the constriction in that region may be so inhibited as to cause the two daughter cells to reunite into one spherical cell but the daughter nuclei remain separate.

As this paper is concerned only with intranuclear structures I shall merely mention here that the mitochondrial threads characteristic of the orthopteran germ cell form the boundary of the kinoplasmic mass and give it an appearance of being composed of threads. I have been unable to ascertain the existence of spindle fibers. The chromosomes may easily be pulled out of the equatorial plate and give no evidence of being attached to such fibers. When one chromosome is dislodged from the equatorial plate the others leave their places, and if left to themselves, clump together into an irregular homogeneous mass.

A curious phenomenon connected with the dissolution of the cells is the production of long slender processes which radiate in every direction from the surface of the cells. The ends of the processes soon grow into rounded knobs which gradually increase in size and often break off in the form of droplets. These droplets rapidly go into solution. Within half an hour or so, however, the entire protoplasm of the cell takes up water and swells. The pseudopodia are then slowly retracted and the cell rounds up and may remain so for a long time.

During the first stages of their formation the pseudopodia occasionally perform irregular oscillatory movements. Their formation is similar to that of sea-urchin eggs when subjected to the cytolytic action of diluted KCl solution. Similar phenomena have been described by Kite[2] and Oliver[3] and Merk[4] in blood cells. Chromosomes show the same phenomenon when isolated in Ringer's fluid. In one case which was very striking a ring chromosome was removed from the equatorial plate. Within two minutes a pseudopod began to appear from one side of the ring. Within five minutes this had lengthened into an attenuated filament which oscillated slowly. The attenuated tip gradually resolved itself into a knob which soon was pinched off in the form of a droplet. By the time a second droplet was formed and pinched off the chromosome itself began to swell and rapidly went into solution.

According to the foregoing experiments the chromosome appears to be a highly viscous and glutinous protoplasmic gel readily swelling in water and possessing very much the same physical properties as the cytoplasm of the cell.

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[2] G. L. Kite, "Some Structural Transformations of the Bloodcells of Vertebrates," *J. Inf. Diseases*, XV., p. 319, 1914.

[3] SCIENCE, N. S., XL., p. 645, 1914.

[4] *Arch. f. Mikr. Anat.*, 80, 1912.

THE GEOLOGIC HISTORY OF LAKE LAHONTAN

THE basin of the great lake that once covered much of western Nevada has been classic ground ever since the early geologists first studied it. The shore lines which are to-day practically as the receding waters left them, the calcareous deposits about its basin, the possibility of saline deposits of commercial importance, have made the deciphering of its history one of the goals of geologic endeavor. King,[1] believing all of the tufa was a pseudomorph after gay-lussite and witnessing the formation of the latter in the Soda Lakes, believed that Lahontan had become as saline through desiccation, had then fallen, depositing the tufa as gay-lussite, and that a second flooding of the lake had caused it to overflow, washing out the saline material and changing the tufa to calcite.

Russell[2] determined that Lahontan had never had an outlet and thereby vitiated King's hypothesis. Believing that the tufas were a deposit from waters saturated with calcium carbonate and taking his clue from the Great Salt Lake, Russell assumed that the waters of Lake Lahontan must have been equally saline, although much of his evidence

[1] King, Clarence, U. S. Geol. Expl. of the 40th Par., Vol. 1, p. 522.

[2] Russell, I. C., Monograph No. 11, U. S. Geological Survey, 1885.

indicated otherwise. Finding the lakes at present occupying portions of the basin to be comparatively fresh, he believed that Lahontan had been completely desiccated and its saline deposits buried before the present lakes formed.

Russell recognized three types of the tufa in the Lahontan Basin; the lithoid, stony and compact; the dendritic, porous and coralline; and the thinolite, crystallized and a pseudomorph after an unknown mineral. For a distance of one hundred feet above the present level of Pyramid Lake these were found to be superimposed, the lithoid at the base, succeeded by the thinolite, and the dendritic covering the other two. While he recognized that there was some lithoid tufa intermingled with the dendritic, he believed that the lithoid had been deposited from waters of slightly different composition from those forming the dendritic tufa. Finding a medial series of gravels in the lake sediments, he believed that Lahontan had formed, diminished through desiccation and deposited the lithoid tufa, had again risen nearly to its former level, had again been desiccated, depositing the thinolite and dendritic tufas and, completely disappearing, left the other salts to be buried beneath the alluvium that swept in from the surrounding mountains. Later a slight change to a more humid climate produced the present lakes.

