TWO DIMENSIONAL DENDRITES AND THEIR ORIGIN

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Introduction

Many writers have mentioned the occurrence of dendritic growths and a number of descriptions of various shapes and occurrences have been noted in mineralogy and geology textbooks. However, the literature has little regarding the origin of this interesting structure from a mineralogic standpoint.

The only statements of origin found by the writer are articles by Schoedler[1] and Lewis.[2] Lewis presented what is perhaps the most extensive discussion of the subject. He described some earthy hydrous manganese oxide dendrites found in a white Triassic sandstone. He gave a brief discussion of their origin, with some suggestions as to the origin of dendrites in other types of rocks. He did not give their mineral composition but it was probably psilomelane or wad.

During the course of this study it was found that all dendrites fell into a natural grouping on the basis of shape. First, those that were dominantly two dimensional, i.e., had considerable length and breadth but were of negligible thickness, and second, those that were three dimensional such as shrub-like deposits in moss agates. The origin of these two groups is different and each constitutes a separate field of study. Further study of the three dimensional forms is in progress.

In order to facilitate description, two dimensional dendrites are placed in two groups. The first group, designated as simple dendrites, includes blade-like deposits with no branches[3] and also blade-like forms that may have one or more broad branches but are not intricately subdivided. The second group is designated as complex and includes those forms that are intricately branched. These are the type usually thought of when dendrites are mentioned (Fig. 1).

[1] Schoedler, Friedrich, Elements of Geology and Mineralogy, p. 56, Joseph Griffin and Co., *London,* **1851.**

[2] Lewis, H. C., On Dendrites: *Proc. Acad. Nat. Sc., Phila.,* p. 278, **1880.**

[3] As in plant description, the main body is called the trunk or stem, and the parts that diverge from it the branches.

Definition of Dendrites

A dendrite is a naturally occurring inorganic deposit, resembling a floral growth in outline, that is found on or in a rock or mineral.

Dendrites may show a great many differences in external form. They may be simple, flat, lath-like forms resembling blades of grass, or have a few broad branches smooth in outline, or, again, they may be as complex in outline as a fern or fully leaved tree.

Composition

Most dendrites are reported as being composed of manganese oxide although the iron oxides, hematite and limonite, have been found fully as common and even more abundant by the writer. In fact, conditions surrounding solubility and deposition being equal, the ratio of abundance of iron oxide dendrites to manganese oxide dendrites should approximate the ratio of iron to manganese in the earth's crust, namely about 55:1. It may be that many iron oxide dendrites have been overlooked, and thus only manganese oxide dendrites cited in the literature. Although manganese oxide is perhaps more common in surface waters than we think, the extreme commonness and widespread distribution of iron compounds from which limonite and hematite may be derived would account for the abundance of dendrites of this composition.

Because of the extreme commonness of iron and manganese oxide dendrites the question arose as to the possibility of compounds other than oxides being able to produce these forms, none having been cited in the literature as being common. The writer carried on a number of experiments to grow dendrites by using a variety of salts. True dendritic structures were produced from sulfates, nitrates, and chlorides.

Occurrence and Distribution

Dendrites occur not only in igneous, sedimentary, and metamorphic rocks but also in various minerals. The collection at the University of Missouri includes specimens in sandstone, limestone, shale, chert, opal, flint, dolomite, barite, basalt, diorite, rhyolite, trachyte, orthoclase, andesite, agate, chalcedony, slate, marble, and clay. In fact, dendrites probably occur in all the common rocks and minerals. They are less common in shales and clays than in any other rock. This is probably due to the fact that shales and clays are relatively impervious to the passage of percolating waters, and also to the fact that fractures in these rocks are sealed soon after their formation. Furthermore, the colors of many dendrites are so nearly like the enclosing rocks that they are not noticed. Only when there is a contrast of colors or an unusual shape, is attention attracted to the dendrites.

Dendrites are found most commonly along joint planes, fractures, and bedding planes. Bedding planes should be ideal zones for the growth of dendrites and doubtless contain them in abundance. However, in outcrops the bedding surface is so seldom exposed that the relative number of dendrites cannot be ascertained. Consequently, most specimens are found in highly jointed or fractured rocks where there is a source of material and sufficient ground water for transportation.

