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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 XXI 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, 191&

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ADDRESS OF THE PRESIDENT OF THE MICHIGAN ACADEMY OF SCIENCE.

DELIVERED THURSDAY, APRIL 3, 1919.

AUDITORIUM, NATURAL SCIENCE BUILDING.

THE HUMAN ELEMENT IN INDUSTRY.

FRANK T. CARLTON.

Industry may be studied from the technical or non-human side or from the human side. Industrial experts have devoted much attention to the study of materials and machines, but unfortunately until quite recently only a minimum amount of attention has been directed to investigation of the most important factor in production,—men and women. In the words of another, "man is on the way to master inanimate things, but hitherto the failure has been in treating human beings too much like things." Wage workers have been treated as machines, as hands, as "factory fodder." Without exaggeration, it may be asserted that one of the most important, if not the greatest, economic problems of today is that of releasing effectively and efficiently, the productive energy of human beings and of groups of human beings. Few individuals work up to their possibilities and rarely are groups of individuals properly and harmoniously coordinated for the most effective results. Factories are filled with wage workers, but what is needed is an efficient and eager working force. There is too much latent talent and energy in the mass of breadwinners which rarely is utilized in productive industry. Our participation in the World War partially revealed America's "tremendous industrial capacity."

The goal of progress in the industrial sphere is twofold:—(1) Increased production at diminishing expense, and (2) increasing satisfaction on the part of workers in their work. Work as well as leisure should offer opportunities for self-expression and enjoyment on the part of the rank and file of workers. The United States sorely needs more training for the sort of efficiency which is not merely predatory, for the fine and rare variety which makes for industrial harmony and social well-being. We should have more careful consideration of desirable modifications in the; old and accepted forms of control in industry. It is the purpose of this paper briefly to discuss two steps which it is urged should be taken in order to raise the level of efficiency in American industry and to insure industrial peace. (1) Greater emphasis should be placed upon the development of individuality in industry. (2) Industrial autocracy should be replaced by some form of industrial democracy or constitutionalism. It is held also that the first cannot be taken without the second.

Many of the fundamental concepts of American democracy may be traced back to the pioneers of the days of Jackson and William Henry Harrison; and Americans are quite inclined to believe that industry until recent years has ever taken the form of the small-scale business of the period from 1800-1850. We are disappointed if the workers of today do not display the same interest in their work as did the pioneer farmer or the small-shop craftsman when working for himself. The employer and the man-on-the-corner today expect the carefully directed worker, deprived of all opportunity for initiative, self-assertion or responsibility, doing a certain simple task over and over again, to exhibit the interest and zeal which is traditionally ascribed to the pioneer American. The common mode of procedure has been vigorously to denounce the worker of today, especially if he be a member of a labor organization. Few have stopped to inquire:—Why are conditions as they are? What steps will insure betterment?

But, with certain exceptions such as are presented by the gildsmen of Western Europe and by the American pioneers who virtually employed themselves, history discloses that from the early days when the captives in battle were forced to till the soil for the benefit of their conquerors, through the long hopeless ages of slavery and serfdom, to the modern wage system with its definite contractual payment of money wages, the great mass of the world's workers have been dragged unwillingly into productive activity. Compulsion—the fear of the lash, of discharge, of hunger and of the lack of comforts—has been the potent, but negative, force which has throughout the ages hastened the steps of the lagging worker. This negative incentive has not and cannot make for efficiency, for joyful and creative work. Coercion will not produce good work; it is first necessary "to produce desire in the heart of the workman to do good work." "Man's place in industry is not to be mastered but to provide free and willing service."

Even today according to critics of the present industrial situation, "the whole industrial arrangement is carried on without the force of productive intention; it is carried forward against a disinclination to produce"; and a disinclination to produce will inevitably breed unreliability and inefficiency. Consequently, the present industrial arrangement in common with the earlier forms known as slavery and serfdom, must be inefficient from the standpoint of output, and also deadening and debilitating in its effect upon the individual workers. In this connection it may also be pointed out that the growth of the corporate form of business and the tendency to interpose "layers of corporate securities" between the owners and the property actually owned, tends to destroy the "pride of ownership" and the "joy of workmanship" which the owner so often exhibited in the days when smaller-scale and more simple industrial enterprises were the rule. The typical owner of corporate securities is an investor or a speculator rather than a person interested in the technical processes of production. The tendency toward routine, toward scientific management, and toward centralized and depersonalized supervision in modern large-scale

industry is making "individuality in industry" a rare phenomenon.

The negative incentives furnished by compulsion are not only inefficient now as was also true in the days of slavery and of serfdom, but, in an era of democracy and of compulsory education for all classes, unless re-enforced and modified by others of a more inspiring and stimulating type, the negative incentives provide social dynamite which will sooner or later put civilization in the imminent danger of a serious social upheaval.

The complex of instincts, habits, passions, prejudices, likes and aversions called man is the slowly and painfully evolved product of unnumbered generations. Man is the resultant of generations in which there was little of routine, regularity or reasoning. Man is endowed with almost ineradicable instincts and impulses which are the fruits of environmental conditions in the ages past. Modern industry on the contrary is a recent and artificial contrivance; it is the gift of the last two or three generations. The man who has become a cog in the gigantic articulated modern tread-mill is subjected to experiences and influences which cut across, thwart and inhibit many of the impulses and keen desires which he has inherited from the long ago.

The problem of the social sciences—if they have any adequate grounds for demanding the appelation of sciences—is to hasten the adjustment of associated men to the conditions of modern life and, to reduce the friction accompanying such adjustment. To accomplish this purpose evidently both the environmental conditions and the psychology of human beings must be carefully investigated. There is reason for believing that the fundamental impulses and instincts of mankind have changed little since the primitive man appeared.

According to McDougal, "men are moved by a variety of impulses whose nature has been determined through long ages of evolutionary process without reference to the life of man in civilized society." Such being the case, our problem becomes one of finding out what these fundamental impulses, instincts and emotions are, and to find expression for them in ways which make for uplift and racial betterment. Repression inevitably spells danger. It is quite clear that the instincts which long racial experience have evaluated as essential to survival cannot be easily swept aside by a few generations of regular industry, relative peace and plenty. We must reckon with them. To continue to disregard them is to close the door upon the possibility of making economics or sociology scientific. Assuming that human nature is not plastic or easy to modify, the most practical solution of the problem of industrial efficiency may be judged to lie in a definite and planned attempt to modify industrial conditions so as to offer as far as possible an outlet for the underlying impulses of mankind.