In the course of work in the vicinity of the Salton Sea,[3] done in connection with Dr. D. T. MacDougal, director of the desert laboratory of the Carnegie Institution of Washington, it was concluded that the tufa at present forming in the sea were being deposited through the activities of blue-green algæ and the bacteria associated with them. The more significant evidence discovered was the constant association of the algæ and the tufa, the extreme localization of the tufas, the formation of the tufa from water that contained considerably less calcium carbonate than would saturate it, and the evident relation between the development of the tufa and the light exposure. Further, a gradual gradation between the dendritic and the lithoid tufas was found in the older tufas of the basin, the lithoid tufa being formed in the dark portions of recesses in the cliffs where the conditions were unfavorable for the normal growth of the algæ. Thin sections of the older tufa show abundant remains of the algæ included in the tufa as are the algæ in the tufa forming at present.

Through the kindness of Dr. MacDougal it was possible to immediately carry the study in to the Lahontan Basin. Around the shores of Pyramid Lake a thin coating of lithoid tufa was found coating the rocks and in places cementing the gravels. The same close association between the algæ and the tufa was observed, and wherever the algæ were found the gravels were cemented and where they were absent no trace of the tufa could be found. Thin sections of the older dendritic tufa disclosed forms similar to those found in the tufas of the Salton Basin and sections of the tufa forming at present showed the algæ imbedded in it. As analyses of the lake water showed it to contain only about one twentieth the calcium carbonate necessary to saturate it, it is evident that the tufa forming to-day is being deposited through the activities of the plant life. As the algæ in the Salton Sea are depositing dendritic tufa from waters containing ten times more calcium carbonate than Pyramid Lake and the tufa being deposited in the latter at present is lithoid in type, it is probable that the calcium content of the lake waters is a determining factor in the type formed.

In the Lahontan Basin a thin layer of the lithoid tufa is in immediate contact with the rocks on which deposits of tufa were formed. Approximately six inches in thickness near the water's edge it decreases in thickness until at the top it merges with the caliche formed on the basalt that is the predominant rock in the basin, and it is practically impossible to say just where the tufa ends and the caliche begins. The dendritic tufa is best developed in a horizontal zone between one and two hundred feet above the present lake. It gradually diminishes in thickness and changes character

[3] Jones, J. C., Pub. No. 193, Carnegie Inst. of Wash., pp. 79–83, 1914.

until at the higher levels it merges with the lithoid tufa. In other words, the gradation between the lithoid and dendritic types in the Lahontan basin is a vertical one and was apparently caused by the increasing calcium carbonate content of the receding lake waters.

Russell placed the upper limit of the thinolite tufa at the thinolite terrace now one hundred feet above the lake. During the present study it was found that the thinolite extended some forty feet above the terrace throughout the Pyramid Basin and there ended in a few scattered crystals at the base of the dendritic tufa. Dana[4] after a careful study of the thinolite crystals came to the conclusion that it was a pseudomorph after an unknown tetragonal mineral, possibly a chlor-carbonate of calcium. Measurements by the writer of some of the more perfect crystals lead to the conclusion that the original mineral was orthorhombic and probably aragonite. On experimentation it was found that when a saturated solution of calcium carbonate was added to the water from Pyramid Lake minute crystals of aragonite closely resembling in their detail the smaller crystals of the thinolite separated after standing a day or two. The thinolite, therefore, was deposited as aragonite at a time when the waters of Lahontan were saturated with calcium carbonate.

As was recognized by Russell, the intermediary gravels are bar and beach deposits, and as only the lithoid tufa is associated with them they represent a low water stage in the filling of the basin.

To sum up the present evidence the broader features of the history of Lake Lahontan are believed to be as follows. As the Lahontan Basin began to fill the waters approximated those in the present rivers flowing into it and contained but little calcium carbonate. As a consequence the algæ as they became established on the rocks about the lake were able to deposit only the lithoid tufa. With the climax of the lake when evaporation became the controlling factor and the lake diminished the relative amount of calcium carbonate present increased more rapidly than the algæ could remove it. With the increasing amount of calcium available the type of tufa deposited gradually changed to the dendritic. Nevertheless, the calcium continued to increase until when the lake had fallen three hundred and fifty feet from its highest level, the waters were saturated and the surplus was deposited as aragonite forming the thinolite tufa. With the removal of the surplus calcium and probably aided by the slower fall of the lakes, owing to the diminished area the algæ caught up and have removed the calcium faster than it was brought in by the rivers until at the present time the lake contains only one twentieth the amount of calcium possible and only the lithoid tufa is being deposited.

