balance, in the form, for example, of a grip-testing machine, he could measure the strength of the muscles of his hand, or the attraction between two bodies, just as well under those circumstances as if he were on the surface of the earth.

Secondly, if we are dealing with only a portion of the physical universe (as is always the case in practical problems), we must either introduce "forces" to account for the action of the residual portion, or else resort to very artificial conventions in regard to "imaginary masses." (It should be noted that the "mass-acceleration" of a body can not conveniently be taken as a substitute for an external force acting upon that body; for the mass-acceleration of the body, like its momentum or kinetic energy, is a quantity inherent in the body.)

Thirdly, the approach to statics, in which the concept of mass plays no part whatever, is peculiarly awkward by this route; whereas if force is taken as the fundamental concept, the problems of statics may readily be taken up either before or after the detailed study of dynamics.

While therefore it is logically possible to choose either mass alone or force alone as the fundamental concept, the latter choice seems practically preferable.

Either the force method or the mass method, I say, is logically defensible; but the method which starts with the equation $F = ma$ is neither the force method nor the mass method. My chief objection to this hybrid equation $F = ma$ is precisely this uncertain wavering between the force concept and the mass concept as the fundamental notion of the science. This wavering is, I believe, the main source of the very real difficulties which the student experiences in regard to "units"—difficulties which are not necessarily functions of the laziness or immaturity of the student, but which are felt more keenly by those of a scientific and critical turn of mind than by those of a merely practical bent. I quite agree with Professor Hoskins that any student of dynamics ought to have sufficient intelligence to grasp the idea of a *systematic system of units,* that is, a system in which certain units are taken as fundamental, and all others are derived; but I do think that the student has a right to expect that the quantities which appear in the so-called fundamental equation shall be the same as the quantities which are taken as fundamental in the system of units. *This is not the case with the equation* $F = ma$. The trouble with this equation is not that it contains mass, but that it contains *both force and mass,* while not both of these quantities are regarded as fundamental in the subsequent treatment.

The use of the equation $F/F' = a/a'$ seems to me, therefore, not merely a matter of practical convenience, but also a distinct advance in scientific precision of thought.

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### GEOLOGIC HISTORY OF LAKE LAHONTAN[1]

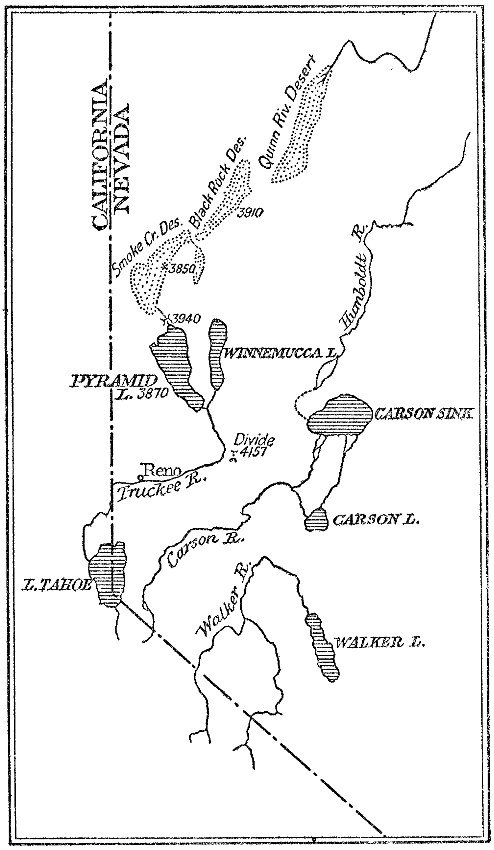
IN reference to the summary concerning the probable history of Lake Lahontan by J. C. Jones, contained in SCIENCE, December 4, 1914, while I am much interested in Professor Jones's conclusions concerning the origin of the tufa, I feel that his statements regarding the interpretation of the age of Lake Lahontan need some important qualifications, and that his conclusions as to the probable accumulation of salines in Lahontan waters are not at all the necessary deductions from the evidence that he has cited.

Professor Jones's estimates on the age of Lake Lahontan and the quantity of salines that might have been deposited by the evaporation of its waters fail to take into account some very important considerations. The assumption that because Pyramid Lake may be and probably is a remnant of Lake Lahontan, which has never been dried up completely, therefore its salines are an index of the age of the whole larger lake seems to me erroneous. A conception of a closer interpretation may perhaps be obtained in the following way.

No one doubts that Lake Lahontan formerly rose to a height of approximately 500 feet above present Pyramid Lake and that its

[1] Published by permission of the Director of the United States Geological Survey.

waters have since largely disappeared through diminishing water supply. The water supply that maintained the larger lake, as that which maintains the smaller lakes of the present day, came principally from a few major streams draining from the higher Sierra. Of these Truckee, Carson and Walker rivers were with little doubt, the dominating factors. The following is an outline map showing the general relation of these drainage systems.




Outline Map Showing Truckee-Pyramid Drainage System and its Former Northward Extension.

