

## Calcareous Incrustation Formed on Cascades at the Indiana State Soldiers and Sailors Monument, Indianapolis<sup>1</sup>

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Several years ago when the cascades at the base of the Soldiers and Sailors Monument were cleaned out thoroughly, a layer of stratified calcareous material, averaging about one inch (25 mm.) thick, was removed from the rounded edges of the six ledges (three in each cascade—see Fig. 1B) over which the water turbulently flows. We propose to describe this incrusting material and discuss some aspects of its formation.

**Occurrence of crust.**—The cascades on which the crust formed are located at the base of the monument on the east and west sides (Fig. 1D). Each cascade consists of three ledges, the upper of which is a shelf, and the two lower, terraces (Figs. 1A-B). Water is discharged by pumps at the outlet on the uppermost ledge, and it then cascades down across the second and third ledges to the basin whence it is recirculated.

According to Mr. Kurt Vonnegut the crust “formed only on the rounded edges (Fig. 1B) of the cascade ledges, on the vertical faces of the second and third drop, and heaviest of all immediately under the water supply outlet. On the edges of the cascades the crust was thin at the top and increasingly heavier downward to the point of drip (Fig. 1C). There was no sediment on the horizontal surfaces.”<sup>2</sup> The crust was also somewhat thicker on the south sides of the cascades, possibly because the hotter afternoon sun accelerated evaporation and hence increased precipitation of calcium carbonate.

The incrustation formed in a period of about 20 years (1902?-1925?), during which time water from a well at the monument was used. About 1925—the exact time seems to be uncertain—the water supply in the well diminished to such an extent that it had to be augmented by water from the city mains, and within a few years thereafter city water was used exclusively and has continued to be used to the present. There was very little deposition of mineral matter after the change from well to city water because the latter is not nearly as “hard” as that from the monument well. Mr. C. K. Calvert, Chemical

<sup>1</sup>We are very grateful to Mr. Kurt Vonnegut for many favors, chiefly the drawings used in Figs. 1A-C and the photograph shown in Fig. 1D, and considerable detailed information about the occurrence of the incrustation. Much of this information was obtained through the kind cooperation of Mr. L. H. Coleman, Supervisor of the Indiana State Soldiers and Sailors Monument. Thanks are also due to Mr. F. C. Jordan, Secretary, Indianapolis Water Company, for information concerning the water consumption at various times and for other courtesies and Mr. C. K. Calvert, Chemical Engineer, for analyses furnished to Mr. Jordan. Finally, we are glad to acknowledge the assistance of Mr. J. Biscoe, Physics Department of the Massachusetts Institute of Technology, who made an X-ray powder analysis of the crustal material.

<sup>2</sup>Personal correspondence, January 18, 1938.