As there is little or no evidence of an unconformity in the tufas, they in themselves do not indicate more than one lake period. The intermediary gravels are all above the present level of the lakes and from such evidence as has been gathered represent but a low water stage in the early filling of the lake basin. With the conclusion that Lake Lahontan had but a single period of extreme high water the question naturally arises as to whether the lake has completely disappeared.

One unfamiliar with the area and reading the reports of King and Russell is apt to gather the impression that a large part of the basin is covered by the tufa. This is not correct. As was noted by Russell, the tufa is extremely localized and occurs for the most part in large isolated masses. It is only the narrow band of recent tufa about the present shores of Pyramid Lake that approaches a continuous layer and it probably covers less than fifty per cent. of the shores exposed. A liberal estimate of the tufa-covered area of the basins of Pyramid and Winnemucca lakes is one per cent. of the total area of these basins and the tufa is much more abundant here than in the remainder of the Lahontan Basin. Estimating an average thickness of eight feet of tufa below the Thinolite terrace and three feet above it to the high-water mark gives sixty-five million tons of tufa deposited in the basins of the two lakes in question.

[4] Dana, E S., Bull. No. 12, U. S. Geol. Surv., 1884.

Assuming that the calcium has been brought into the Lahontan Basin in the same ratio to the sum of the sodium and potassium as it is being brought in by the present rivers and calculating how much calcium carbonate would have to be deposited to have maintained the same ratio to the sodium and potassium in the present lakes gives in round numbers one hundred million tons. As this figure is approximately the same as the amount of tufa deposited, it indicates that Pyramid Lake is a remnant of Lake Lahontan and that the latter has never been completely desiccated.

If this be true it is possible to approximate the age of Lake Lahontan by computing the number of years necessary for the Truckee River, the only important stream at present flowing into Pyramid and Winnemucca lakes, to carry into the lakes the amount of salt at present in solution. Several independent determinations were made, using the total solids, and such of the individual salts as were likely to have suffered little loss through deposition. Of these the chlorine gave the maximum figure, 4,500 years, while the others ranged from a thousand to 2,500 years. Unfortunately the Truckee flows also into Winnemucca Lake and there is some evidence that the latter may have been desiccated since the beginning of Lake Lahontan. Further, in times of high water Pyramid Lake has discharged into Winnemucca and it is uncertain how much saline material may have been lost by burial in the Winnemucca basin, if any. Judging from the correspondence between the actual amount of tufa deposited and the amount that should have been deposited, as indicated by the amount of salines still present in the lake waters, it is believed that the loss from this source has been slight.

A comparison of the total solids in the lakes to-day with those present at the time of Russell's visit when the lake was practically at the same level gives two thousand years as having elapsed since the basins first began to fill. From these concordant results it is probable that Lahontan first began to form within the last five thousand years.

There is abundant evidence of the comparative recent formation of the terraces, beach lines, and other shore phenomena of the ancient lake in their freshness and absence of erosion. Even where there is a considerable drainage basin behind them the terraces are barely notched by the streams that cross them and any one who is familiar with the erosive power of the not infrequent cloudbursts of Nevada can but wonder that the records of the old lake have stood so long without extensive defacement. Although faulting is still in progress, yet the shore lines and sediments of Lahontan have suffered little displacement. Careful measurements of the elevation of the terraces in different parts of the basin show them to still be horizontal.

Estimates go to show that if the rainfall of the drainage basin increased to somewhat less than double the present rainfall the Lahontan Basin would again fill to its former level. The recent work of Huntington[5] with the big trees of California indicates that there was such an increased rainfall in the immediate vicinity of the Lahontan Basin at the time it is believed the old lake was at its height.

While the work is still in progress yet it is so nearly finished that it is not believed that the above conclusions will be materially modified. The conclusion that Lahontan has never been completely desiccated and that the waters of Pyramid and Winnemucca lakes are residuals makes it possible to forecast the amounts of potassium deposits in the portions of the Basin that are at present desiccated. An estimate made for the Black Rock Desert indicated that if all the potash deposited from Lahontan were segregated in a single square mile it would form a deposit only three inches thick, and if potash beds are found in this desert they must have been formed in the buried sediments of a lake of which we have no knowledge at present.

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[5] Huntington, Ellsworth, Rept. of Smithsonian Inst., for 1912, pp. 383–412, 1913.