Simple and complex forms may be found in the same locality and in the same rock. The simple forms are usually associated with the larger openings. As the openings decrease in size the complexity of the structures usually increases. Many openings have either increased or decreased in size since the deposition of the dendrites either by solution along the joint plane or by the opening or closing of the joints by earth movements. Therefore, it is difficult to state the size of opening necessary for the deposition of any particular form. The width of the fissure is doubtless small and probably approximates a capillary opening in size.

Capillary openings (sheet openings) are between 0.254 and 0.0001 mm. wide. In openings of this type the dendrites may grow upward due to capillary action, or they may spread laterally. In many cases, however, the openings are super-capillary in size and the dendrites grow downward because the waters bearing the mineral salts migrate downward due to gravity. Where the openings in the rocks are super-capillary simple dendrites predominate because the solutions seep downward along irregularities of the wall rock and deposits are made along the channels. Little or no branching is found. In many instances the wide part of the fissure is completely filled with material of which the dendrites are composed. The growth of the dendrites sealed the fissure against the further percolation of ground waters and permitted the accumulation of mineral matter in the wide part of the opening.

Megascopic Description

Dendrites that grow in joints or fracture planes are forced to become two dimensional, that is, their length and breadth are far in excess of their thickness which is limited to the width of the opening in which the dendrites are formed. Their length and breadth may be nearly the same, or one dimension may greatly exceed the other. Some may be a foot or more in length and others microscopic in size.

In cross section the dendrites are usually broadly ovate with minor indentations around the edge. The outside of the stems of some may be smooth at one point and rough or strongly indented at other points. One side of the dendrite may be smooth and the other irregular. This is to be expected when a dendrite is deposited on a porous or irregular surface. The rough irregular side represents the deposit in the interstices between the grains of the rock on which the dendrite was deposited. If the dendrite did not fill the fissure then the side of the dendrite away from the rock is smooth. If the fissure is filled with dendritic material then both sides of the dendrite are rough, the irregularities on the surface of the dendrite articulating with the irregularities on the surface of the rock fissure. Dendrites also grow in smooth joints, and the surfaces are smooth in the same proportion.

Dendrites usually begin as a simple blade that becomes more complex as it develops from the initial point of growth or as the planes in which the dendrites are growing come closer together. Some joint planes are completely coated with dendritic material where the opening is wide, but complex forms are produced where the joint plane pinches together (Fig. 2).

The branches are not regularly spaced. They may be both opposite and alternate along the same stem, or many branches may diverge from one point, either near the base or some distance away from it. A number of branches may go out from one side of the stem without corresponding branches on the other side. The broadest branches are usually near the base of the stem. Exceptions to this are found where the solutions have been guided along some particular channel and a concentration of the deposit has thus been brought about.

The ends of the branches of the dendrites are dominantly of two types. The first, and most abundant, is rounded, subcircular, or ovate. In some instances the end is wider than the stem of which it is a part. The second type is acicular and usually there is the tapering of the branch to a sharp point.

Dendrites may have a variety of colors, but red, yellow, brown, black, and green predominate. In fact, other colors are rare. The cause of the abundance of these tints is evident. Since most dendrites are formed of iron and manganese oxides, the color of the oxides will predominate. A number of green dendrites were observed in shales which probably represent mixtures of ferrous and ferric iron.

Microscopic Description

The materials of which nearly all dendrites are composed are amorphous, at least no crystalline substance has as yet been observed. The dendrites are likewise opaque.

There is little difference between the megascopic and microscopic appearance. The microscope reveals a more detailed splitting and bifurcation of the branches as well as more details of the irregularities of the edges. Some dendrites were found to be made up of a series of flat but rounded aggregates, similar to oolites. No nuclei were observed, and the aggregates tended to be botryoidal and overlapping although some segregated flattened spheres were seen. These rounded aggregates may merge into three dimensional dendrites.

Origin of Dendrites

The possibility of making dendrites artificially was suggested by Schoedler[4] in 1851. He states:

> We find frequently tracings resembling trees or mosses between slabs or plates of rock, forming *Dendrites*, which may easily be imitated, and their origin illustrated by placing some finely levigated clay between two plates of smooth glass, or stone, and pressing them slightly together. A variety of ramified designs are thus obtained, similar to the hardened formations occurring in Nature, which may easily be mistaken for petrified moss or other vegetable objects.

