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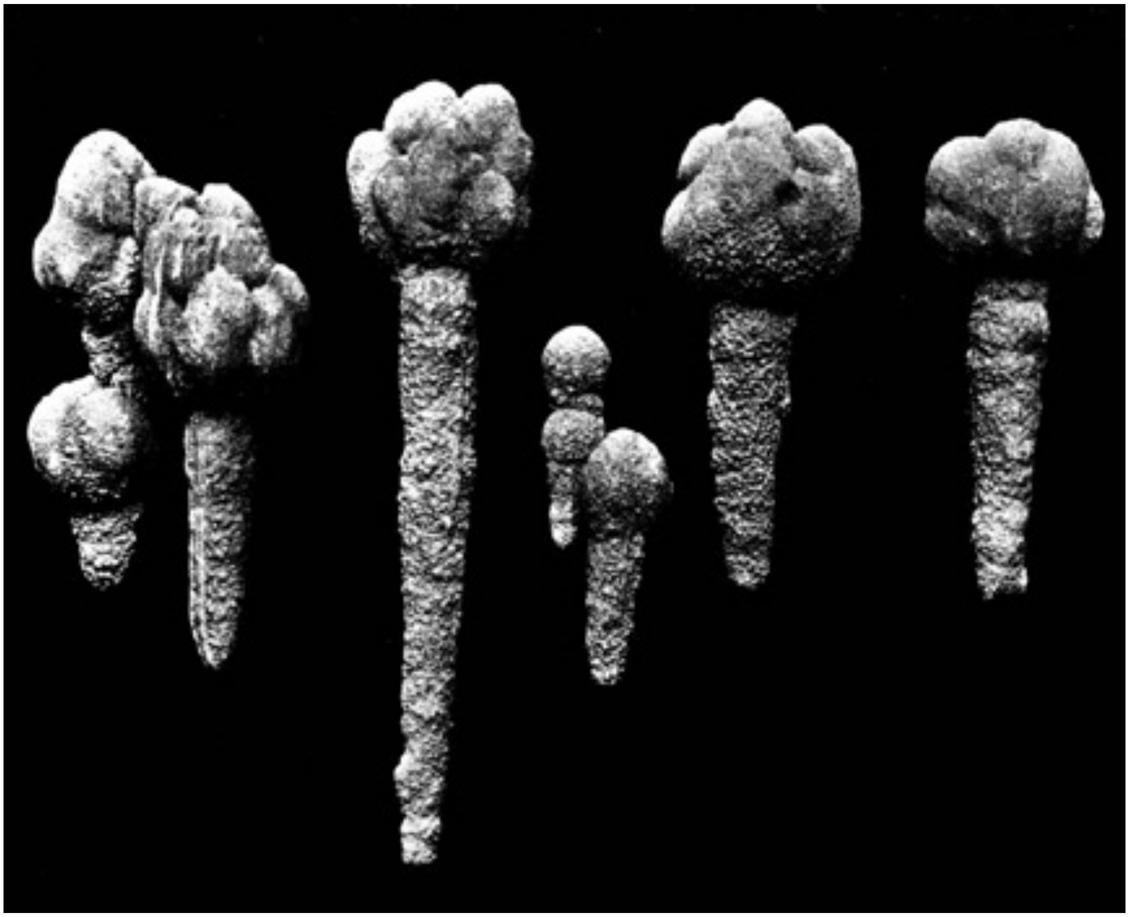