Heretofore, economists and other social scientists have been prone to consider men—workingmen at least—to be single-track individuals,—persons of few and fairly simple guiding instincts and impulses. We have built up a sort of straw man, and then proceeded with calmness to argue on the basis of this artificial, air-castle-like development of our own making. Students of American industrial problems have rarely stopped to study the actual, flesh-and-blood man and his motives. We have paid little attention to the problem of adapting industry and environment to men. We have naively accepted the crude idea that the great mass of people must fit into the new industrial environment even though it be quite dissimilar to that of preceding ages,—the ages in which the type of man was molded and cast. It was a maxim of Catherine II of Russia that a ruler operates on human skin which is exceptionally ticklish. The same proposition holds in regard to direction and control in the industrial field. It is a ticklish proposition in which the wants, prejudices, preconceived notions, ambitions and instincts of human beings cannot be disregarded with impunity.

For example, is industrial inefficiency and restriction of output due to the lack of potent incentives which touch the rank and file of industrial workers? Upon the correct answer to this question depends the possibility of formulating worth-while plans for industrial improvement. The late Professor Parker declared that laziness, in so far as it exists, is "an artificial habit, inculcated by civilization." The slacker in industry is produced by "the job and the industrial environment." Students of child life are practically agreed that the normal healthy child is neither lazy or bad. The artificial environment which adults ignorantly or selfishly provide, often makes him appear to be so. The normal adult is only the youth overlaid with custom, precepts, inhibitions and experiences.

On the other hand, a recent writer who is a student of psychology quite emphatically asserts that "peoples and individuals are by nature indolent." And, certainly unless prodded by opposition, rivalry, changed environmental conditions, unsatisfied wants or some other potent incentives, human beings tend to settle down comfortably into ruts, amiably to let well enough alone, and to be satisfied with much less than their best or near-best. The normal individual may not be lazy in the sense of desiring merely to loaf; but he does not love the routine of present-day industry as a regular day-after-day, year-in-and-year-out process from which the only tangible result from his point of view is a meager living for himself and family accompanied by extreme weariness of the flesh. Normal men may indeed possess an imperious instinct of workmanship or contrivance; but the up-to-date factory practicing minute subdivision of labor is equipped with excellent means of inhibiting this instinct. Undoubtedly, a worker may become so inured to routine that he will feel uncomfortable when out of the traces of his daily occupation; but such is an acquired feeling. It does not make for the zest and interest which lead men to push joyously ahead to newer planes of achievement.

The two points of view discussed above are not necessarily contradictory. Normal human beings are so

constituted as to enjoy activity which makes for worth-while results. What is considered to be worth-while obviously changes with time, place and kind of civilization. But, the normal active, non-lazy individual placed in an environment chieflly characterized by monotony and the lack of incentives for improvement or change, will after a time accept the present achievements as sufficient and follow the daily routine without enthusiasm. Certain vigorous and recalcitrant persons will rebel and try to escape from the hum-drum and correctness of the place and period; these are the heretics, the radicals, the I. W. W.'s.

One of our able and successful business managers out of his experience has put the matter very clearly. "The desire for self-expression is one of the most fundamental instincts in human nature, and unless it is satisfied it is bound to manifest itself in all sorts of abnormal ways which today are working such havoc in society." The late John E. Williams testified before the Commission on Industrial Relations that "the I. W. W.'s would not be very different from the other people if they had the proper organ of expression. It is just that sense of futility of their lot, of their means of action, that makes people resort to these measures of force." The last sentence is worthy of more than passing notice; it presents a vital fact from a man of much practical experience. Unfortunately, industry is offering little opportunity for self-expression to the average worker; it does not stimulate the interest of the worker in his work. In the use of potent incentives, modern large-scale routine industry has progressed little beyond slavery and serfdom.

It is too much to expect men to act conservatively and according to the customary procedure when they have little or no opportunity for the normal expression of human wants and desires. If they are unable to satisfy the instinct for food or for self-assertion, they will inevitably become biased, gnarled, knotted and perverse individuals. To make them more like the well-to-do conservative, the unblessed must be made more well-to-do. The much-abused and much-feared I. W. W. is composed largely of men whose instincts for family life, for acquisition of wealth, for contrivance or workmanship, and for self-assertion have been inhibited. Better treatment, better wages, opportunity in youth to acquire a little property are solvents for extreme radicalism.

Psychologists point out that changed environments have frequently changed individuals in an extraordinary manner,—from ne'er-do-wells to leaders, from criminality to useful citizenship, from sluggishness to a condition of mental alertness. A change in industrial methods, in the workshop conditions, in the incentives to activity may likewise work marvelous changes in the activities and the attitude of workers. "Primitive man, like his animal ancestors, expended tremendous strength and, having won his fight, relapsed into inaction, revelling in the fruits of victory."[1] The man in the factory, the mine or the store is capable of extraordinary activity on occasion,—note his activity when witnessing a close base-ball game, when on a strike or in case of an emergency such as a fire. The vocation of the mass of wage workers today offers very little to fire the workers or to arouse their latent energy or talents; there are few or no episodes which stir the blood and call for temporary, excessive or invigorating expenditure of effort. As a consequence the average worker soon exhibits the all too familiar "tendency to minimum effort." In modern industry, except for a small group, "improvement stimulus" is practically lacking. The great mass of unstimulated workers become uninterested and inefficient workers; they do not feel those incentives which stir human beings into activity. Yet, business competition can be made to offer opportunities for potent stimuli. One force, group or gang may become interested in its performance as compared with that of another or with its preceding performance. But, unless the workers have some very definite, voice in determining the conditions of rivalry, in sharing in its benefits, it is presently, looked upon as a scheme on the part of the employer to increase profits,—and too often with excellent reasons for such conclusion.

The situation in American industry—a skilled staff of mental workers and a mass of routine workers without any voice in the management of the industry in which they work—runs directly counter to the ideals of American political democracy and to the fundamental principles upon which the American public school rests. The schools of Germany "were organized upon the servility of the people"; but those of the United States on the ideal of individual initiative and equality of opportunity. Unfortunately, in this country industry and, too frequently, the school as well are destroying the plasticity, the initiative and the self-reliance of the youth; and the much-lauded systems of scientific management seem to constitute a further step in the same direction.