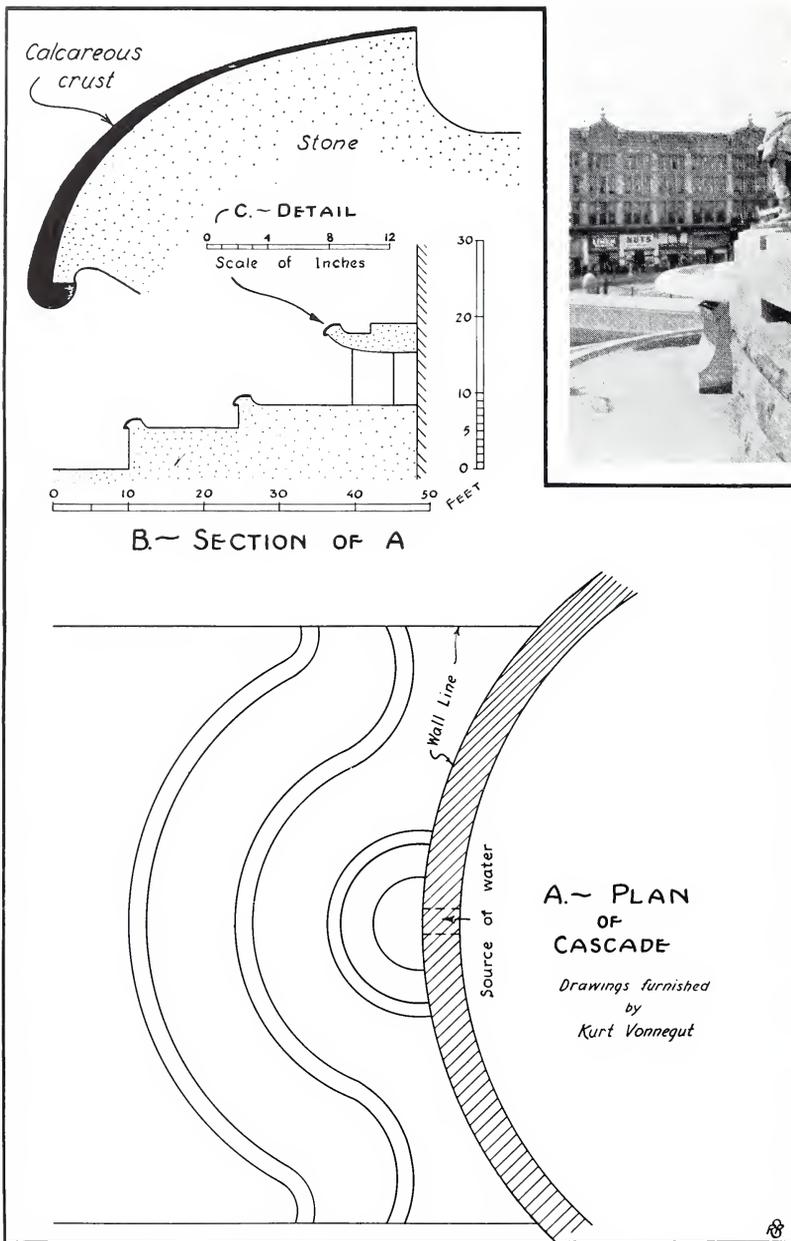


Fig. 1. Sketches and a view of west cascade at the Indiana State Soldiers and Sailors Monument, Indianapolis. (After K. Vonnegut).

Fig. 1D. View of the west cascade, looking northwest, showing the three ledges over which the water flows.

Engineer, kindly furnished the two analyses below, which show the solids in the water from the two sources, with the comment that the monument well "has been out of use for several years" and that "the water is much harder than the city supply and deposition (of calcium carbonate) from it will be at a higher rate, but the city water, under the conditions in the monument basin, will deposit lime."<sup>3</sup>

In the following analyses, Sample No. 1 was taken from the monument well on September 30, 1909, and Sample No. 2 is an average of city water for a seven-year period.

	1. Monument well	2. City water
	(in parts per million)	
Insoluble .....	10.5	7.3
Calcium (Ca).....	153.2	72.0
Magnesium (Mg).....	46.8	13.0
Sodium (Na).....		27.0
Sodium and Potassium chlorides.....	124.6	
Iron .....	0.07	0.42
Aluminum (Al) .....		0.31
Sulphate .....	192.7	58.0
Chloride .....	78.0	20.0
Carbon dioxide (CO <sub>2</sub> ).....	16.0	
Alkalinity .....		217.0
Temporary hardness.....	332.0	
Permanent hardness.....	268.0	
Total hardness.....		290.0
Total solids.....	878.0	342.0

During the period when the incrusting deposit was made, it has been reported that the cascades usually operated from 9:00 A. M. to 5:00 P. M. during the warmer months (approximately April 15 to October 15) with a flow of about 4,000 gallons per minute for each cascade.

Apparently the repeated aeration and evaporation of the water, as it flowed turbulently over the cascades, and the consequent evolution of carbon dioxide from this as well as from release of pressure, caused precipitation of the calcium carbonate.

The basins were drained and cleaned bi-monthly during very hot weather and monthly during the remainder of the time the water was flowing.

**Nature of crust.**—The deposit formed a thin crust over the curved lip of each ledge, and this ranged from 5 to 40 mm. thick with greatest thickness at the point of drip on the ledge nearest the water source (Figs. 1A-C). Chemically, the deposit is rather pure calcium carbonate (95% ± 5%) with minor amounts of MgO, R<sub>2</sub>O<sub>3</sub>, and free C and a trace of sulphate. Mineralogically, it is calcite.