PLATE XIX: Sand Calcite "Sand Spikes" from Imperial Valley, California

# SAND-CALCITE CONCRETIONS FROM SALTON, CALIFORNIA

by Henry Windsor Nichols

A series of five sand-calcite concretions (Museum No. G, 1301) presented to the Museum by Mr. Herbert Brown of Yuma, Arizona, appear worthy of description. Regarding the conditions of the occurrence of these concretions little is known. Mr. Brown simply states that they were handed him by a commercial traveler as having been obtained by him at Salton, California. As there are extremely large sand dunes in the immediate vicinity of Salton, it is probable that the concretions were formed in these. Whether or not the form represented by the specimens at hand is a common or an unusual type in that locality is unknown. These concretions (Plate XIX) are formed of sand cemented by calcite, and are, therefore, of the type of the well known Fontainebleau and Saratoga Springs concretions, from which, however, they differ in several respects. The Salton concretions take the form of an irregularly botryoidal ball from which projects a stout, tapering stem in such wise that the object assumes the shape and proportions of an ancient mace. The change from head to stem is abrupt, much as if the stem were driven into a hole bored in the head, and there is even a slight annular depression in the latter where the stem enters. The botryoidal appearance of the head is due to a compound structure—each head being built up from a number of spheroidal concretions grown together. While there is but little flattening of the concretion as a whole, the subordinate spheroids are much flattened and also elongated in the line of the principal axis of the concretion. The specimens have a very rough surface from the presence in large numbers of rhombohedral points of arenaceous calcite crystals. These points suggest that these concretions, like those from Devil Hill, Wyoming, described by Barbour[1], are aggregates of moderately large crystals. Lines of stratification (Plate XIX) intersect the specimens in such a direction as to indicate that the principal axes lie conformably with the strata in which they form. The slight flattening of the complete individual as well as the greater flattening of the subordinate spheroids of the head is in the plane of bedding of the surrounding sand.

The specimens in the possession of the Museum weigh from 45 to 952 grams. The diameter of the ball lies between 30 and 70 millimeters, and that of the thickest part of the stem between 20 and 30 millimeters. The head of the concretion, therefore, varies much more in size than the stem. The stems, however, are very variable in length; the shortest is 55 and the longest 210 millimeters. Two of the specimens are compound, consisting respectively of two and three individuals grown together.

The specific gravity of the concretions is 2.69, and they are therefore a little denser than the average concretion of this character. Concretions of sand and calcite from Saratoga Springs in the Museum collections have a density of 2.62; those from Fontainebleau of 2.42. The sand-calcite concretions and crystals from Devil Hill, Wyoming, which have been studied by Barbour, 1 have a specific gravity, as determined by the present writer, of 2.64. According to Dana, the Fontainebleau crystals vary in specific gravity from 2.53 to 2.84. [2] The great variation in these figures is, however, not to be taken as indicating corresponding variations in the true density of the objects. They rather indicate differences in the methods employed by various experimenters and differences in the shape and size of the pores of different specimens. It is evident that the true specific gravity of a mixture of calcite and quartz cannot be less than 2.65, the specific gravity of the lighter constituent. The very great influence of the character of the pores and of the shape and size of permeable objects of the character of those under consideration are discussed in this paper. For the reasons there given, the specific gravities of the Salton, Fontainebleau, and Saratoga Springs specimens, determined at the Museum, are probably low, but it is believed only slightly so.

The carbonate cement of the Salton concretions is soluble rapidly and with brisk effervescence in cold dilute hydrochloric acid, and is therefore essentially calcite. The dissolved cement, however, yields noticeable quantities of iron to chemical tests.

The sand of the Salton concretions, when cleansed by cold dilute hydrochloric acid, is of a light gray color, subangular, and very fine. It all passes a 60 mesh sieve, 17% is retained upon an 80 mesh 48% additional upon 100 mesh, and 35% passes through a sieve of 100 meshes to the inch. It appears that the closeness with which the sand packs itself has some bearing upon the nature of the concretion. A sand of similar physical constitution was prepared from a mixture of glass sands by the use of sieves. This sand was packed into a glass cylinder and compacted by long tapping of the outside of the cylinder by a stout wooden rod. This sand, so compacted, enclosed between its grains 40% of voids which were calculated by the usual formula. [3]

Such a sand undisturbed in its natural bed may be assumed to compact itself in time somewhat more than it may be compacted by a few minutes' tapping in the laboratory. Such undisturbed sand beds, according to King and others [4] contain 35% to 40% of pore space. Therefore if a sand-calcite concretion is composed of calcite filling voids previously existent between grains of sand, it will have by volume a composition of calcite 35-40%, silica 65-60%. The composition by weight will be approximately the same, as the specific gravities of the minerals differ but little. Such a composition has in fact been proved by the only two determinations of this character known to the author for similar concretions. These were carried out upon material from the two widely separated localities Devil Hill, Wyoming,1 and Fontainebleau, 2 France.

