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Sampling Protocol Used at the Cathedral of Learning in Pittsburgh, Pennsylvania

by

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Introduction

Stone buildings that are exposed to the effects of rain, wind, and urban pollutants deteriorate over time. Sharp edges become rounded, carved details may be lost, and the stone surface may be disfigured by accumulation of dirt or by dark surficial crusts. The Cathedral of Learning in Pittsburgh, Pennsylvania is being studied to learn about pollutant delivery and deposition on a high-rise stone building. The Cathedral of Learning is a 42-story limestone building, located at the University of Pittsburgh. It was built between 1929 and 1937 and is a well known landmark in Pittsburgh. A group of researchers from Carnegie Mellon University, led by Cliff Davidson, are using the building as a field laboratory to study air pollution damage to buildings. Some of the project components include: assessing the distribution of deterioration, monitoring meteorological conditions and pollutant deposition at the building, and modeling the pollutant delivery and deposition on the building. In order to link the pollutant monitoring and modeling with the visible black surficial deterioration on the building, the surficial deposits must be examined and identified. This report describes the approach used to sample surficial accumulations on the building.

Samples of the surficial deposits from the Cathedral of Learning will enable us to examine the accumulations to determine their constituents and characteristics. The samples will be examined with optical and scanning electron microscopy (SEM), with energy dispersive X-ray analysis, and perhaps with X-ray diffraction. The primary goal of the sampling is to relate features of deterioration that are visible on a large scale with specific information about the characteristics of the deterioration that may have an impact on the stone. Thus, two important factors for successful sampling at the building are: choosing appropriate and representative locations, and obtaining appropriate samples for the analytical techniques we expect to use.

Approach

Examination

One of the goals of the overall project at the Cathedral of Learning is to assess the distribution of deterioration, so a visual survey of the building was conducted before beginning any sampling. During the visual survey I looked for: patterns in the visible deterioration, small and large scale features of the surficial accumulations, visible differences in the alteration crusts that could be described in distinct categories, locations of the different types of crusts, and correlations between the visible characteristics of the crusts and the locations of the crusts on

the building. Although no quantitative estimates were made, the visual survey helped to identify broad categories of visible features and their prevalence on each side of the building.

The building has distinctive areas of dark and light surfaces. Viewed as a whole and from a distance, two sides of the building (those facing Fifth Avenue and Bigelow Boulevard) are lighter and appear to have less accumulation of crusts than the other two sides. The top of the building has much less dark accumulation than the lower areas. On a large scale, there appears to be a typical "V" or "W" shape to the pattern of the dark and light areas. While some of the dark areas are partially or completely sheltered from above, in many cases the sheltering appears to be minimal and some of the dark accumulations seem to occur on straight vertical surfaces. The dark areas appear black or they may have a red-brown color; the light areas appear to be limestone surfaces without any surficial accumulation. There are variations in the surface finish on many of the blocks of limestone in the building, but the surface finish does not appear to influence (or correlate with) the type of alteration crust that occurs there.

Choice of sites

The Cathedral of Learning has a very complex shape with many different levels (Figure 1), so there are potentially many places where samples could be collected. Sampling sites were selected based on several factors, but my primary concerns were to coordinate with the pollution deposition studies and to determine whether the characteristics of the crusts vary around the building. A practical consideration of site selection was whether an area of the building was accessible for sampling. Within a sampling area, such as on one of the patios, sample locations were selected for one of three reasons: to document the visible variations in the surficial accumulations, to closely represent (without interfering with) one of the pollutant monitoring sites, or to duplicate a similar location on another side of the building.

