and judicially considered in connection with the great mass of stratigraphical evidence with which it links itself, and of which it furnishes at once the key and clearest exponent.

From this decisive locality, there stretches away north-easterly, to Keweenaw Point, a belt of outcrops constantly maintaining the typical character, *bedding*, and *dip* of the Keweenaw series. Mr. Strong mapped no less than fifty-five exposed areas within the county in which occur the unconformities on the St. Croix (*Geol. of Wisc.*, iii.; *Atlas*, sheet xix.); and no concealed interval of so much as four miles occurs along the belt within thirty miles of the decisive locality. Throughout the whole broad belt to Keweenaw Point, occupying several thousand square miles, all the outcrops, numbered by hundreds, are of the Keweenawan class, and there are *none of any other kind*. This we conceive to be decisive evidence, notwithstanding some concealment from drift.

b. To the second class belong the unconformities of Douglas County, in the extreme north-western corner of Wisconsin, and those of the Keweenaw range of Michigan. In the former region, in a distance of twenty-five miles, there are four excellent sections across the junction-line. These have been described in detail, and illustrated by Sweet. On the one side, the Keweenawan beds dip from 35° to 50° southward, terminating northward in upturned, worn edges. Approaching these from the opposite direction are horizontal beds, which, at a distance from the contact, are simple sandstones, but, near the junction, become conglomeritic from material manifestly derived from the copper-bearing series. The beds are locally broken and bent upwards near the junction; but this, in our judgment, does not vitiate the evidence of unconformity at the time of deposition. We maintain that these sections afford strong evidence that the Keweenaw rocks were upturned before the flat-lying beds abutting against them were formed.

Upon the discussion of the controverted contact-line along the base of the great escarpment of Keweenaw Point, I will not here enter, partly because it might be useless without elaborate discussion, and partly because I could scarcely fail to trench upon data that belong to another. The whole region in controversy has recently been re-examined, and sketches carefully prepared, intended to show the exact facts exposed to observation, stripped of the bias of interpretation. Pending their appearance, I need only call attention to the fault-line long since claimed by Foster and Whitney to exist here, — a view in which several subsequent students of the region acquiesce, among them Irving and myself, with qualifications. Now, while the existence of this fault may be maintained consistently with the view that the flat-lying sandstones on the east are the equivalents of the uppermost beds of the tilted series on the west, and also with the view that the eastern sandstones were deposited unconformably against the cliff formed by the upturned beds, the faulting in this case being held to have previously taken place, it is altogether inconsistent with the view that the eastern sandstones pass continuously under the cliff.

c. Besides the above regions, which present more than a dozen separate localities of actual or approximate contact, several other districts afford strong evidence of unconformity, though they do not rise to actual, at least to ocular, demonstration. The more important are found on the upper St. Croix River, on the Snake and Kettle Rivers in Minnesota, and in the vicinity of Lake Agogebic, Michigan. These localities present horizontal quartzose sandstones, regarded as Potsdam, lying near upturned igneous and detrital silicate rocks, referred, on the basis of irrefragable evidence, to the Keweenawan series. The relations of these are so close, that all recent investigators who have examined them regard them as instances of unconformity between diverse formations, and find no other explanation consonant with the general geology of the region. It was my purpose to present the more significant facts relating to these little-known districts, upon two of which I have made unpublished observations; but space forbids. Let it be observed, however, that in all cases the upturned beds are distinctly Keweenawan in type, and are referred to that series on stratigraphical evidence, that, apart from controversy, would be accepted as conclusive, while all the horizontal beds, which are exhibited at eight separate localities, are quartzose, and definitely of the type referred to the Potsdam. We hold these to be facts of much significance as parts of the chain of evidence. The wide range of territory represented by these several cases of unconformity adds to their force as evidence of the distinctness of the formations.

5. *The inherent consistency of the view.* — The harmony of the foregoing evidences, drawn from diverse sources and from widely separated localities, and the mutual confirmation they lend each other, as well as their accordance with the entire phenomena of the region, are inherent arguments for the correctness of the whole.

6. *The dynamic simplicity of the view.* — No important orographic movements, beyond those that must be independently assumed to explain the attitude of the Huronian strata of the region, and such faults as there is independent evidence of, are invoked. On the other hand, an extraordinary amount of local faulting and disturbance seems necessary to the alternative hypotheses, and this notwithstanding the unmetamorphosed condition of the beds.

7. *The discovery by the United States geologists of a like series in the Grand Cañon of the Colorado.* — This, while not a direct argument, has an important collateral bearing on the question. By reference to p. 183 of No. 6 of this journal, it will be seen that a series remarkably similar to the Keweenawan in its essential characters occupies the same general position and attitude, lying in inclined, unmetamorphosed beds, unconformably below the upper Cambrian, and also resting unconformably upon the crystalline archaean series. The observations of Bell show a somewhat similar group bordering Hudson's Bay; but too little is yet known of it to indicate its true horizon. The ultimate acceptance of the Keweenawan group as the representative of an important period in geological history, will, of course, largely depend on the discovery of similar formations elsewhere, or the persistent failure to otherwise fill the gap between the Cambrian and Huronian.

T. C. CHAMBERLIN.

Washington, D.C., May 5, 1883.