A determination of the percentage of sand and calcite in the Salton concretions was made upon material broken from the stem. The fragments were treated with cold dilute hydrochloric acid and the insoluble sand weighed. The concretion was found to contain: sand, 29.17%; calcite, 70.83%. This corresponds to a composition by volume of about: calcite, 70%; sand, 30%. The above facts may be tabulated as follows:

COMPOSITION BY VOLUME OF SAND-CALCITE CONCRETIONS FROM THREE LOCALITIES:

| | Sand, % | Calcite, % |
|---|---|---|
| Theory | 65 - 60 | 35 - 40 |
| Devil Hill | 64 | 36 |
| Fontainebleau | 50 - 63 | 50 - 37 |
| Salton | 30 | 70 |

From this table it appears that in the Fontainebleau and Devil Hill concretions the calcite is little, if any, in excess of that required to fill the voids between the sand grains. The Salton concretions, on the other hand, have but half the sand and twice the calcite required for such a constitution. There are four hypotheses which may account for this excess of calcite: 1. The concretion may have formed in a partially opened crevice; 2. Part of the calcite may be fragmental; 3. Part of the sand may be impregnated with or replaced by calcite; 4. The calcite when crystallizing may have exerted pressure upon the sand grains and moved them apart. The first hypothesis, a partially opened fissure, is practically negatived by many conditions and may be dismissed at once. Between the other three, microscopic study might discriminate. A slide was therefore prepared for this purpose, from a cross section of the stem of a concretion. The sand grains in this slide proved to be of the usual character of those sands which are derived from acid crystalline rocks. The great majority of the grains were quartz. Partially kaolinized feldspars were present in some quantity, also scattered fragments of biotite, muscovite, dark amphiboles, and a few grains of minerals not readily recognized. Such minerals as garnet, ilmenite, magnetite, etc., were completely absent. The grains varied from angular to well-rounded, but the greater portion were of a sub-angular character. With the exception of the slight kaolinization of the feldspars the minerals of the sand grains were wholly unaltered. The calcite proved to be wholly in the cement, and the cement contained no other mineral than calcite. No alteration of the calcite was observed, nor any calcite of fragmental origin, nor did any of it replace sand. The calcite was found to occupy more than half the area of the slide, the grains of sand seldom touched, but were separated by bands of calcite cement, which varied greatly in width. These calcite bands were frequently much wider than the diameter of the enclosed grains. It appears, therefore, that the calcite in crystallizing has exerted sufficient pressure to push apart the sand fragments, although no anomalous optical features were noted indicating strain in the cement. The cement was in the form of calcite crystals of cross sections comparable in magnitude with those of the sand grains. While many of them lay in parallel positions, sufficient data could not be secured from a study of the slide to determine whether or not the calcite is in the form of radiating crystals or of other regular or irregular aggregates. The concretions in the Museum collections which possess a character most resembling the Salton forms in shape and appearance are from the two well-known localities the Paris Basin, and Saratoga Springs, New York. The specimen from the Paris Basin which appears to possess the most in common with the Salton concretions is a chain of four sand-calcite balls from Clermont. (Plate XX, Fig. I.)

This consists of four spheres between 140 and 160 millimeters in diameter united into a slightly curved chain 49 centimeters long. The spheres where they join interpenetrate for perhaps one-eighth to one-twentieth of their respective diameters. Each ball is nearly spherical with no marked flattening and is simple. The only complication of form is an abrupt change in diameter of the spheres giving each the external form of a laminated body from which the external shell has been half broken away. This is, however, a consequence of differing rate of growth for different sides of the sphere and is in no wise dependent upon internal structure. These deposits, which are associated with mineral springs, are doubtless more or less tufaceous in character.