Samples were obtained from four levels of the Cathedral of Learning: the roof, the 16th floor, the 5th floor, and at ground level (Fig. 1). Most of the samples were collected on the 5th floor level because this level provided the easiest access to several sides of the building that had visible surface accumulations and because a significant portion of the pollutant sampling has been conducted at this level. Most of the samples were collected from dark surficial crusts. The light areas that were sampled mostly appear to be limestone with no visible surface accumulation, but samples were collected in some of these areas for comparison with the black and red-brown crusts. In several cases, pairs of samples were collected from adjacent dark and light areas. On the 5th floor patio, where the pollution monitoring is located, samples were also collected just below (in order to be close to without interfering with) some of the SO_2 and carbon particle deposition measuring sites. Figure 2 shows where all of the samples were collected.

Method of sampling

The method I used to collect samples was determined by two factors: I wanted to impact the building as little as possible, but I needed to collect enough material in a sample to adequately examine it. A few grains are sufficient material for SEM examination, but more material provides a more representative sample. Powder X-ray diffraction generally requires more material than is needed for SEM examination, but even so, a useful X-ray pattern can be obtained with a thin layer of powder that covers about one square centimeter area. Thus, very

little material (less than 0.5 g) was required for any particular sample. Typically, samples were obtained by scraping the stone surface with the blade of a pocket knife while holding a small plastic box (1 inch x 1 inch, with a hinged lid) below the sampling area to catch the scraped material. When possible, other samples were collected by prying or plucking small pieces of material from the surface of the stone. I used this technique where the surficial accumulations appear to be spalling off (peeling off in a thin layer). While collecting the samples, by either method, I observed and recorded information about the material I was sampling. Some of the features of particular importance to note include:

- How easy or hard was it to remove the material? (This may indicate the tenacity of alteration crust.)
- Did scraping change the appearance of the area where the sample was collected? (For example: did removing the alteration crust make the original stone surface visible or were there traces of the alteration crust still adhering to the stone surface?)
- What does the sample look like after it is collected? (The material might be a fine or coarse powder, its color may differ from what it appeared to be when it was on the stone surface, the surficial crust may have pieces of the underlying stone adhering to it, etc.)
- For intact pieces that were removed, is there a difference in the appearance of the outward facing surface and the inward facing surface? (This may indicate something about the weathering of the piece, or may help explain why it was spalling off.)

In some instances it is useful to examine the stone surface with a hand lens (10x magnification) prior to sampling to identify specific targets for sampling, or to record characteristics of the material to be sampled. Recording a description of the specific location of the sample is an important part of collecting the sample. Photographing typical or special areas where samples were collected may be useful for interpreting and illustrating the characteristics of the surficial accumulations.

Most of the samples collected at the Cathedral of Learning were scraped powders. Where possible, small pieces of crust (the largest is 18 x 15 x 1 mm) were pried off because they may provide the best type of sample for SEM examination of the crust surface. Samples of a few unusual features were plucked from the stone surface, for example: sample CL801-5 consists of metallic spheres, about 2 mm in diameter; and sample CL801-7 consists of white spherical grains, about 1 mm in diameter. Brief descriptions of all the samples are given in Table 1.

Sample Summary

Thirty seven samples were collected during this phase of the project. Thirty of the samples represent common or typical features of the surficial accumulations that are distributed around the building (Table 1). Seven samples represent various unusual or localized features (Table 1, bottom). The samples were collected from all four sides of the building and facing three corners. The side of the building from which a sample was collected is indicated by the street name that the side of the building faces (see Table 1). More samples were collected from the Forbes Avenue side of the building than from any other side (Table 2). Samples were collected from four levels of the building, but most of the samples were collected on the 5th floor

level. Black crusts were the most common type of crust sampled. Three pairs of light and dark samples were collected near each other: CL801-3 & -4, CL801-15 & -16, and CL801-27 & -28. Several sets of samples were taken from similar locations on opposite sides of the building: CL801-23 & -26, CL801-11 & -17, CL801-18 & -10 & -1 (Figure 2 and Table 1). Analyses of these samples will be integrated with information about where and how they were sampled on the building, in order to provide a picture of the surficial deterioration at the Cathedral of Learning.