The effect of routine in industry is to divide the army of unskilled and semi-skilled workers in this country into two classes: (1) those who are becoming more and more lethargic, and (2) those who rebel against the autocracy of business and the monotony of the work thus augmenting the ranks of the migratory workers. The trend in industry is to reduce the relative demand for skilled men and to add to the relative number of unskilled workers. The future of the workers in the occupations requiring little skill is, consequently, becoming of increasing significance. The great mass of laborers have little opportunity for self-expression, self-assertion and self-direction. They are in too many workplaces servile, driven, cowed. These conditions do not make for efficient workmanship or for good citizenship. Docile and mechanized workers cannot be as efficient, their per capita output will be less that of workers who take an interest in their work, who have an opportunity to do creative work, and who have some even though it be small, voice in the management of the business. The laborer may be made to work; but the unwilling worker is below the par of efficiency. Every teacher knows that the uninterested pupil does not measure up to his possibilities; it is not as well understood that the uninterested wage worker is the

inefficient and careless worker. Moreover, such a situation may easily develop the combustible stuff out of which is formed the personnel of the I. W. W. or of the Bolsheviki. Out of the regimentation of docile individuals into well-disciplined groups of zestless individuals grows the danger of sudden and violent self-assertion.

The thwarting of the instinctive desires among working people tends as in the case of school children, to produce unrest, abnormality, delinquency and, in some cases, violence. Workers, thwarted by industrial conditions, become abnormal men and women. Keen observers have noted the growth of "sullen hostility" toward the employing class on the part of the migratory workers. The great group of migratory or nomadic workers have lost the incentives and the point of view which places emphasis upon workman-like qualities. They are drifting and rootless workers who are hostile to employers, to organized society and to the ideals which the middle class and the more conservative type of workmen blessed with home ties and a stake in life, hold dear. The problem is not one of statics or of going back to a pre-war footing; it is rather one of movement toward industrial democracy of the type advocated by the British Labor Party or toward syndicalism and I. W. W.-ism. The urgent problem is to find a practical middle ground in industry between autocracy or Prussianism and syndicalism or Bolshevism.

Programs for reconstruction or re-adjustment should be formulated with this situation in mind. The reactionaries of today are playing into the hands of the syndicalists and ultra-radicals. Punishment alone is insufficient in dealing with criminals; and it will likewise prove insufficient in dealing with the radical members of the I. W. W. The United States should give them an opportunity to earn an honest livelihood, to gain a semblance to equality of economic opportunity, and to satisfy the fundamental and deep-seated instincts of human nature such as self-assertion, acquisitiveness and contrivance. If we are not ready to take this step toward making this country safe for democracy, let us again read the records of historic political and social upheavals.

The ideals of the American educational system—though very imperfectly carried out in actual practice—call for the development of thinking and self-reliant individuals. For the rank and file, industry has been putting a premium upon docility and the absence of thinking or contriving. Why ask our public schools to train the great mass of workers, if the latter are to become semi-automatic human machines? In fact, such training aids in increasing unrest and discontent. The remedy, however, is not retrogression in regard to education. The remedy for many of the social and industrial ills of today is to be found in greater individualization in the work-shop, in greater stimulation of the spirit of initiative and self-reliance, and in a growing interest in the quality of output, among the great drab mass of wage workers. How can this remedy be applied?

The problem is: Can routine, sub-divided industry be made interesting? Can the "creative impulse" be given play? Can the "adventure of business" be opened up to the wage workers? Or, must plans for betterment be directed solely or, at least in a large measure, toward securing the short working day and such utilization of leisure time as will make for physical, mental and moral uplift? The second alternative is one worthy of promotion; but our present concern is with the former. In fact, if more potent incentives were disclosed in industry, if workers became more interested in their work, if one's work expressed in some degree his individuality, and if the workers were given a share in the responsibility of management, the recreation problem would be less difficult of solution. The remainder of this paper is to be devoted to a brief consideration of the first alternative.

Keeping in mind the considerations which have been presented, let us briefly analyze some of the recent plans for industrial betterment.

1. The much-heralded and much-lauded scientific management has accomplished important results; but has fallen far short of maximum possibilities. Efficiency engineers almost without exception have failed adequately to take into account the human side of the industrial equation. In their neatly prepared programs, the employees are as pawns to be moved at will on the industrial chessboard. The workers are practically shorn of all responsibility. But the road to efficiency in industry and to interest in work and output does not lead toward bureaucratic control. The most vital weakness in scientific management of the typical sort is that it does not lead the workers to take an interest in increasing the output of the shop. I am not arguing that all work can be transformed into pleasurable activity. Quite likely work will remain work, and play continue to be play. But I do not contend that in some measure it is possible to reduce the drudgery which so often accompanies work in modern industry, and that it is possible to make certain kinds of routine work interesting. Further, it is contended that this may be accomplished in part by giving the worker some voice in the planning and administration of industry, by providing a vent for his instinct of contrivance, and by making him feel that his work is worth-while.

2. Welfare work and profit sharing are highly paternalistic and are viewed with suspicion by the rank and file of industrial workers. The workers' point of view is neglected in nearly all plans for welfare work or for profit sharing.

3. A recent and promising step has been taken by certain managers of industrial plants. It is an attempt to introduce individuality into industry, to treat the worker as a self-respecting man capable of taking some responsibility upon his own shoulders. "It is our plan," writes Mr. R. B. Wolfe, "to increase his (the workers) responsibility, and we feel that it is our duty to teach him to exercise reasoning power and intelligence to its fullest extent." A definite attempt is made to enlist the creative spark which is the inheritance of all men, in increasing

productivity. The desire to do good work which all men possess is appealed to. The personal touch between management and men is introduced. Bonus schemes and premium plans are little used as incentives. This plan is a long step in the right direction. The greatest weakness in it as an adequate solution of the labor problem is disclosed by pointing out that no provision is apparently made for control by the workers. It is not necessarily a step toward industrial democracy; but it does give some recognition to the psychology of workers.