The crust exhibits wavy stratification, which is due largely to undulating films or thin zones and bands of black, carbonaceous matter (Fig. 2). These prominent black bands, numbering at least 16 or 17, are believed to represent the soot, dust, and other impurities which accumulated on the surface of the crust during the winter months when the water was not flowing. The stratification paralleled the surface of

<sup>3</sup>Personal correspondence, January 14, 1938.

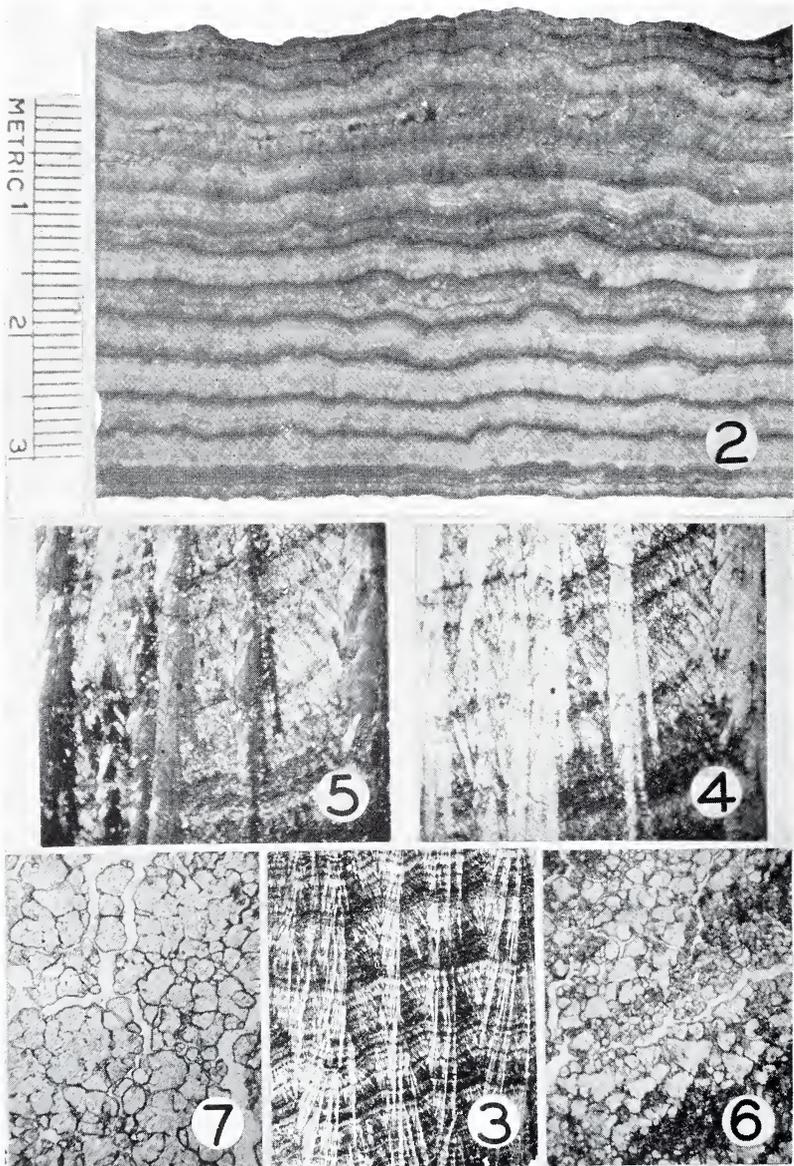


Fig. 2. Polished transverse section of the thickest part of the crust, showing the prominent black bands, between which are many thinner and fainter films of impurities. The more prominent bands are crowded in the lower part and incomplete in the upper.

Fig. 3. Photomicrograph of a small portion of the crust (X 2.5), showing several dark bands and bundles of transecting, acicular crystals of calcite.

Fig. 4. Photomicrograph of a section (X 10) transverse to the crust and parallel

the stone ledge on which it was deposited, and the acicular calcite crystals are disposed essentially at right angles to this surface and the stratification (Figs. 2, 3).