This sampling effort concentrated on surficial accumulations above ground level, particularly on the fifth floor level. The sampling locations were chosen partly to make the samples as relevant as possible to the pollutant monitoring that Carnegie Mellon University is conducting at the Cathedral of Learning and partly for two practical reasons. Although one might ideally plan to sample identical locations on each side of the building at a specific level, this may not be feasible (1) because of limited physical access to some areas (without scaffolding) and (2) because surficial accumulations are not present on all sides of the building in the same positions. For example: several samples were collected on the 16th floor patio facing Forbes Avenue and, although there is a corresponding area on the 16th floor facing Fifth Avenue, there are no blackened surficial accumulations on the Fifth Avenue side of the building on the 16th floor. Analysis of the samples may also identify any gaps or redundancies among the samples collected at the building. If additional samples are needed they will be specifically chosen to answer questions that are based on what I have learned from studying the building and the samples collected during the first sampling effort.

Summary

The sampling program used at the Cathedral of Learning consists of the following elements:

1- Assess the building to determine the extent and nature of the deterioration that is to be sampled.

2- Choose areas for sampling that are accessible and because they might contribute to understanding the overall picture of surface accumulation at the building.

3- Collect samples that represent the visible features of the alteration.

4- Use a sampling method that is as non-destructive as possible. Without disfiguring the building, collect enough material for the analytical method(s) that will be used.

5- Document sampling locations and sample characteristics.

6- Determine additional needs for sampling, by evaluating and synthesizing analyses from the initial set of samples collected.

Acknowledgement

I would like to thank Vicken Etyemezian for his cheerful help as a guide and for arranging our access to the roof patios, when I collected samples at the Cathedral of Learning.

Figure 1. The complex structure of the Cathedral of Learning. Fifth, Bigelow, Forbes, and Bellefield are the names of the four streets that bound the building. The Roof Patio, the 16th floor SW Patio, and the 5th floor SW Patio are sites of the monitoring conducted by Carnegie Mellon University researchers.