4. We are, however, witnessing some of the first steps toward industrial democracy. The joint responsibility of management and employees for the quantity and quality of output is being recognized by the new style of scientific management. William Filene's Sons' Company of Boston give their employees organized into the Filene Cooperative Association a voice in managing the business and in shaping the policies of the company. Up to date this company has found its employees to be reasonable and conservative. In January, 1919, the daily press reported that an ice company in Detroit had given a council composed of representatives of its employees a voice in determining the policies of this company. Under war conditions both the Fuel Administration of the federal government and the National Coal Association of coal mine operators favored a long step toward democracy in industrial control in the coal mines. "In each mine we are now appointing a committee of six persons. Three of them represent the management. The other three are chosen from among the rank-and-file employees. In unionized districts these three representatives of the employees will be chosen by action of the union. And for what purpose? Not to discuss wages and profits. Other committees will deal with the division of the spoils of production. These committees are to deal with production itself, with its technique. We shall have union officials charged with a responsibility for getting out more coal. We shall have rank-and-file employees, at the end of each day, apportioning the blame for inadequate output, part of it to such and such failures by the working force, part of it to such and such failures by the management."[2] In England, various plans have been proposed or adopted which lead toward "constitutionalism in industry."

These and other plans of forward-looking business concerns are innovations; and many hard-headed individuals are ready to sneer and to point out the impossibility of success. It should not be forgotten, however, that every worth-while innovation meets ridicule and opposition. One writer on business affairs puts the matter in a nutshell when he writes: Many managers "don't want to learn new ways." They want to get results in their way. The ways of business managers are too frequently traditional and autocratic. The foundation principles come down from the time of slavery. Little or no attention is paid to the wishes or ideas of the workers. It is assumed by the old-fashioned employer that the average worker is a blockhead and one to be driven. The former puts fear into the breasts of the workers. The possibility of harmonious conferences in regard to grievances and production methods is scouted. The traditions of the American business world regarding the rights of employers and employees and of the relations between managers and men are about to suffer from disturbing influences. A new era is dawning; but just what it will be depends greatly upon the willingness and the ability of leaders in the business world to adjust their policies and to study the situation from other points of view than that of the man "who proposes to run his own business to suit himself." "The job must be made worth while" for the worker, —if efficiency is to follow. The old idea that the essence of the labor problem consisted in keeping laborers contented on wages which were insufficient to live upon, is being replaced by a more hopeful, humane and scientific point of view.

The leader of the new type in industry is studying men. He pays good wages, he maintains a model plant, he makes it possible for his employees to hold up their heads and be men. The new industrial leader recognizes that human energy can only be released and properly guided by utilizing the motives which underlie and determine human conduct. It may again develop into a case of democracy and many mistakes versus autocracy and smooth action. But in view of the peculiar make-up of the human being, autocracy and smooth action may spell inefficiency through subtle forms of sabotage and the lack of zest or interest in the process or in the amount of output.

5. A stable form of industrial democracy must rest on a stronger foundation than the more or less erratic impulses of employers or the war emergency powers of the government. It must rest upon an organization of workers which has a firm footing outside any particular industry. An organization of workers in one business unit without outside affiliations or members, is in great danger of being dominated by the employer and to lack stability and backbone; but a national labor organization stands on firmer ground, its foundation is broader and its outlook less restricted. One essential to the development of industrial democracy is the recognition of labor organizations. "Within-the-family" organizations will almost inevitably be dominated by the most powerful interest which is almost certain to be in such a case the employer interest. However, the most significant step taken in the organization of labor in recent months, the shop steward's movement in England, is essentially a "within-the-family" organization.

Up to date, labor organizations in the United States have been primarily fighting machines; their functions have been mainly protective. The hostile attitude of employers and employers' associations have inevitably produced this reaction. Unions cannot be expected to take any active interest in production problems until their members are assured that the necessity of continuing as a fighting organization is a thing of the past. With increasing participation in governmental affairs on the part of labor, guarantees of a living family wage, greater

security of employment, a short working day, and the cooperation of committees of workers with the representatives of capital in business management, a marked and significant change may be expected in the structure, ideals and functions of labor organizations, and in the attitude of their members toward restriction of output and kindred difficulties which now bulk large on the industrial horizon. The instinct of workmanship or contrivance, the creative impulse or spark "cannot actively assert itself until the instincts more directly concerned with immediate survival are given satisfaction."[3] Efficiency in industry or in other forms of human endeavor depends in a large measure upon releasing the creative impulse, upon the joint responsibility of labor and capital. Definite recognition of labor organizations and the participation of representatives of the workers in the councils of industry give promise of being fundamental factors in the next forward step in industry. The War has given the idea of collective bargaining a firm foothold. It was very definitely promoted by the National War Labor Board. The war experience of the nation shows clearly that it should become a permanent factor in our industrial organization.

It is also clear that many union rules and regulations do not permit of maximum productivity. In England, the exigencies of the Great War made it necessary to sweep aside the great mass of union restrictions. Regulations primarily intended to defend unionism have limited output and impaired efficiency. In a large measure, the problem under consideration is one of transforming unionism from being a negative or restrictive force or factor to that of being a positive or directive force or factor in industry. As this salutary transformation is in the process of consummation, restrictive rules will be gradually sloughed off.

Optimists viewing the phenomena of the recent struggle may assert that the old antagonism between labor and capital is on the road to oblivion and that the necessity for unions is now largely of historical significance only. Because business men were quite willing and ready to respond to the call of their country and to put aside personal gain in the interests of the nation, it may be urged that the business men will never again be so unresponsive to the broader or social aspects of business. A well-known man connected with the Fuel Administration in one of the States wrote in a farewell letter to his associates in that service. "You have proved that Americans can act from public motives, that deep in the soul of them is power to respond to a selfless ideal, that latent in the heart of the practical business man is the hunger for service unbribed, unrewarded and self-compensating." Granting that during the progress of the Great War many of the dollar-a-year men and other industrial captains were converted to high ideals and excellent performance in the interest of social and national good, it will indeed be remarkable if a large percentage do not backslide after the pressure and the enthusiasm generated during the War have disappeared and after the prosaic times of peace have re-appeared. There is reason to fear that these new motives will prove, like beauty, to be only skin-deep.

