DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

Preliminary Report on Examination of Column Capitals at the Jefferson Memorial, Washington, D.C.

by

Elaine S. McGee and Mary E. Woodruff

U.S. Geological Survey, Mail Stop 959, Reston, VA 22092

Open-File Report 93-350

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

1993

Preliminary Report on Examination of Column Capitals at the Jefferson Memorial, Washington, D.C.

by

Elaine S. McGee and Mary E. Woodruff

Abstract

An examination is being made of the column capital volutes at the Jefferson Memorial in Washington, D.C. by Elaine McGee and Mary Woodruff, from the U.S. Geological Survey. The intent is to see if features can be identified that would explain why some of the volutes have cracked and failed. Access from scaffolding being used for the stone survey at the Memorial has permitted close examination of the stone and aided our recognition of cracks and identification of features that might explain their presence. To date, 126 of the 216 volutes at the Memorial have been examined. So far, we have examined five of the volutes from which pieces fell or were removed in 1990. The fracture faces on the broken volutes are nearly identical to the fracture faces on the pieces that were removed. The absence of an inclusion rich zone on these fracture faces supports our earlier interpretation that while inclusion phases may contribute to a weakness in the stone, they are not likely to be the sole cause of the failure of the volutes.

Cracks and indentations in the marble have been identified on a number of volutes, particularly on the outward facing volutes that are directly exposed to wind and rain. We group the flaws identified on the volutes by location on the volute and by apparent severity. Thirty two volutes from nineteen columns have cracks that are open and (or) appear extensive. Although we have identified a number of linear openings in the lower half of the volutes that are in the general location of the fracture plane on the broken volutes, none of these pieces is loose or appears in danger of immediate failure. Cracks may be associated with inclusion traces in the marble. However, a significant number of cracks are not associated with inclusions. These cracks appear to have developed along horizontal planes in the marble that coincide with changes in texture in the marble. The areas where grain and texture changes occur may be indicative of a weakness in the marble that is a remnant from the formation of the marble. These planes of weakness appear to extend through the single blocks of marble that form a given column capital. Generally, if one volute is cracked or missing on a column capital, the others are likely to have some cracks in a similar location. Although zones of grain or texture changes can be identified on exposed volutes, at this point they are very difficult to recognize on volutes that retain some surface polish or on volutes that have developed surficial accumulation of dirt and alteration crusts. Zones of grain or texture changes are associated with cracks, but not all areas of visible texture changes have developed cracks. This suggests that some external factor (like moisture penetration or vibration) takes advantage of the weakness in the marble to develop the cracks.

Preliminary Report on Examination of Column Capitals
at the Jefferson Memorial, Washington, D.C.

Table of Contents

Introduction

In May of 1990, a portion of a column capital volute fell at the Jefferson Memorial in Washington, D.C. During subsequent examination of some of the column capitals, another piece fell when it was accidently knocked by some moveable scaffolding. Preliminary examination revealed that several other volutes were cracked, and six pieces that were deemed to be severely cracked were removed. An earlier report (McGee, 1991) examined the pieces that were removed from the Memorial to determine if the pieces possessed inherent characteristics that caused weakness in the stone and led to its failure. It was concluded that no single factor contributed to the failure of the volutes, and the failure may have come about through a combination of external influences taking advantage of some weakness in the stone. Although inclusions are present in the marble pieces, with one exception, they were not concentrated along the fracture plane. The report recommended that examination of the broken volutes at the Memorial and examination of the remaining intact volutes might help to more clearly identify what led to the fracturing of some of these pieces, and might give a better indication of the extent of the problem.

We are examining the column capitals and volutes at the Jefferson Memorial as access from scaffolding being used for the stone survey of the Memorial permits. The close proximity to the stone provided by the scaffolding has been essential in helping us closely examine, and sometimes touch, the stone in order to distinguish cracks from inclusion traces or spider webs. The first set of scaffolding at the Memorial provided full access to all of the column capitals on the outer circular part of the Memorial, and partial access to some column capitals on the inner circle. Figure 1 shows the location and numbers of the column capitals examined to date, and the location of the missing pieces. This preliminary report covers the column capitals that were accessible to, and were examined from, the first set of scaffolding. We have examined all four volutes on 27 column capitals, and have partially examined 9 column capitals. Eighteen capitals have not yet been examined at all. In all, this report covers 126 volutes, or nearly 60% of the 216 column capital volutes at the Memorial.

Each of the columns at the Memorial has been assigned a number (1-54) that corresponds to the number used in the original diagrams during construction of the Memorial.[1] A further notation is used to distinguish each of the four volutes in the column capitals. The letters A or D indicate that the volutes face inward, toward the center of the Memorial; the letters B or C indicate volutes that face outward (Fig. 1).

