limestone and the Little Falls dolomite. The three species are best displayed in the Saratoga area, where the reefs are, in ascending order, the *C. proliferum*, the *C. ruedemanni* and the *C. undulatum* reef (described in detail by the writer in a paper now in press as a bulletin of the State Museum).

There are several facts that indicate organic origin for these forms. *C. proliferum* develops cabbage-like heads or stocks, composed of alternating limy and sandy layers. In the "Petrified Gardens," near Saratoga, they are seen to best advantage. Here the stocks, of great size, are so crowded that they touch and the spaces between are filled with coarse sand. These facts, together with the abundance of macerated Cryptozoon material, are interpreted as indicating the outer side of the reef where conditions were more favorable to growth and storm waves broke. Approaching the shore, that is northward in this area, the stocks become smaller and are more scattered in the rocks until, as north of Lester Park, in rill channels the individuals lose their characteristic shape and have grown out into long stringers which indicate not only organic, but plant origin for these forms. The same condition is seen in the *C. ruedemanni* reef in the "Petrified Gardens." In solution crevices vertical sections of *C. proliferum* show the mode of growth, starting from a point and expanding upward, which, with the dichotomous budding so well developed in *proliferum*, is an indication of plant life. From its early discovery the association of Cryptozoon with oolites has always been noted. The constant association of fossil calcareous algae with oolitic structure and also with dolomite has been pointed out by a number of writers (see Garwood, 1913, p. 552).[1]

Cryptozoons of the same age as those in the Saratoga Springs region have been found in Dutchess County, N. Y., southward in New Jersey, Pennsylvania and Maryland and still farther south in certain formations of the Appalachian Valley through Virginia, Tennessee and Alabama and west into Oklahoma and Texas. Species have been described from lower Ordovician (Canadian) rocks of northeastern New York and western Vermont (Champlain Valley) and elsewhere in the United States and Canada. In other countries they have been reported from the Cambrian rocks of Norway, Lower Paleozoic strata of Ellesmere Land and elsewhere and from the base of the Ordovician of Eastern Asia (South Manchuria and North Korea) where the Cryptozoon reefs constitute a great display.

DIFFERENT VIEWS HELD ON THE ORIGIN OF THE SARATOGA MINERAL WATERS

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H. P. CUSHING wrote in 1914:[2] "There are few problems in geology more difficult than those concerned with the origin of the mineral waters of a specific region." This is well proved by the various views advanced by geologists and chemists. The problem of the Saratoga Springs became a prominent issue in two large lawsuits, the first between spring owners, the last one by the state against the Carbonic Acid Pumping Companies. In both these suits numerous experts were called and the mapping of the Saratoga quadrangle by H. P. Cushing and the writer was ordered in connection with the last trial. At these trials the geological and chemical experts finally testified as a rule that the water was of magmatic or volcanic origin. J. F. Kemp, one of the experts at the trials, published a full account—"The Mineral Springs of Saratoga"[3]—in connection with the second trial, in which he states that the Saratoga waters are characterized by high content of chlorids and bicarbonates of sodium, calcium and magnesium, high content of uncombined carbon dioxide and extremely small content of sulfates. He distinguishes three divisions of underground water from the standpoint of origin, *meteoric* waters derived from the rainfall, *magmatic* waters derived from cooling igneous rocks and *connate* waters, generally marine waters buried in the rocks at the time of deposit and retained in them. Then by a process of elimination he rules out connate waters because they lack sulphates in solution, and meteoric waters because we know of no chemical method by which carbon dioxide and the chlorids might be produced in such waters, and finally concludes that these constituents are likely of magmatic origin. He inferred that the carbonic acid gas, the chlorids, bromids, iodids, fluorids and sodium carbonate are of deep-seated origin and that the carbonated waters take on calcium and magnesium carbonates from the limestones and more especially from the Little Falls dolomite.

H. P. Cushing, who made the most thorough study of the geologic conditions surrounding the Saratoga Springs, agreed that the carbon dioxide and the chlorids have a deep-seated source, but ruled out volcanic or juvenile origin of the waters, because the waters are not thermal and there is no evidence of

[1] *Geol. Magazine*, Dec. 5, 1913, 10: 440–46, 490–98, 545–53.