On the other hand, the War unmistakably demonstrated that the support of labor was indispensable to the nation in a national crisis; and, since the government intervened in the operation of so many businesses, the War has also tended to depreciate the importance of the functions of investors and managers. When the United States entered into the Great War, workers were appealed to to speed up and to increase production. But the appeal was for the workers to stand back of the government and the boys in the army. The appeal was not made to loyalty toward employers. It is a sad commentary on modern industry that it has been so conducted and so managed that incentives to better work rest upon considerations entirely outside the industry itself.[4] Now, therefore, is not an opportune time for arrogance on the part of business men; it is the time for careful, intelligent and open-minded study of the industrial situation. We seem to be on the threshold of a new era in industrial relations. The employer who can only think in pre-war terms is a menace to industrial peace. In short, it is asking too much to expect labor to rest its case on the recently awakened social conscience,—a war product. In view of past experience, it must be anticipated that workingmen will continue convinced that union organization is essential to insure that workers will be treated like men and that sufficient emphasis will be placed upon the human element in industry. If the nation is on the threshold of a new era, organized labor must be recognized, bargained with and given a voice in determining working conditions and methods. Under such conditions unions can and will divert their energies from squabbling over the distribution of the output of industry to the new and more alluring goal of raising the level of productive efficiency and of giving the "joy of workmanship" a conspicuous place in modern industry.

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[1]Swift, Psychology and the Day's Work, pp. 28-29.

[2]Hard, *The New Republic*, September 21, 1918.

[3]Tead, *Instincts in Industry,* p. 150.

[4]See Marot, *Creative Impulse in Industry*, pp. 57-58. See also *The Nation*, Feb. 8, 1919, pp. 192-3.

GEOLOGY AND GEOGRAPHY.

NOTES ON THE STRATIGRAPHY OF THE RACINE FORMATION OF THE NORTHERN PENINSULA OF MICHIGAN.[1]

G. M. EHLERS.

The use of the name Racine is suggested by the writer for the thick-bedded, white dolomite formation at the top of the Niagaran of the Northern Peninsula, which heretofore has been designated as Guelph and Engadine. Dr. A. C. Lane[2] in 1908 referred to the formation as Guelph, correlating it with the formation of that name in Ontario. In 1915, Mr. R. A. Smith[3] provisionally named the formation Engadine and indicated its probable correlation with the Guelph. In the following year, the name Engadine was accepted by the Michigan Geological and Biological Survey[4] and the formation definitely correlated with the Guelph. Recent studies by the writer indicate, however, that the Engadine dolomite includes strata which are older than Guelph as well as strata of Guelph age. The name Guelph, since it was not proposed to include these older strata, is therefore inappropriate for this formation. The Engadine formation, furthermore, is with little doubt continuous with the formation in eastern Wisconsin which was named Racine by Professor James Hall[5] in 1862. The name Engadine, since it is applied to a formation previously designated as Racine, should therefore be rejected.

The division of the Racine of Wisconsin into the Guelph and Racine by Professors Chamberlain and Whitfield is apparently unwarranted. These writers[6] applied the name Guelph to the uppermost strata of the Racine formation of this state, upon finding that they contained a fauna very similar to that of the Guelph formation of Ontario. They[7] retained the name Racine only for the lower strata of the formation, designated by that name by Professor Hall. When making this division, Professors Chamberlain and Whitfield[8] recognized that the Wisconsin Guelph and Racine, as used in their restricted sense, do not differ essentially in lithologic character and that numerous Guelph species are present in the Racine beds. In a communication to the writer, Dr. E. O. Ulrich of the United States Geological Survey states that, so far as he knows, there is no stratigraphic nor paleontologic break between the beds of these formations. Because such a break seems to be absent, Dr. Ulrich would not divide the formation designated Racine by Professor Hall. It is the writer's belief that most stratigraphers will agree with Dr. Ulrich that the division of the Racine of Wisconsin by Professors Chamberlain and Whitfield is unjustified.

There seems to be no better reason for dividing the Racine formation of the Northern Peninsula of Michigan than of Wisconsin. The strata throughout the formation in the Northern Peninsula are very similar in lithologic character and no evidence of a stratigraphic or paleontologic break seems to be present.

In the Northern Peninsula, the Racine formation is at or near the surface of much of the region adjoining the north shores of Lakes Michigan and Huron. It is exposed at many places on the shores of the Point Detour peninsula, Poverty and Big Summer Islands, Lake Michigan. The land adjacent to Lake Michigan between the Point Detour and Seul Choix Point peninsulas is probably underlain by older Niagaran strata of the Manistique formation, although parts of this land, especially the extremities of the more lakeward extended peninsulas, may be occupied by the Racine dolomite. A small outlier of the Racine dolomite occurs at the village of Whitedale, which is situated northwest of Seul Choix Point on the Minneapolis, St. Paul and Sault Ste. Marie Railroad. Most of the Seul Choix peninsula is underlain by the Manistique strata, areas of Racine dolomite occurring only on its southwest and northeast sides. This local areal distribution is due to the erosion of the latter formation from the top of a low anticline, having a crest-line parallel to the northwest-southeast axis of the peninsula. A continuous belt of Racine dolomite, having an average width of six miles, extends from the Seul Choix Point peninsula to the Detour Passage and borders the north shores of Lakes Michigan and Huron except where it extends across the base of the large, triangular-shaped St. Ignace peninsula. The surface rocks of the St. Ignace peninsula and possibly the southern part of the St. Martin's Point peninsula belong to the Monroe-Salina group. The southern portion of the Point St. Vital peninsula is apparently underlain by the Manistique formation. A narrow strip of land, adjoining the shore of Lake Huron between this peninsula and the village of Detour on the Detour Passage, may also be underlain by the Manistique, although it seems more probable that it is underlain by the Racine dolomite. Outcrops of the latter formation are numerous along the south shore of Drummond Island. The presence of a few exposures of the underlying Manistique formation along this shore is apparently due to the erosion of the Racine dolomite from the tops of very low anticlines.

The Racine formation consists of very thick beds of hard, highly crystalline dolomite of a predominant white color. Some beds are bluish-white or very light-gray. Upon weathering, the color of the beds, especially the bluish-white ones, changes to a light-buff or brown. Some strata are also characterized by many cavities, which are more or less completely lined with crystals of dolomite. The beds generally show a very poorly developed and irregular jointing. In the unweathered condition, the dolomite is usually massive, but upon weathering, it often shows numerous, more or less closely spaced and uneven planes of bedding.

The Racine formation in the Northern Peninsula is probably 275 to 300 feet thick and has a general dip southward of 40 to 60 feet per mile.