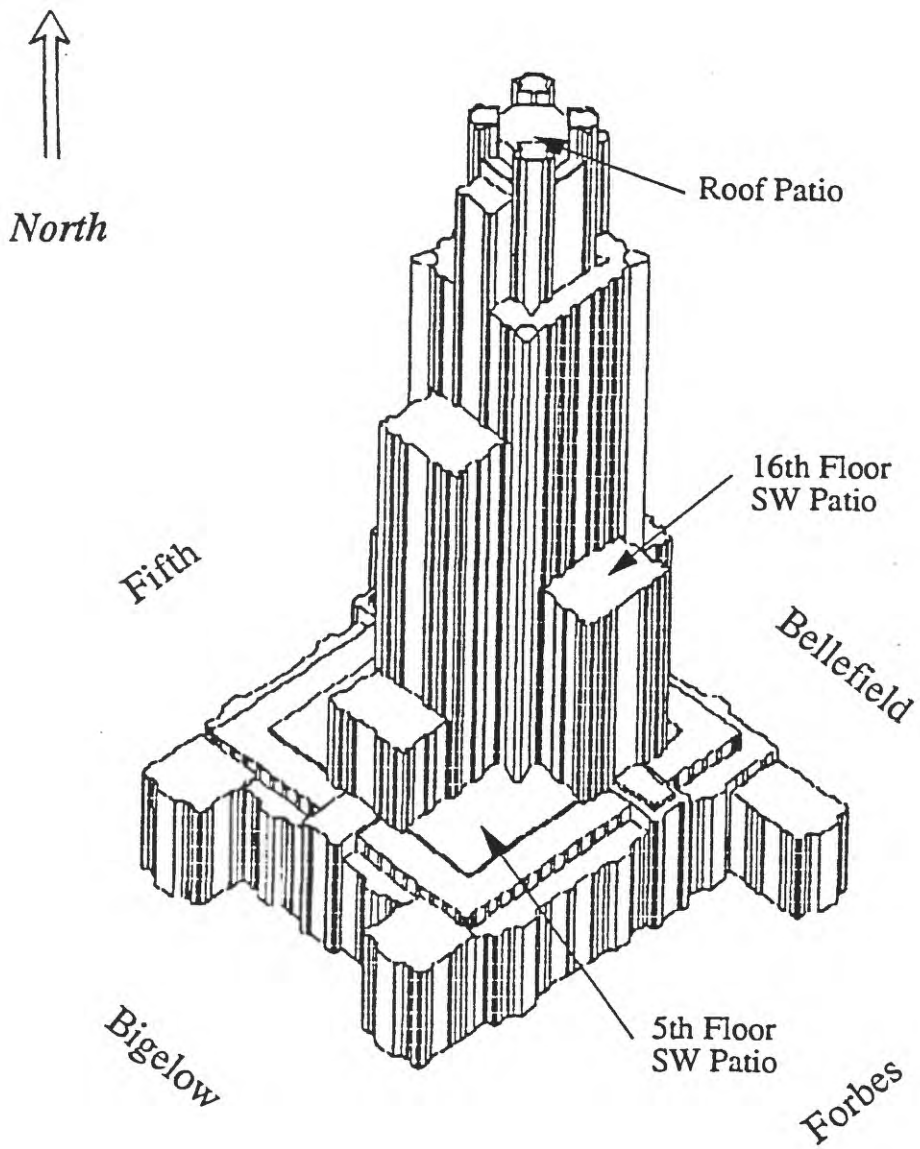

Figure 2. Plan view of the Cathedral of Learning to show the sampling areas (★) and the individual sample locations (small numbers). Shading and stippling are shown to distinguish some of the various roof levels; 5 and 16 indicate the 5th and 16th floor levels, respectively. Meteorological condition sensors are also shown; u-v-w anemometer measures wind direction in three vector directions, WS and WD sensors measure wind speed and wind direction.