Approximate equilibrium was maintained in the larger Lake Lahontan through the balance of evaporation and inflow. Evaporation varies directly with the surface area of the water body. Inflow is supposed to have been gradually decreasing as the lake level was falling. When, however, the waters fell to the level of any divide which would separate the basin into two or more distinct parts, the equilibrium that had been maintained for the lake body as a whole would hardly be continued in exactly proportionate relations in the two separated parts. Each part must have then established a new relation of separate inflow and evaporation ratio, and it is almost a certainty that an overflow would for a time be established from one side toward the other over the intermediate divide.

Such an overflow may have occurred over the Fernley divide from the Truckee Basin into the Carson Basin. The evidence of channels there is not very clear. At lower elevation, however, such an overflow did occur from the Pyramid Basin into the Smoke Creek and possibly beyond. The channel of this overflow is indisputably clear, broad and well defined. Its bottom is only 70 feet above the present water level of Pyramid Lake. The surface of the Smoke Creek desert to the north is below the water level of Pyramid Lake to-day. The Smoke Creek and the more northern deserts have no present perennial water supply. Although subject to floods from winter storms, they are essentially dry basins. The waters that filled these basins during the higher Lahontan stages came, with little doubt, principally from the Truckee River. The chief water supply of these broad evaporation areas came, therefore, through the more restricted basin of Pyramid Lake and flowed by way of a narrow pass at the north end of Pyramid Lake. As a late stage in the lake history, the waters of Lahontan lowered beyond the 70-foot level above present Pyramid Lake level, and a distinct overflow drainage was set up out of Pyramid toward the north. During all this time that concentration of Lahontan waters was going on, the lake in Pyramid Basin was being freshened by overflow. Only when the flow of Truckee River had diminished to such an extent that it no longer exceeded evaporation within the restricted basin of Pyramid (including Winnemucca as in all previous references) did concentration, within the Pyramid Lake waters proper, begin. Estimates of age based on this concentration may indicate therefore something as to the age of this latest and perhaps shortest stage of Lahontan history, but they can hardly represent anything more. Tufa deposits above the Pyramid outlet level have no simple relation to the quantity of salines now retained in Pyramid waters, nor can any simple deduction be reasoned therefrom. If Pyramid Lake waters are comparatively fresh, that is more likely to be the result of freshening by overflow than of freshening by desiccation. However, desiccation of Lahontan waters and perhaps of concentrated saline solutions may have taken place in the dry basins to the north. Large quantities of salines were accumulated in an analogous system below the Owens River, and, owing to natural relations there, they have not since been covered up. There is a good chance that similar deposits may have been formed in some concentration sink of the Lahontan Basin, which have since been buried in playa muds.

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BOTANY IN THE AGRICULTURAL COLLEGES

DR. E. B. COPELAND'S article in SCIENCE for September 18, 1914, entitled "Botany in the Agricultural College," opens up for discussion a many-sided problem of high pedagogical importance to agriculture. While we may agree to the definition "that the raising of crops is essentially nothing more or less than applied botany," it is a pitiful commentary that what we know of the raising of crops has in the main been gained without the help of the botanist. Indeed, one of our best-known American botanists contends that problems of crop production may safely be left wholly to the argonomist and horticulturist.

The chemist infinitely more than the botanist has interested himself in the great problem of securing a larger crop return from the soil. Indeed one must give high credit to the chemists for the insistent efforts they have made to bring their science into affiliation with all other sciences and with practical industries. We have to-day almost endless subdivisions of chemistry, such as biological chemistry, agricultural chemistry, engineering chemistry, physiological chemistry, bacteriological chemistry, etc. There is hardly a line of human endeavor to which the chemist has not striven to apply his knowledge in a practical way. Much of the so-called agricultural chemistry is more properly plant physiology, but chemists have occupied the field with scarcely a protest from botanists. In striking contrast to the chemist, botanists have shrunk from what should be the major application of their science; namely, that of crop production. A marked exception is plant pathology along which line the best contributions of botanists to agriculture have been made. In very recent years the study of genetics as applied to agricultural crops also promises to produce much of high economic value. It is true that there are numerous texts purporting to treat of agricultural botany, but they are mostly of a character creditable to neither agriculture nor botany. The best texts that relate to agricultural botany or at least to crop production have been written not by botanists but by chemists.

Perhaps no one really questions that the study of the factors that go to make crop production is the province of plant ecology and of plant physiology, including genetics, but one may search the whole literature of these subjects without finding a single paper devoted to the relation of any one environmental factor to quantity and quality of yield, the very thing with which crop production is concerned. Botanists seem scarcely to have realized that yield is a measurable result of the same sort as the rate of growth, or the amount of water transpired, or of carbon assimilated.

Our actual knowledge of the relation of factors both external and internal to yield is very largely the work of non-botanists. Indeed, excepting for the work of chemists it is still largely confined to the facts gathered by actual experience in the growing of crops, most of it antedating the development of modern science.

Since the advent of modern science six great discoveries or lines of advance have contributed to greater crop production or at least to a