The Racine dolomite lies conformably upon the strata of the Manistique formation. The uppermost Manistique strata consist of thin, uneven-bedded, siliceous dolomites of a buff to brown color. They are also characterized by relatively few silicfied corals, such as *Favosites favosus, Halysites catenularia*, *Alveolites undosus* and *Cladopora laqueata*, which become very abundant in lower strata of the formation. At some localities, the contact between the two formations is well-defined; at others, it is more or less obscured by a few feet of transitional strata, which, in the writer's opinion, should be included in the Racine formation, because they are more nearly related in lithologic character to the Racine than to the Manistique strata.

So far as known, the contact between the Racine dolomite and the overlying strata of the Monroe-Salina group is not exposed. The lowest, observable strata of the Monroe-Saline group, which apparently are very near to this contact, outcrop on the bottom and sides of the Carp River in the S. E. ¼ Sec. 12, T. 42 N., R. 4 W., Mackinac County. These strata are composed of thin-bedded, fine-crystalline dolomites of light pinkish-gray and brownish-gray color.

The correlation of the Racine formation of Michigan with the Racine formation of Wisconsin is based chiefly upon the lithologic similarity and apparent continuity of the strata. This correlation is supported by the fact that the Racine formation occupies the same stratigraphic position in both states. In northeastern Wisconsin, the formation rests upon the Upper Coral Beds. In Michigan, it rests upon the same strata, which are included in the Manistique formation. The Racine formation, in both states, is overlain by Cayugan strata of similar lithologic character. Whether these beds are of exactly the same age in the two states is, however, not known.

The lowermost strata of the Racine formation of Michigan and northeastern Wisconsin and the massive, sparingly-fossiliferous beds of dolomite at the top of the Lockport formation of Cockburn and Manitoulin Islands, Ontario are lithologically similar and with little doubt continuous. The uppermost beds of the Lockport of the Ontario region southeast of Manitoulin Island may represent a further extension eastward of these same beds.

Certain information, communicated to the writer by Dr. M. Y. Williams of the Canadian Geological Survey, indicates that the uppermost strata of the Lockport of Dawson Point, Lake Timiskaming are lithologically similar to the lowest beds of the Racine of Michigan. These widely separated rocks may occupy the same stratigraphic position.

The Guelph formation of Ontario, in the opinion of the writer, is to be correlated with certain strata composing the upper part of the Racine formation of Wisconsin and Michigan. This correlation is determined chiefly by the presence of Guelph fossils in the rocks of the three regions. As previously noted in the first part of this paper, numerous Guelph species were also found to be present in the lower strata of the Racine of Wisconsin (Racine beds, in the restricted sense) by Professors Chamberlain and Whitfield. A few Guelph species, *Favosites cf. occidens*, *Amplexus whitfieldi*, *Pycnostylus guelphensis*, *Poleumita cf. scamnata*, *cf. Pycnomphalus solarioides* and *Trimerella* sp., have been collected by the writer from strata near and a short distance below the middle of the Racine formation in Michigan. The reason that a larger number of Guelph species have not been found in Michigan is, in the writer's opinion, due to the fact that most of the upper strata of the Racine formation, which would be likely to contain numerous Guelph species, are inaccessible, owing to a covering of glacial soils. Since the Guelph fossils may occur in the lowermost strata of the Racine of Wisconsin and Michigan, which are with little doubt of upper Lockport age, they do not afford a means of determining the number of feet of Racine strata in the two states that should be correlated with the Guelph beds of Ontario.

The Eramosa beds of Ontario may be a correlative of certain strata of the Racine formation.

It is not the purpose of this paper to indicate all the formations which may be correlated, wholly or in part, with the Racine of Michigan. Such stratigraphic relationships will be considered more extensively by the writer in a forthcoming paper upon the Niagaran deposits of the Northern Peninsula, which will be published by the Michigan Geological and Biological Survey.

It is necessary to note, however, that the Racine formation of Wisconsin and Michigan is closely related in age to the Leclaire limestone of Iowa. Professor Hall[9] stated that the Racine of Wisconsin " * may be considered indentical with the Leclaire limestone of Iowa, holding precisely the same geological position, and containing some similar if not identical fossils; * * *." In a communication to the writer, Dr. Ulrich states that there are various reasons for believing that the Leclaire and Racine formations are not exactly equivalent. In consideration of Dr. Ulrich's opinion, the names Leclaire and Racine should be employed for the formations in question. If Professor Hall's opinion regarding the equivalency of the two formations should be proven correct, the name Racine, for the uppermost Niagaran formation of Michigan and Wisconsin, would have to be rejected for the older name Leclaire.

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[1]Published with the permission of the Director of the Michigan Geological and Biological Survey.

[2]Lane, A. C., Ann. Rept. for 1908, Michigan Geol. Survey, pp. 56-57.

[3]Smith, R. A., Pub. 21, Geol. Ser. 17, Michigan Geol. and Biol. Survey, pp. 150-151, 1915.

[4]Allen, R. C., Smith, R. A., and others, Geological Map of Michigan:—Pub. 23, Michigan Geol. and Biol. Survey, 1916.

[5]Hall, James, Report on the geological survey of the State of Wisconsin, Vol. 1, p. 67, 1862.

[6]Chamberlain, T. C. and Whitfield, R. P., Geology of Wisconsin, Vol. 2, pp. 335-336, 1878.

[7]Op. cit.

[8]Op. cit., p. 377 and faunal lists, pp. 384-389.

[8]Hall, James, Report on the geological Survey of the State of Wisconsin, Vol. 1. p. 67, 1862.

GLACIAL AND GLACIAL LAKE FEATURES IN THE VICINITY OF KALAMAZOO.

FRANK LEVERETT.

(Abstract.)

The Kalamazoo Valley was covered by the icesheet down to the time of the Battle Creek moraine, and there was direct drainage southward to the St. Joseph River and thence past South Bend to the Kankakee River which drains to the Gulf of Mexico. The Lake Michigan ice-lobe then shrank back to the position of the Kalamazoo moraine and a lake developed in front of it immediately east of Kalamazoo which drained southward past Austin and Gourdneck lakes and the village of Vicksburg to Portage River and thence to the St. Joseph River at Three Rivers. It is proposed to call this Lake Kalamazoo because of its close relation to the site of the city. It stood at an altitude of about 870 feet, or 100 feet above the business portion of the city. It was, however, very shallow to the south of the valley and its bed carries only a small amount of lake silt. It was this lake that determined the abrupt eastern limit of the outwash plain of the Kalamazoo moraine in the district just south of Kalamazoo.