The sand-calcite concretions of Saratoga Springs, New York, tend to form sheets by the coalescence of many individuals and thus much of the material is better described as sandy calcareous tufa than as concretionary. The two specimens shown in Plate XXI illustrate this phase. These are respectively 15 x 40 and 17 x 20 centimeters in area and both are from 3 to 6 centimeters thick. Both specimens are fragments evidently broken from considerably larger sheets. The individual concretions from these sheets are forms modified from the sphere by agencies which have produced a flattening and elongation, so that the simplest form of common occurrence is a somewhat flattened ovoid or pear (Plate XXI, Fig. 1) with the same appearance of lamination which occurs upon the Paris Basin specimens. The larger number of those concretions which unite to form a sheet of tufa at Saratoga Springs are much more elongated than these pear shapes. Many of these more elongated forms so coalesce as to lose their identity and present merely a solid, wavy surface. When the individuality is not so completely lost, there arise, first, shapes resembling a long-necked gourd, then, as the elongation becomes greater, the flattening becomes greater also, the form becomes wavy in both the horizontal and vertical planes and deep, strong, longitudinal and occasionally transverse striations appear. Thus the elongated individuals forming these sheet-like bodies of concretion tend to become flat and more or less curved.

Besides the tufaceous sheets, separate individual concretions are common among the Saratoga Springs material. These show little or no flattening and sometimes but little departure of any kind from a spherical form. They are frequently heavily striated in a meridional direction by deep grooves which come together at two poles. When compounded, they assume grotesque and imitative forms. The nearest approach to the. Salton forms is a double concretion from

Saratoga Springs (Plate XX, Fig. 2). This consists of two cones with hemispherical bases. They are similar in form but differ in size. The apex of the smaller is united with the base of the larger. The length of the specimen is 38 centimeters and its greatest diameter 8 centimeters. This may be considered as two independent concretions which have grown together, and the larger cone alone may be compared with the California specimens. This larger cone is as smooth on the surface as the sand which enters into its composition will permit. It is slightly curved. There is the usual fold-like longitudinal swelling where it has grown faster in one direction than another. The cone tapers gradually with no abrupt change of curve from the widest portion to the apex. The relation between the specimens from Salton and those from Saratoga Springs and the Paris Basin are best brought out in tabular form:

COMPARISON BETWEEN SAND-CALCITE CONCRETIONS FROM THREE LOCALITIES:

Salton. Saratoga and the Paris Basin Surface: Roughened with rhombohedral points. Never striated. Smooth. Often striated Spherical forms: Compound. Oblate. Simple. Prolate or ovoid. Pseudo-concentric. Elongated forms. Circular section. Straight. Flattened section. Curved or Wavy. Junction of spherical to elongated form. Abrupt. Always gradual.

Lack of data prevents discussion of the nature or origin of these concretions from Salton, California. There is, however, one suggestion which is called forth by the shape of these objects when they are compared with some hitherto unrecorded forms of concretions of an entirely different character. The stem of any one of these California specimens is very like a stalactite depending from the head.

In certain sand dunes, notably in the “Hoosier Slide” of Michigan City, Indiana, flat sheet-like bodies of limonite concretion form in certain strata of the sand. When these are dug out, numerous small stalactites of limonite are found depending from their lower surfaces.

These stalactites are, however, too friable to be preserved. These, limonite concretions form, by deposition from a sheet of ferriferous water which flows during wet weather along a more permeable layer of dune sand or upon the surface of a comparatively close-packed and impervious stratum. It is evident that this comparatively impermeable layer is able to form in wet weather some fashion of floor for the stream of iron-bearing waters. This floor is, however, but imperfect and very leaky, so that the limonite stalactites have ample opportunity to form where the water drips through. It is very possible that in the case of these sand-calcite concretions some similar structure of the dunes near Salton has permitted a similar stalactite to form at the base of such concretions as were favorably placed.