[2] N. Y. State Mus. Bull. 169, 1914, p. 153.

[3] N. Y. State Mus. Bull. 159, 1913.

igneous action of any recency in the vicinity, or anywhere else in the eastern United States; and he especially rejected the volcanic knob at Schuylerville because he believed it at least Mesozoic in age (recent radium-lead measurements of the rock by Dr. A. C. Lane have shown it to be of Ordovician age as the present writer proposed at first). He concluded that the waters were mixed and in part may be connate and also of metamorphic origin, as urged by Ruedemann.[4] It was the writer's opinion that the carbon dioxide and some of the salts may originate in the eastern mountain regions where deeply buried sediments may still be undergoing metamorphism and impure limestones are still crystallizing into schists and producing free carbon dioxide. This is especially probable, as the source of the waters is clearly to the east and northeast.

Later, Dr. Paul Haertl, a German expert from Kissingen, who was twice called to Saratoga, in discussion with the writer recognized three possible origins of the carbon dioxide, *viz.*, volcanic, chemical (by reaction of limestone and sulfuric acid producing anhydrite and gypsum) and metamorphic by metamorphosing of limestone under pressure and heat. In his final report he favored the volcanic origin and accepted the metamorphic origin as an alternative. Dr. Herbert Ant, chemist of the Saratoga Commission, held for some time the view of the chemical origin of the gas and salts of the water in the thick deposits of Canajoharie shale, overlying the limestone and dolomite. Dr. R. J. Colony in his report to the Saratoga Springs Commission finally advanced the unusual view that the carbonic acid gas and minerals may be derived from a cooling batholith deep down below the sediments.

Dr. Brewer and Dr. Baudisch, for the first time among experts, seem now to be able to give a positive clue to the origin of at least one important element of the mineral salts, clearly pointing to a marine origin.

CHEMICAL CLUES TO THE ORIGIN OF THE SARATOGA MINERAL WATERS

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DIFFERENT investigators have often attempted to unfold the mystery of the origin of the Saratoga waters. These attempts could, however, remain only mere speculations, since a direct tracing of the water by special indicators was out of reach. Even the most basic and vital question whether the water comes from magmatic deep-seated sources or whether it is of meteoric origin remained unsolved.

The latest intensive geological investigation of the Saratoga basin was carried out by the late Professor R. J. Colony, of Columbia University, in 1929.[5] Colony believes that most of the constituents of the waters, including sodium and potassium, are derived from deep-seated primary rock out of which the elements are dissolved by the meteoric water supersaturated with carbon dioxide.

About barium, Colony writes: "It is possible that the barium, too, have a deep seated course, but I am not sure of it."

Colony did not like the marine hypotheses of the origin of the water; the rejection of it he expresses boldly in the following sentence: "It is inconceivable that *sulphate-free* waters can have been derived from any marine source."

The fact that the Saratoga waters do not contain sulfates has been a puzzle to most of its investigators, and it was always the reason why the marine origin of the waters had been rejected. We will see later that the absence of sulfates in the waters is easily explained and does, in fact, harmonize well with its marine origin.

Potassium, which in amount ranges from 72.33 to 750.19 parts per million, is in itself an important constituent of these waters. That Saratoga water is of marine origin can be demonstrated by studying the isotopes of the element in the different strata from which the waters come and from the water itself. In comparison with sea water, it is interesting to note the amount of sodium and potassium which has entered and remained in solution in sea water.[6]

PER KG. OF SEA WATER

	Supplied	Present	Percentage
Na	16.8 g	10.70 g	66.0
K	15.0 g	0.37 g	2.5

Potassium is very important for the life process of marine algae, and we find it in some specimens concentrated in remarkable amounts. The abundance ratio for isotopes of potassium in ocean water all over the world has been shown by Brewer to be 14.20 to 14.25.[7]

As shown in a recent paper of A. Keith Brewer and Oskar Baudisch on "The Isotopes of Potassium and

[4] N. Y. State Mus. Bull. 169, p. 165*ff*.

[5] R. J. Colony, Legislative Document, No. 70, 1930.

[6] V. M. Goldschmidt, *Jour. Am. Chem. Soc.*, April, 1937.

[7] A. K. Brewer, *Jour. Am. Chem. Soc.*, 58: 365–370, 1935.