An attempt was made to reproduce two dimensional dendrites by several experimental methods. In some cases very good dendrites were formed, in others only partial success was obtained, and in some experiments the results were negative. The best artificial dendrites were grown in the laboratory along joint planes and by the distribution of suspended material due to surface tension of evaporating waters. In each case dendrites similar to those found in nature were produced. It is of interest to note that finely divided suspended materials, on the evaporation of the water, left dendritic structures in every way similar to those formed chemically.

[4] *Op. cit.*, p. 56.

Growth of Dendrites in Joint Planes

In growing dendrites in joint planes, several strips of ordinary window glass about two and one-half inches square were bound together. The spaces between the plates of glass simulated the joint planes in rocks. The plates of glass were then placed beneath a funnel which contained a number of crystals of iron sulfate. Water was allowed to drip over the iron sulfate, to pass down the funnel stem and onto the upturned edges of the plate of glass. This process was allowed to continue for about a week. The plates, with the edges up, were then set aside for several days to permit any of the ferrous iron in the joints to become oxidized.

The resulting dendrites grew downward from the place where the transporting liquid fell on the upturned edges of the glass plates. The base of the dendrites tended to radiate fan-like from the source of the iron bearing solutions. The dendrites were complex and consisted of slender frond-like forms averaging two centimeters in length and three millimeters in width. The stems had many branches (about 30) the ends of which were sharply pointed.

The formation of the dendrites probably started as soon as the water began to penetrate the openings between the plates. As the dendrites formed, the openings were progressively sealed against the further entrance of solutions and growth ceased. The form of the dendrites was probably influenced by the surface tension of the transporting liquid. The crystal structure of some iron compound may have played a part, but the form of the dendrite could not be directly related to it.

The iron in the above experiment was probably transported as the hydroxide and was oxidized to limonite by oxygen from the air, or by the oxygen in solution in the water. Oxidation started as soon as the water came in contact with the crystals, and consequently some of the limonite was transported in suspension before coming in contact with the glass plates, but the amount was undoubtedly small. Most of the oxidation occurred between the plates.

Good dendrites were produced by using a water solution of cobalt nitrate. Several glass plates separated by onion skin paper were placed in the solution. For several days no dendrites were produced but as the concentration of the cobalt nitrate increased, due to the evaporation of water, small dendrites started to form between the plates and along the contact of the solution and the beaker. In a short time (about two hours) the dendrites grew to be a centimeter in length. The fact that dendrites grew on the surface of the beaker suggests that two walls closely spaced are not necessary to their formation. No natural occurrence has been noted, however, where two walls are not present.

Dendrites Resulting From Surface Tension of Evaporating Liquids

A number of experiments were carried on to study the rearrangement of suspended materials in a liquid as the liquid evaporated. The materials suspended were limonite, pyrolusite, and kaolin.