SAND-BARITE CRYSTALS FROM OKLAHOMA

These specimens (Museum No. G. 1285, Plate XXII) were collected by Prof. Charles N. Gould of the University of Oklahoma and presented by him to this Museum. They are found, according to Prof. Gould, along the outcrop of a belt of red sandstone in Eastern Oklahoma. This belt is about ten miles wide and extends for a distance of fifty or seventy-five miles through several counties, particularly Cleveland, Oklahoma and Lincoln counties. Prof. Gould referred to the specimens in conversation as “sand crystals.” Dr. Otto Kuntze in a similar way calls them “barite pseudomorphs.” In the catalogue of a Western mineral dealer they are listed as identical with certain “silico-barite concretions” collected in Kansas. An Eastern dealer calls them “gypsum pseudomorphs.” It may be inferred from these differing appellations that there is more than a little uncertainty regarding the nature of these objects.

Twelve specimens which came into the possession of the Museum at the close of the St. Louis Exposition vary from 2.5 to 7 centimeters in diameter and from 1O.5 to 364 grams in weight. They assume the form of rosettes which are composed of aggregates of tabular crystals resembling lamellar-nodular aggregates of gypsum, barite and other minerals. The faces of the plates are, however, somewhat rounded on the edges as if eroded and hence not sufficiently definite in form to permit of exact measurements or determination. According to Prof. Gould they vary in size from that of a pea to a diameter of five inches. They are found both enclosed in the sandstone and weathered out.

A series of 32 specimens received later confirms the characters of the earlier lot. They include a number of globular specimens which, however, have the same structure as the rosette forms, from which they differ in the number and dimensions of the component plates. That is, the globular forms are merely thick rosettes. One-specimen consists of a group of many nearly globular forms enclosed in the weathered matrix which assumes the form of a red sand. This sand appears to be the residue left from solution of the limonite cement of a ferruginous sandstone.

The rosette appears upon both sides of an approximately octagonal plate which may be designated the basal plate of the aggregate. This is penetrated obliquely by a variable number of similar plates which appear to intersect at the centre of the aggregate and project on both surfaces. These plates make angles of approximately 30 with the bases. While these plates appear as if passing through the basal plate and any important one appearing on one side may be readily discovered on the other, yet the two rosettes are never exactly alike. One is always more complex than the other and formed of smaller plates. These plates generally, but not always, lie in a confusedly whorled position. They are not simple but frequently consist of two plates inclined to each other at angles of approximately 30 and intersecting some in the vertical aid some in the horizontal plane. By repetition of this compounding of plates, always at angles of approximately 30 so far as the roughness of the material will allow determination, the apparently irregular orientation of the leaves of the rosettes may be accounted for. By a greater degree of this compounding also is the greater complexity of one face over the other produced. The specimens, examined detail by detail, are decidedly unsymmetrical, yet when the broader features only are considered, symmetry of a high order is present. The rosettes on either side of the basal plate while not identical in detail are so in mass, and proportioned so that the aggregates are symmetrical with respect to the plane of the basal plate, as well as to a central axis at right angles to this plane. There is also a tendency in some of the specimens towards an axis of hexagonal symmetry in the plane of the basal plate. The secondary plates appear to so twist as to all intersect along this axis.

The position of those portions of the plates which lie buried in the body of the specimen may be followed by the cleavages upon the fractured surfaces. From an examination of—these cleavages it becomes evident that the plates do not really intersect or interpenetrate. While the projecting and visible portions are plane, that portion of each plate which is buried in the mass of the aggregate is invariably curved and frequently very strongly so. Hence a plate that appears from the general form to pass through the basal plate frequently curves sharply into almost a U shape, with both sides projecting upon the same side of the specimen while another similar U-shaped plate lies symmetrically in the opposite rosette. Other plates upon approaching plates that they appear to penetrate, terminate there in a wedge, and a similar form symmetrically placed gives the appearance of a penetration that does not exist. In some instances the aggregations are double. One specimen consists of two rosettes in parallel position which have simply touched each other and adhered. Another consists of two individuals at right angles which have grown together giving the effect of a more or less spiral, elongated form.