After forming the Kalamazoo moraine the ice-border made a stand immediately west of the moraine and caused ponding of water in the vicinity of Alamo at an altitude about 50 feet lower than that of Lake Kalamazoo, and this found southward discharge along the inner or west border of the Kalamazoo moraine to the St. Joseph River at Niles and thence southward to the Kankakee at South Bend. It is proposed to call this Lake Alamo.

With the recession of the ice-border to the position of the Valparaiso moraine the waters in front of the Lake Michigan ice-lobe became ponded in the vicinity of the Kalamazoo River at a level about 50 feet lower than Lake Alamo, or an altitude of 765 feet to 770 feet. A long lake was formed that extended from Gun Lake southward to Decatur where it opened into Dowagiac River, and this in turn entered another lake opposite Dowagiac which extended to the Kankakee River at South Bend. This ponded condition is known as Lake Dowagiac and has already been figured in Monograph LIII of the U. S. Geological Survey. This lake had well-defined shore lines on a considerable part of its border and evidently persisted for a period of some centuries at least.

When the Lake Michigan lobe was forming the system of moraines known as the Lake Border morainic system, which lies just outside the border of Lake Michigan, the Kalamazoo waters were ponded below Allegan to a height sufficient to find discharge southward into Lake Chicago, which stood at a height of about 60 feet above the level of Lake Michigan, or 640 feet above sea level. With the recession of the ice from this morainic system the Kalamazoo River drained directly into Lake Chicago.

The paper took up a description of the moraines and other glacial features which have been referred to in this abstract, and brought out by means of maps the relation of the moraines to the ponded waters.

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MAPPING THE UTILIZATION OF LAND.

[Abstract of Article published in the Geographical Review, New York.]

C. O. SAUER.

The principles of geographic mapping, properly so called, can hardly be said to be formulated. Geographic field work is still in its beginnings, and the geographic survey is not even projected. The true geographic map, although based on maps of the sorts mentioned, must attempt to set forth economic conditions. Certainly the aim of such a map would be to represent the ways in which the people of the area make their living and the character of this living, insofar as these things can be placed within the inelastic frame of a map.

The problem may be attacked, in the mapping of a small area on a large scale. In this, way simplicity of material is secured and the amount of generalization is much reduced. Of such a map it may be expected that it shall succeed in building up a panorama of its area, and that this representation will place in full and true light the area both as home and place of business of a group of people. The analysis, thus undertaken, may be expected to bring out the distribution of the significant activities of the area, to suggest their interrelations, and to indicate the local economic opportunities and disabilities. This means a census taking in map form with two principal problems, a major one in the selection of the economic conditions to be represented, and a secondary one in securing proper graphic expression. The present paper is concerned primarily with the former problem.

Since utilization is the key-note, the map must distinguish first of all between productive and non-productive areas, or else, between what the Census designates as improved and unimproved land. In the former classification the critical element is yield, in the latter, labor. In this way a grouping of land utilization of the following sort may be arrived at: Barrens, woodlands, permanent pastures and meadows, cultivated lands.

BOTANY.

A STUDY IN THE DIFFERENCE IN SOIL REQUIREMENTS OF PINE AND SPRUCE.

L. J. YOUNG.

An area on the Saginaw Forest, planted to Norway spruce in 1904, has furnished an interesting and instructive demonstration of the great importance in forest planting of choosing the proper species with reference to a given combination of site conditions. In order that the business of forestry shall yield a profit, the rate of growth of the timber must not fall below a certain minimum. The more it exceeds that minimum up to a reasonable limit, the higher the profits. The proper species for a given site is, then, one which will make the growth demanded by the general economic conditions existing on any particular forest to determine the right species is not always easy, and in the case of this particular area a mistake seems to have been made, for the growth over a considerable part of it has been far from satisfactory.

At the southern border a narrow strip is practically level, and here the growth of the spruce has been fairly good. To the north of this strip the land slopes moderately toward the lake, and this slope comprises most of the area. Here the growth has been poor, and on several spots very poor. At the foot of the slope is a slight depression, which runs toward the east, becoming somewhat deeper in that direction, and all the trees in the bottom of this have made excellent growth. To the north, of this depression the land rises a few feet into a rounded knoll and here again the growth has been very poor. The result of these varying conditions is a very irregular stand, in which the present height of the trees varies from a minimum of 0.8 of a foot to a maximum of 21.1 feet, with an average of 6.5 feet.

Up to the time of its acquisition by the university, this land had been handled as a part of a farm and apparently had received little care, so that the surface soil on the slope had washed badly and three large gullies had been formed by erosion. The best of the soil from the slopes and the knoll to the north had been carried into the depression at the foot of the slope, forming a deposit of fine loam six inches thick without any admixture of gravel. On the slopes, coarse gravel occurs plentifully in the soil from the surface down.

Examinations of samples taken from different parts of this area showed that the soil on the slopes contains less moisture, very much less organic matter, and less lime than that from the more level portions. Undoubtedly the lack of these important plant foods is largely responsible for the unusually poor growth of the trees on the slopes. It is noteworthy, however, that even the better portions of the area are so poor that the grass cover established between the trees has always been very thin and scant.

It has long been known that the pines as a class are more frugal than the spruces, i. e., demand less from the soil, in order to make an equal growth. To demonstrate this fact and to secure data for making a definite comparison between pine and spruce on the one hand and different species of pine on the other, three species of pine were planted in the spring of 1915 among the spruce on the spots where the spruce had made the poorest growth. The species planted were *Pinus strobus*, *Pinus sylvestris* and *Pinus ponderosa*. The ages of the stock were as follows: *P. strobus*, four years; *P. sylvestris*, three years; *P. ponderosa*, two years.

The height of all the trees on these plots was measured in March, 1919, after four growing seasons, for the pine and fifteen growing seasons for the spruce. The results of these measurements are shown in the following table:

	—Total Height in Feet—		
Species.	Maximum.	Minimum.	Average.
Norway Spruce	7.0	0.9	2.88
White Pine	3.1	0.4	1.3
Scotch Pine	5.1	2.2	3.8
Western Yellow Pine	2.0	0.5	1.1

Since the growth of all of these species is relatively slow during about the first five years after planting, the pines have not yet had a fair chance to show what they can do. At the end of the next five years the differences, will undoubtedly be much more striking. But even within the short space of fours years the Scotch pine has been able to make an average total height growth that is one foot greater than that made by the spruce in fifteen years, with a minimum height more than twice that of the spruce.