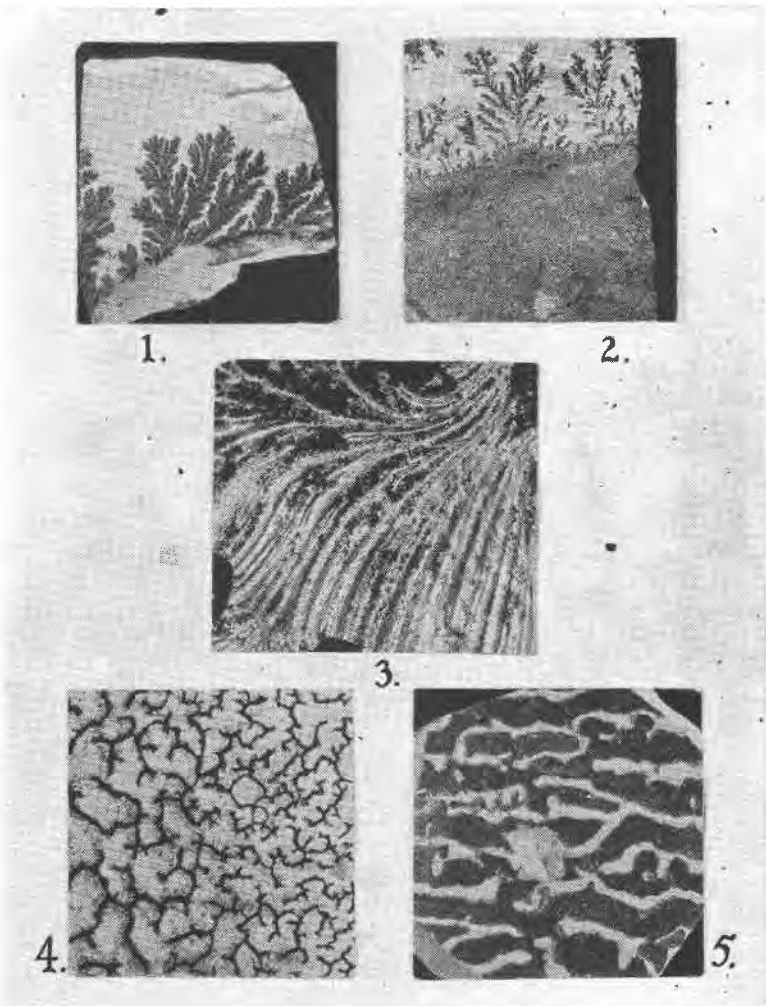
In each case the mineral was ground as fine as possible in an agate mortar. About 0.05–0.10 gram portions were placed on microscope slides. A drop of water was placed on the powdered mineral and stirred with a needle in order to suspend as much of the powder as possible. A cover glass was placed on the slide which was then allowed to stand until the water had completely evaporated. Designs distinctly dendritic in shape resulted in most cases (Fig. 3).

Aggregates, rounded in outline, were numerous, suggesting that the surface tension of the water caused minute flattened drops to form. When the water evaporated a rounded deposit resulted since the suspended material would tend to be concentrated about the outside of the drop.

Associated with these deposits were numerous curved branch-like deposits, indicating that the evaporating liquid tended to assume a spherical shape but was prevented by the cover glass.

Another design that formed commonly when a large amount of powdered mineral was used is shown in Fig. 4. When kaolin was used the resulting dendrites were flat narrow bands about one millimeter in width (Fig. 3). When the mineral used was limonite the dendrites formed were about two to three millimeters wide (Fig. 4). The branches were irregular in outline and diverged at a large angle from the main stem, forming a netlike pattern. Around the edges of the stems faint curved dendritic branches pointed inward. Dendrites similar to this type have been found in the flint clays near Rolla, Missouri (Fig. 5).

As stated before, the most common types of dendrites are those formed in fissures, cracks, joint planes, and bedding planes. The mechanism whereby dendrites are formed in these places is per-



Explanation of Figures

FIG. 1. Complex dendrites of limonite on Mississippian (Burlington) chert. ×1.5.

FIG. 2. Dendrites developed in a wedge-shaped joint plane. At the wide part of the joint the entire surface is covered with limonite. The complex structure developed where the joints pinched together. ×1.7.

FIG. 3. Artificial dendrites formed by the action of surface tension on drying liquids. The material used was pyrolusite. ×4.

FIG. 4. Net-like dendrite pattern of artificial dendrites formed by surface tension. They are kaolin. ×2.

FIG. 5. Limonite dendrites in flint clay. ×1.5.

haps identical in all cases. The transporting agent is almost invariably ground water, and salts forming the dendrites may be transported considerable distances, but the majority of dendritic materials are carried only short distances. Long transportation suggests solubility, but dendrites are usually composed of insoluble oxides.

In some cases the dendritic materials are doubtless derived from the weathering of the wall rock in which they are deposited. In basic rocks the decomposition of the ferromagnesian minerals along the joint planes provides a ready source for the dendritic materials. In dolomites the ferrous iron commonly isomorphous with the magnesium supplies dendritic material. In limestones and shales the breaking down of pyrite liberates an abundance of iron to supply the ground waters.

Time of Origin

It can be readily seen from the foregoing discussion that two dimensional dendrites are dominantly epigenetic in origin. They were formed in cracks and fissures after the enclosing rocks were consolidated.

Summary

The widespread occurrence of dendrites has permitted a study of their composition, shape, and origin. Duplication of both simple and complex dendrites in the laboratory, under conditions similar to those in nature, has suggested a number of ways in which these forms may be produced. The most common are by deposition in joint planes, and by the influence of surface tension upon evaporating liquids.