The general surface of the crust is like that of pebble-grained leather but is somewhat undulating with occasional prominent nodular protuberances. Former surfaces appear in transverse section (Fig. 2) as prominent wavy black bands, and the protuberances appear as areas of radial crystallization (Fig. 2).

The fainter and less regular dark films, numbering as many as 10 or 12 between the more prominent bands, may represent dust and other impurities related in some way to the cleaning of the cascades during the summer. The thickness of the material between the more prominent dark bands averages slightly over 2 mm., and this thickness, containing the 10 or 12 films just mentioned, is believed to represent one summer's deposit of calcium carbonate.

The crust is quite porous, especially in the upper third (Fig. 2), where cavities 1 mm. or more across appear and the banding is interrupted and incomplete. The upper part of this imperfect record possibly represents the deposits made during the period when city water was being used to augment the monument well.

The specific gravity of the crust is about 2.50 (2.44-2.59), which is slightly more than that of the Indiana (Salem) building stone (2.48) and slightly less than that of the lithographic St. Louis limestone (2.65).

**Formation of crust.**—The crust consists of calcite<sup>1</sup>, but the conspicuously acicular structure strongly suggests that the calcium carbonate precipitated originally as aragonite and later recrystallized to the more stable calcite, retaining, however, the acicular character of the original aragonite. This suggestion is supported by the fact that the blade-like crystals of calcite cut across numerous prominent black bands, portions of which may or may not be preserved within the crystals (Figs. 3, 4). Apparently the original crystals—assumed here to have been aragonite—maintained their direction of growth through several summers with seasonal increments added in optical continuity. Then later, when the aragonite changed to calcite, the general crystal form was preserved, and in many instances portions of the numerous films and bands of impurities were preserved. In some cases, however, all traces of the original bands have been eliminated (Figs. 3, 4).

Under the microscope the crustal material is resolved into dark zones and thin bands through which are scattered bits of impurities,

<sup>1</sup>Mr. Jonathan Biscoe, Department of Physics of the Massachusetts Institute of Technology, kindly made an X-ray powder analysis of the material and found it to be calcite; the mineral was also identified microscopically.

with the elongated crystals, showing how the crystals transect several bands of impurities.

Fig. 5. Same as Fig. 4, with nicols crossed, showing the elongated character of the calcite crystals. The matrix is also calcite, with impurities.

Fig. 6. Photomicrograph of a section (X 10) parallel with the crustal surface and transverse to the crystals, showing the latter as rounded polygons which separate readily from each other.

Fig. 7. Portion of crust, X 20, showing same as Fig. 6.

the soot, dust, etc. already mentioned; these zones are transected by bundles of diverging or rectilinear, acicular crystals (Figs. 3, 5). In sections cutting the crystals transversely, the latter appear as rounded polygons and give uniaxial optic axis interference figures, showing that they are elongated parallel to the *c* axis (Figs. 6, 7). The material readily fractures parallel with the crystals which then separate as subprismatic needles with satiny luster.

The deposit obviously was derived from the well water, and it is possible to estimate roughly what fraction of the total calcium dissolved in the amount of water used was precipitated. From its dimensions the total mass of the deposit is estimated as five tons.

Assuming that the well water had the analysis reported (given earlier) and that approximately 3,500,000 gallons were used annually, then as now, it has been calculated that about 5% of the calcium in the water was deposited.

**Summary.**—This example of rather rapid deposition of calcium carbonate illustrates how that substance may be precipitated from ordinary ground water at normal surface temperatures and pressures. In this instance, the calcium carbonate precipitated from calcium-rich water bearing dissolved carbon dioxide and appreciable amounts of magnesium, sulphate, and chloride ions.

We believe that the carbonate originally precipitated as aragonite and later recrystallized to its present form, calcite. We recognize the possibility, however, that the deposit may have been calcite from the beginning.

The prominent dark bands in all probability represent annual accumulations of winter dirt, made when the cascades were not in operation. The maximum thickness of 40 mm. was deposited in about 3,600 eight-hour days in the 20 (more or less) summers of operation. This rate of deposition—approximately 2 mm. per summer—corresponds fairly well with the observed thickness of material between the more prominent, presumably winter-deposited dark zones. If deposition at this rate were continuous, about 12 mm. of calcium carbonate would be deposited annually.