The exterior of the specimens is of dark reddish-brown color, while the interior is of a pale pink closely resembling the color of some pink orthoclases. When broken, a good cleavage develops in the form of a minute step structure of very brilliant facets in parallel position with pronounced pearly lustre. When the fracture is examined under the magnifying glass the cleavage is obscured by a granular structure .which is exactly that of a broken face of sand stone. The specimen is obviously composed of grains of sand cemented by a mineral which possesses an eminent cleavage in at least two directions. The average specific gravity of the nodules is 3.348. The individuals do not vary greatly in density from this mean. The color is discharged upon intense ignition but returns upon cooling. The color after ignition however, is fainter than before.

A slide was prepared and studied under the microscope. This appeared as an aggregate of angular quartz fragments of several sizes enclosed by a cementing mineral which completely filled all voids or interspaces between the quartz. The quartz grains were surrounded by a thin red coating which resolved under high power into groups of brownish red isotropic spherules and ellipsoids upon the surface and in- the fractures of the quartz grains. The granular fragmental material was almost wholly quartz. One small, isotropic fragment of yellow color, high refraction and no visible cleavage, presumably garnet and one good sized fragment of clouded orthoclase appeared.

The cement was an anisotropic mineral of two cleavages, one better defined than the other, which lie at an angle of 90. There was a third cleavage parallel or nearly so, with the plane of the slide which did not appear as cracks upon the surface of the section. The extinction was parallel to the principal cleavage, which lies in the plane of the axis of least elasticity. The index of refraction of this mineral was greater than that of the quartz. The cement throughout the entire slide was part of one crystal with the growth of which the sand grains present had not interfered. This was indicated by the cleavage, which was everywhere parallel with itself, and by the interference color which was the same throughout the slide. The high specific gravity of the specimen and the presence of much barium sulphate, taken with the features shown in the slide indicate that this cement is barite. In this slide it was evidently cut parallel to m and showed the usual cleavage parallel to c and one set parallel to m. An analysis of the specimens made in the Museum laboratories by the author gives the following result:

| | |
|---|---|
| $SiO_2$ | 36.99 |
| BaO | 35.76 |
| $SO_3$ | 19.20 |
| $Fe_2O_1$ | .82 |
| $Al_2O_3$ | 5.36 |
| CaO | 0.51 |
| MgO * | 0.03 |
| $H_2O$ | 0.27 |
| Organic† | 0.32 |
| | 99.26 |

In the above comparative table, showing the specific gravities, sizes of particles, and percentages of sand and calcite, values were computed upon material broken from the heads of representative specimens. The sand-calcite percentages were determined by treatment of weighed fragments with cold dilute hydrochloric acid, after which, the remaining insoluble sand particles were washed, air dried, and again weighed, the loss being figured as calcite. The relative percentages of the various sized particles were obtained by screening through standard mesh sieves.

This corresponds with a mineral composition (disregarding the silica required for the aluminous minerals) of:

| | |
|---|---|
| Barite | 54.42 |
| Quartz | 36.99 |
| Miscellaneous | 8.59 |
| | 100.00% |

From the analysis it would appear that some aluminous mineral is present but the slides fail to disclose such in quantities required to satisfy the analysis. Inasmuch as barite frequently contains similar elements as impurities even when well crystallized, it appears best to provisionally include the minor elements in the barite for an approximate determination of mineral composition. The mineral composition thus becomes:

| | |
|---|---|
| Barite | 63 |
| Quartz | 37 |
| | 100% |

This corresponds to a specific gravity of 3.77 against 3.380 actually found for the individual from which the material for the analysis was taken. This discrepancy would be too great were it not for the fact, elsewhere discussed in these papers, that the specific gravity determined for these mineral aggregates is commonly too low owing to air trapped in pores, cracks, etc., which cannot be wholly removed by boiling or by the air pump. If, however, we assume that all the bases except the barite are in the form of silicates which have a density equal to quartz, the calculated density 3.62 is but slightly lower than that before obtained.

