetting and drying. This has produced a smooth cemented surface, and to the naked eye they look like ordinary silicious pebbles. On picking them up their light weight and friability easily distinguish them from the latter. Figures 5-9 are broken to show the concentric and radial structure. Figure 10 shows the smooth surface. Figure 5 shows a snail shell as the center of concretionary deposit. Figures 6 and 8 show two original centers of deposition, that is, two different pebbles which became coherent and the later concretionary layers surrounded them both. This is one of the ways in which small pebbles are combined into larger ones, or in which a continuous crust of marl may be formed on the lake bottom.

Figure 11 shows some of the filaments of Cyanophycese remaining when the $CaCO_3$ has all been dissolved out of the pebble. This mass was at first coherent enough to retain the original size and shape of the pebble on being lifted out of the water by forceps, but has been broken up to get material for microscopic study.

Figure 12. One of the marl pebbles with the algae in a growing condition. This pebble has been kept in water in the laboratory for 8 months, and the outer layers had living algae at the time of photographing.

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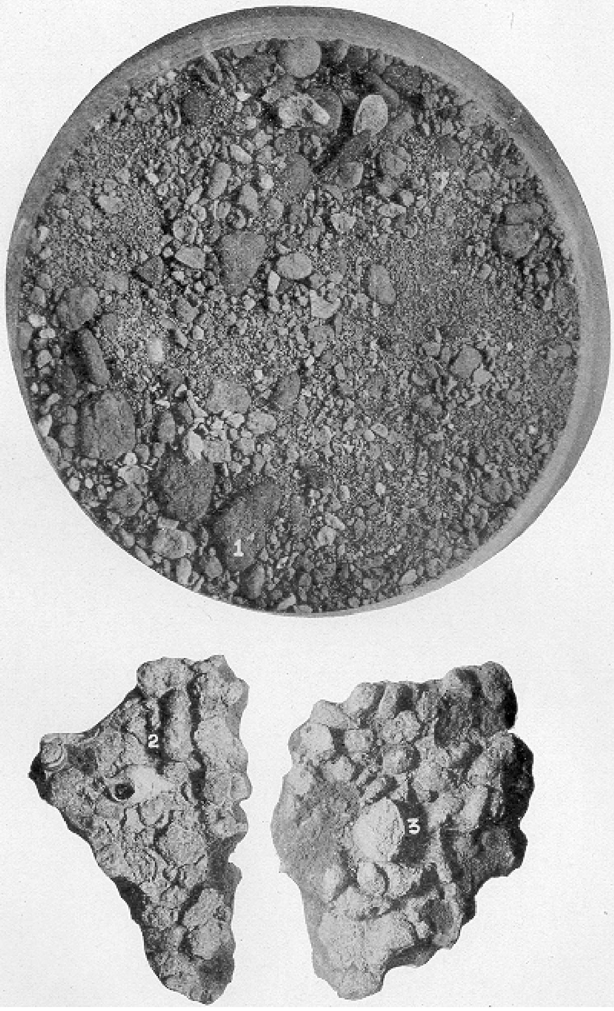

MICHIGAN ACADEMY OF SCIENCE. PLATE XVII