LIQUEFACTION, VAPORIZATION, AND THE KINETIC THEORY OF SOLIDS AND LIQUIDS.[1]

THIS paper discusses at length the two kinds of vibratory motion which the molecule of a solid body may have, rotary and translatory. It is demonstrated that the mean kinetic energy of such an oscillatory

[1] Abstract of a paper presented by H. T. EDDY, Ph.D., University of Cincinnati, to the Section of physics and chemistry of the Ohio mech. inst., April 26.

motion as is possible for a molecule of a solid reaches a maximum value which can only decrease, whether the amplitude of the oscillation be increased or diminished, and that the only way in which it is possible to increase the mean kinetic energy of this kind of motion is to impart sufficient additional energy to change the motion into one of complete rotation. By such a process, greater freedom of motion is given to the molecules, and a large amount of energy becomes potential. This is regarded as explaining the phenomenon of liquefaction.

It is shown by an extended mathematical discussion of the cohesive forces and resistance to compression, by which molecules hold each other at mean fixed distances, that the mean kinetic energy of the vibration of molecules about their mean positions also has a maximum value which can only be increased by removing them to such mutual distances that the cohesive forces no longer act. In this process a large amount of energy also becomes potential. This is regarded as the rationale of the phenomenon of vaporization.

It is further shown, that, on this theory, it might very readily occur that the specific heat of a liquid should at first decrease, and then increase, as Rowland has proved is the case with water, but that the specific heat could not at last decrease.

The cause of the relatively large specific heat of most liquids is treated. It is shown that the distribution of rotary velocities in free rotation, such as the molecules of a liquid are supposed on this theory to have, is such that the atoms of some small per cent of the molecules in any given mass must be torn asunder. What per cent of the liquid may be thus dissociated will depend upon the temperature and constitution of the liquid; it being smaller for the simpler liquids, and increasing with the temperature. Electrolysis is an evidence of this action. Such dissociation sufficiently accounts for the generally high specific heats of liquids.

There is a general qualitative accordance of the theory with observed specific heats. A further confirmation of the theory is found in the clear explanation it affords of the existence of a critical temperature, above which a vapor is uncondensable by pressure alone; for, when the mean kinetic energy of all the molecules of a liquid acquires a value greater than the maximum possible in a liquid state, the liquid is not only vaporized, but necessarily becomes an uncondensable gas, and remains so.

GERMS AND EPIDEMICS.[1]

AFTER a brief historical sketch showing the idea that certain diseases, and especially marsh-fevers and the plague, are caused by the entrance of minute living organisms into the body, to be a very old one, but one which, until within a few years, has had no experimental proof, some definitions were given of the terms now used in discussion of this subject; and the word 'microdeme,' meaning 'little living thing,' was proposed as a general designation for the minute living particles found in almost all air or water. The microdemes include the *Microphytes*, or minute vegetable organisms, and the *Microzoa*, — the microzomes, the bacteria, microbia, micrococci, etc. There is at present no evidence that any microdemes are derived from any source other than other living organisms, nor that the special microphytes which cause the various processes known as fermentations or putrefactions ever develop into the higher forms of fungi; although this is still an unsettled question, and there is some reason to think that some of the higher fungi may act as ferments.

The prevailing opinion at present is, that there are many different kinds of microphytes, each having special powers, and that each can only propagate its own kind within a certain limited time.

But it is also probable, that by changes in nutriment, temperature, etc., changes in their habits and powers may be produced through natural selection. These changes are so considerable as to cause them to appear to be new species. The germ theory is, that certain diseases are due to the presence and propagation in the system of minute organisms which have no part in its natural economy. The word 'germ,' however, is often erroneously applied to independent organisms which originate outside of the body itself, such as the particles in vaccine lymph which are not microphytes, and can hardly be called independent organisms.

The diseases caused by large and comparatively well-known organisms are called parasitic. Such are some varieties of skin-disease; as ring-worm, or the so-called live spots, the fungus foot of India, and the disease of the ear due to the growth of a peculiar Aspergillus. A new disease of this kind is the so-called actinomycosis, due to a fungus which forms tumors near the angle of the jaw, and which causes death when it becomes generalized.

An account was then given of the organisms found in splenic-fever, relapsing-fever, chicken-cholera, leprosy, etc., and the method of Pasteur for the so-called attenuation of virus was described. This method appears to depend largely on the exposure of the broods of micro-organisms to the influence of oxygen; and recently MM. Nocard and Mollereau have announced that the same can be effected much more rapidly by the use of oxygenated water. The question as to whether Pasteur's inoculation with artificially modified virus will afford permanent protection is still unsettled, for sufficient time has not elapsed to decide it; but there is reason to hope that it will be found to be of great practical benefit.

The effects of microdemes in producing pyaemia and puerperal-fever are well described, and attributed to a poison secreted by them, of the nature of the so-called ptomaines, rather than to their mere mechanical presence. This knowledge is practically applied in what is called antiseptic surgery; and the surgeon now undertakes, without hesitation, operations which, twenty years ago, would have been deemed quite unjustifiable; for he knows, that by insuring that neither through the air nor the water, the sponges nor the instruments, nor in any other way, a single microdeme which has not had its powers of growth and reproduction totally destroyed shall gain admission to the wound, he need have no fear of blood-poisoning.

As regards diphtheria, it is probable that it is due to a common micro-organism, which, under circumstances not yet understood, becomes virulent, as the micro-organisms of common sweet-hay infusion may be transformed into those which cause malignant pustule.

The connection of consumption with a microphyte is still doubtful, though not improbable; and the same may be said with regard to malaria.

A sketch was then given of some of the characteristic phenomena attending the great epidemics. For some, the germ theory appears to afford the best explanation; for others, such as influenza or cerebro-spinal fever, this theory is quite inadequate.

Special attention was called to the many points in

[1] Abstract of a lecture by Dr. J. S. BILLINGS, given in the Saturday course at the U. S. national museum, Washington, Feb. 17.