By the method described earlier, the space occupied by the quartz and barite may be calculated. The calculation so made shows that the quartz occupies 50% of the volume of the concretion and the barite 50%. As sand naturally packed generally includes about 40% of voids between the grains, it appears as if the barite had crystallized between the grains of sand and very slightly pushed them apart by pressure when growing. Indeed there are in the slide examined, here and there a few evidences of slight pressure upon the cement in the shape of a rise in the order of interference color combined with a wavy extinction. These spots however are very few and very small. These specimens are, therefore, not concretions in the narrow sense of the term, but crystal aggregates of barite with sand present as a mechanically held impurity. They bear the same relation to the known occurrences of sandstone with barite cement that the sand-calcite crystals of Fontainebleau and Devil Hill do to the sandstones with calcareous cement.

## LIMONITE-SAND CONCRETIONS, SPRING LAKE, MICHIGAN

These concretions (Museum No. G. 1223, Plate XXIII) were collected at Spring Lake, Michigan, by the author. They occur on the tops of dunes where the sand has been overgrown with grasses and shrubs. In places the vegetation has disappeared and the sand has again begun to move. Thus there are formed shallow pits where the surface has been removed to depths of from an inch or two to five or six feet below the sod. These concretions lie on the surface of these pits in the loose sand. From the shallowness of some of these pits, it is evident that many of the concretions must be formed within a few inches of the original sodded surface of the dune. Inasmuch as in the deeper pits the supply of concretions is not perceptibly greater than in the shallowest of all, it appears that few, if any, of the concretions originate at any considerable depth below the surface. The concretions are irregular, lumpy forms without approach to any regularity or symmetry beyond the fact that the majority of them are more or less flattened and many have one flat side. They are occasionally penetrated by minute cylindrical holes up to 2 mm. in diameter such as would be the case if they had been penetrated by rootlets. They are of reddish-brown limonite color rarely approaching a hematite-red in places. They are but slightly consolidated and may be readily reduced to their constituent sand grains by pressure of the fingers. They do not commonly exceed 5 centimeters in any dimension. In composition they are dune sand cemented by a small proportion of limonite which does not fill the voids between the grains. The limonite is merely a coating on the sand grains. Whenever the grains touch their coatings coalesce, thus cementing the sands into a concretion. There is no evidence of any nucleus in any of the specimens examined nor is there any determinable concentric structure.

There is no mystery about the origin of these forms beyond the determination of which of three or four common agents has been the predominant precipitant of the cement. The sand of the dunes in which they were found is, like nearly all dune and beach sand, of a yellowish-brown color. This color is due to a thin coating of limonite. Where the dunes have not been fixed by vegetation, this color is not noticeably lighter at the surface than it is in depth. Where a dune is fixed by vegetation a light sod often forms over the surface. Under this sod the sand is much lighter in color for a depth of a few inches than it is at greater depth. Hence it is to be inferred that the organic compounds derived from the vegetation have, as is customary, dissolved the iron oxides from that sand which lies immediately under the sod. From organic compounds containing iron dissolved in the so-called humus acids, the metal is rapidly precipitated by any one of several agents, the more common of which are spontaneous changes in the organic solvent, bacterial action, oxidation and hydrolysis. The hydrated ferric oxide precipitated is deposited by preference as a film upon the surface of the sand grains and by spontaneous dehydration forms the limonite cement.

As the precipitation has followed so immediately on solution as to produce concretions within a few inches of the surface it is probable that the precipitating agent is either air in the pores between the sand grains, iron-secreting bacteria, or more probably a hydrolization of iron compounds of weak organic acids consequent upon large dilution of the solvent when removed from the immediate vicinity of the decaying root or leaf which is the source of its supply.

Such small limonite-sand concretions forming near the surface of semi-fixed dunes are, therefore, due to an action of vegetation upon the limonite coatings of the sand grains of the dune, an origin not unlike that of the bog and pond limonites.

* From air-dried specimen, by Penfield’s method.
† Loss of ignition less water.

[1] Bull. Geol. Soc. Amer., Vol. XII. p. 165.
[2] Dana: system of Mineralogy, p. 266.
[3] King: Physics of Agriculture, p. 115.
[4] Ibid, p. 126, Warington: Physical Properties of Soil, p. 66.