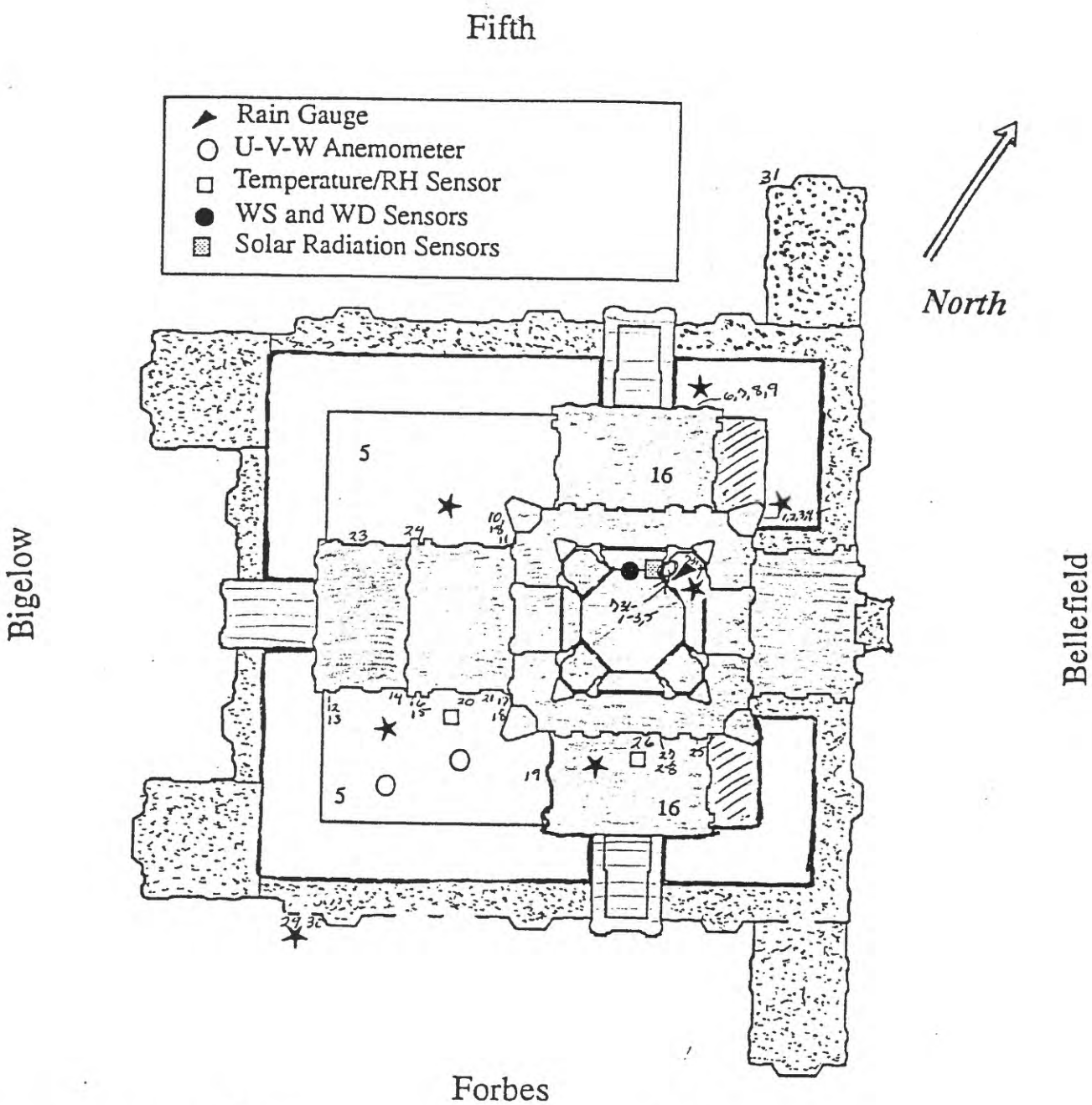

Table 1. Samples Collected from the Cathedral of Learning

Typical surficial accumulation samples are listed on pages 8 & 9; special samples are shown separately, at the bottom of the table (on p. 10).

sample #	lvl	side	lc	location	type	field description
CL801-1	5	Bellefield	1	angled wall, ab 4 blks up	black	pry piece off; hard to get spall off
CL801-2	5	Bellefield	1	angled wall, ab 5 blks up, nr 801-1	black	pry spall off easily; orange red underneath
CL801-3	5	Bellefield	1	angled wall, ab 4 blks up, nr -4	black	scrape easily, very powdery, fine
CL801-4	5	Bellefield	1	angled wall, ab 4 blks up, nr -3	light	scrape surface
CL731-1	40	Bellefield & Fifth		light blk, wall	red-brown	pry off easily w/ fingers
CL731-4	40	Bellefield & Fifth		exposed area at top	light	scraped
CL801-9	5	Fifth	2	wall	red-brown	pried/scraped rust and blk fr grooves, some surficial
CL801-8	5	Fifth	2	wall, at drip edge area, ab 2 blks up	black	scrape fine grns
CL801-6	5	Fifth	2	wall, ab 6 blks up	black	spall pieces pry off
CL801-11	5	Bigelow & Fifth	3	deep corner wall	black	scrape fine powder
CL801-24	5	Bigelow & Fifth	3	wall	red-brown	surficial, picked off w/ fingers
CL801-22	5	Bigelow & Fifth	3	angled wall, 3rd blk up	black	scrape easily
CL801-23	5	Bigelow & Fifth	3	window rib, 2nd fr crner, Lmost rib, L side, nr C-spot	black	scrape
CL801-10	5	Bigelow & Fifth	3	angled wall	black	pry spall pieces
CL801-19	5	Bigelow	4	wall, white area nr C-sampling	light	scraped, rusty bit popped off
CL801-17	5	Bigelow & Forbes	4	deep corner wall	black	scrape easily