If the different species are compared on the basis of the average annual height growth made since the germination of the seed, these results are obtained:

Species.	Average Annual Height Growth in Feet.
Norway Spruce	0.17
White Pine	0.16
Western Yellow Pine	0.18
Scotch Pine	0.54

During the years to come the average annual growth of all the pines may be expected to increase decidedly while that of the spruce will probably decrease. Just how much the growth of the pines will increase and which one of the pines will be leading at the end, time only will tell. The present figures are merely indicators, but already emphasize the wide difference between the Norway spruce and Scotch pine in adaptability to poor soil conditions.

The coniferous forests of Europe are composed almost entirely of Scotch pine and Norway spruce, so that a great deal is known as to their rate of growth under European conditions on sites of different qualities. It is interesting to compare their figures with the ones given above as a means of evaluating the quality of the site

under discussion. The average annual growth of Norway spruce for the first fifteen years (this period is taken from the time of planting) on sites of the poorest quality used for spruce is 0.23 of a foot. Our growth has been 0.19, which shows that these poorest spots are somewhat lower in quality than the poorest spruce sites of Europe. Using the pine figures in the same way shows that these same spots correspond almost exactly to the medium, or average, quality of sites used abroad for Scotch pine.

Taking the growth of the spruce for this plantation as a whole, however, we find that it is nearly equal to that of sites of medium quality. If Scotch pine had been planted over this whole area, it doubtless would have made even better growth than the average of the best pine sites of Europe. Speaking technically, this means that by growing spruce on this area we are working with Site II; in pine it would be Site I. The European growth figures for these sites at the end of 120 years are:

Scotch Pine.	Average diameter, 15.4 inches. Average height, 103 feet.
Norway Spruce.	Average diameter, 11.5 inches. Average height, 84 feet.

In 1924, at the time of the next measurements, we shall be able to predict more definitely the probable growth of the white and western yellow pines, a thing that we are unable to do at present because of their habit of starting more slowly than the Scotch pine.

University of Michigan.

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THE BIOLOGICAL METHOD OF DETERMINING THE FERTILIZER REQUIREMENT OF A PARTICULAR SOIL OR CROP.

R. P. HIBBARD AND S. GERSHBERG.

Soil experts and chemists are loath to put any dependence on the result of a chemical analysis of either the crop or the soil as far as using them to plan a fertilizer treatment. The best and only logical way, then, to determine the crop's needs is to grow the crop on the soil and make a detailed study of the relations between the two. The great majority of fertilizer experiments have not been so planned. The combinations or ratios of the three fertilizer constituents commonly used have been greatly restricted, and except in a few cases the soil has been ignored.

The method suggested here consists in a-well planned series of combinations, each one varying from the other and all the rest in small increments. In this way a wide range of ratios or combinations are used and there are no missing ones in the whole series. Obviously this is a more logical method than the hit-or-miss one, in which the combinations are selected at random.

To indicate the method by which a series of combinations is planned, since space for a figure is not available, one must picture to himself an equilateral triangle, the kind that has often been used when one desires to express in a diagrammatic manner the relations between three variables or three quantities, such as the three fertilizer salts, acid phosphate, sodium nitrate and potassium sulphate. This particular triangle which we wish you to think of indicates at the points of intersection of the various lines all the possible combinations or ratios of the three salts, where each constituent varies from the other by increments of ten per cent. There are eight horizontal rows of combinations, counting from the base to the apex of the triangle. In the lower row there are eight combinations; in the one above, seven, and in each succeeding row one less.

Many such series or sets of combinations have been arranged for water cultures in the greenhouse. This same method can be used in the field, but when the plots are large, as for example one-twentieth of an acre, the work would be difficult and almost impossible. However, the plots can be cut down to small sizes and a number of checks or controls introduced to average up individual differences. Then at the end of the experiment the undesirable combinations can be eliminated and the others run on plots of larger size. Another way to obviate this difficulty would be to run a series with few numbers of combinations. Let the combinations differ in increments of 20 per cent.

In the summer of 1918 a complete series of 36 combinations, run in triplicate, was put out on the station farm. The experimental plots were 2 feet by 40 feet. Besides the 36 combinations of three fertilizer salts, there were several plots on which applications of single salts and double salts were made. Here and there scattered through the series were check or control plots. The soil was a sandy loam and the crop oats. At the end of the experiment the best combination of fertilizer salts was determined by the yield of grain and straw. Although it is hazardous to judge from one season's work, the results indicate that the best combination is that in which there is a large amount of acid phosphate. This is true only for this particular soil. The plot -that was treated with acid phosphate alone, however, did not yield as well, showing that a small amount of the other two fertilizers was needed. A subsequent experiment should consider the ratios in this region of the triangle in more detail and on larger plots. With another crop on another type of soil, some other ratio might be the best. These matters have yet to be determined. Three experiments are now running: One on the college farm with oats on a poor sandy soil; one at Clio, Michigan, on the farm of L. J. Reed with corn on sandy loam; and the third on the farm of Ezra Levin with potatoes on a fine sand, containing only a little organic matter. It is the hope of this article that others will be interested to work out their soil and crop needs by the ratio method. If so inclined one could collect a large amount of a certain soil type in the fall, and during the winter set up some such

series as outlined above. In this way the preliminary work could be done away with and a small series run on a large scale in the field in the spring. The farmer, not inclined to study the soil because of inadequate apparatus and supplies, could send the soil samples to a laboratory, where such a study as outlined above could be made and from the data collected a method of treatment devised and forwarded to him.

It is believed that three or four weeks' growth of plants in pot cultures will give data which can be used to predict the probable yield at maturity. In fact, there is every likelihood that a mathematical scheme can be worked out to show what the final yield will be after merely a few weeks of growth. Thus in the winter time one can wisely plan what sort of combination will be best to use for a particular crop on a particular soil. Truck growers who use large greenhouses have excellent facilities for working out such a method which will aid them in planning the fertilizer treatment of their soils in the field.

In conclusion it may justly be said that chemical analyses of soils and crops have taught us much in some lines, but little or nothing as to the fertilizer requirements. The crop test method is the only reliable one left, and if a wide range of combinations are selected and logically worked out, something definite and tangible can be obtained. There are great possibilities for improving our practice in the utilization of fertilizers in plant production. We need exact knowledge as to the best salts to use together and the best ratios or combinations.

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