sample #	lvl	side	lc	location	type	field description
CL801-18	5	Bigelow & Forbes	4	angled wall, rough surface	black	pry small bits off easily
CL801-26	16	Forbes		window rib, R center part	black	hard to scrape fine powder
CL801-27	16	Forbes		blk wall nr -28	black	scrape easily, fine, surficial
CL801-28	16	Forbes		wall, nr -27	light	spall light on outside, blk on wall side
CL801-25	16	Forbes		wall, 3rd blk up, edge	black	scraped easily
CL801-21	5	Forbes	4	wall, nr -20?	orange	orange layer beneath blk, hard to get just orange
CL801-20	5	Forbes	4	wall, rough surface, nr sampling 2 blks up	black	scrape easily
CL801-15	5	Forbes	4	wall, in shadow of C sampling, rough stone surface, nr -16	black	fine powder scrapes off easily
CL801-16	5	Forbes	4	wall, nr -15 white area nr C-spot	light	scrape
CL801-14	5	Forbes	4	window rib, L, L side 2nd window fr corner	black	scrape powder
CL801-13	5	Forbes	4	wall, nr AB monitoring loc., nr -12	red-brown	pry spall piece easily
CL801-12	5	Forbes	4	wall, nr AB monitoring loc., below rainshield area, nr -13	black	hard to scrape, tightly adhered
CL801-29	1	Forbes		wall, under horizontal trim	black	lumps scrape easily, smooth=fine grains
CL801-30	1	Forbes		wall, flat area above trim	black	scrape
		special samples:				

sample #	lvl	side	lc	location	type	field description
CL801-5	5	Bellefield	1	angled wall, ab 4 blks up	black	pry out sm spheres w/ knife
CL731-2	40	Bellefield & Fifth		under metal bar	red-brown	scrape; took some stone material w/it
CL731-3	40	Bellefield & Fifth		stain area; previous bar?	red-brown	pulls off easily
CL731-5	40	Bellefield & Fifth		stain nr metal lightning strip	green	scraped
CL801-7	5	Fifth	2	wall	other	clr white spheres, easily pried off w/ exacto blade
CL801-31	1	Fifth		wall, base course of stone (ss)	black	spall pieces, come off easily, blk outer sfc
CL731-6	1	Forbes		wall area nr steps	light	small piece pulled off easily

lvl = level on the building: the number designates the floor (roof = 40, ground level = 1)
lc = sampling areas on the 5th floor (areas 1-4); area 4 is where the monitoring is set up
location: describes the specific area sampled
type: type of sample - black, red-brown, light, other (orange, green, other)
field description: describes how the sample was obtained, may include information about ease of sampling

abbreviations: ab = about, blks = blocks, nr = near, fr = from, w/ = with, crnr = corner, L = left, sfc = surface, (ss) = sandstone, C-spot = Carbon spots painted on the building to determine rate of loss, C-sampling = carbon particle deposition sampling area, AB monitoring = area of sulfur deposition measurements

Table 2. Summary of samples collected

Typical surficial accumulations

Level:	#
Roof	2
16	4
5	22
Ground	2

Type:	#
Black	20
Red-brown	4
Light	5
Other	1

Side:	#
Bellefield	4
Bellefield & Fifth	2
Fifth	3
Bigelow & Fifth	5
Bigelow	1
Bigelow & Forbes	2
Forbes	13

Special samples

Level:	#
Roof	3
16	0
5	2
Ground	2

Type:	#
Black	2
Red-brown	2
Light	1
Other	2

Side:	#
Bellefield	1
Bellefield & Fifth	3
Fifth	2
Bigelow & Fifth	0
Bigelow	0
Bigelow & Forbes	0
Forbes	1