---

[1]*The column capital numbers used in the report on the volute pieces that were removed from the Memorial (McGee, 1991) differ from those used in the present report. The preferred numbers are the original stone setting numbers, that are used in this report. The volute letter designation is the same in both reports.*

Purpose

Our examination of the column capitals at the Jefferson Memorial has three goals related to mitigation of the failure of the volutes. First, we are interested in examining the fracture faces of the broken portions of the volutes at the Memorial to see how they compare with the fracture faces of the pieces that were removed, and that we examined earlier. Second, we are examining the intact volutes to look for cracks that might be similar to those that probably were present on the volutes that failed; to see if there might be some feature that will explain why the volutes cracked and failed where they did. Third, we are examining all the volutes to see if we can determine why some have cracked and others haven't.

Observations Summary

Fracture Faces

To date, we have examined five volutes which were broken in 1990 (40A, 30C, 29D, 17A, and 10B; Fig. 1). The fracture faces on these volutes are nearly identical to the fracture faces on the pieces that were removed; although there may be a little less surficial dirt on the fracture faces of the volutes at the Memorial. Most importantly, we have not found any evidence for an inclusion rich vein on the fracture surface of any volute except the one (29D) that had abundant inclusions on the fracture face of the removed piece. This is a significant observation because it means that 1) the fracture plane did not break unevenly to leave an inclusion rich zone on only one portion of the broken volute, and 2) the presence of abundant inclusion phases is <u>not</u> integral to the failure of the volutes. This also supports our earlier idea that while inclusion phases may contribute to a weakness in the stone, they are not likely to be the sole cause of the failure of the volutes.

Cracks on the Volutes

We have observed a number of flaws on the volutes. They range from small or hairline openings to slight indentations that may permit moisture to more readily penetrate the stone. Almost all the open cracks and indentations that we observe on the volutes extend horizontally across the face of the volute. Some flaws are more prominent than others, and some are potentially more detrimental than others. Although we identify a number of cracks on the volutes examined to date, we have not found any volutes that are loose or appear to be in immediate danger of failing.

We use three categories for cracks on the capitals, to indicate the general location of the crack and to aid comparisons with the broken volutes. **Type 1** cracks are linear openings in the lower half of the volute; they are found on the volutes in the same general area as the fracture planes where some pieces were removed earlier (Fig. 2 A,B) (McGee, 1991). **Type 2** cracks are also fine lines or openings, but are located at the center knob or above, where the stone is more massive (Fig. 2 A,C). We suspect that these cracks are less likely to lead to failure of the volute than type 1 cracks, because of the geometry and the mass of stone that would be involved. **Type 3** indicates the loss of small pieces of stone anywhere on the capital, and may also reflect poor local integrity of the stone; this type does not appear to indicate future loss of larger pieces (Fig. 2 A,D). Typically type 3 flaws are located near the designated volute, usually on the abacus corner or on the egg and dart trim. We have found a few horizontal cracks on the backs of some volutes (on the flared part); these are identified as type 1 or type 2, based on which region they would fall into if a plane were extended from the crack to the face of the volute.

We define a crack as a linear opening in the stone. As mentioned above, close examination of the stones has been necessary to distinguish cracks from inclusions that sometimes occur as darkened thin, linear traces. The inclusion traces are often raised compared to the surrounding marble or they are at the same level as the surrounding stone. In some cases, thin linear inclusions have weathered out of the stone leaving lines that are slightly recessed compared to the surrounding stone surface. We have included these recessed inclusion traces as cracks, because where the inclusion has weathered out of the stone, it presents an opening through which moisture, salts, or organisms can penetrate into the stone. These small openings may act as zones of weakness, or may combine with other areas of weakness in the stone that could eventually cause the stone to fracture. Once there is an opening in the stone, physical and (or) chemical processes may act to further weaken the stone in that area, and the stone may eventually fail there.

Some of the cracks we have identified are clearly related to inclusion traces in the marble (Fig. 3). The crack occurs among inclusion traces, and sometimes small pieces of mica (the typical inclusion phase) can be seen in the bottom of the crack. Other cracks occur where there is no evidence of any inclusions, but there appears to be a slight change in the coloration or texture of the calcite grains in the area of the crack (Fig. 4). We identify these features as "grain changes" and we believe they indicate a textural change in the marble that may reflect a zone of weakness from former shear planes that were present when the marble formed. On some volutes it is impossible to tell whether inclusion planes or textural changes exist where there is a crack (Fig. 5). These features were most difficult to identify on sheltered volutes that retain some of the stone surface finish, or on volutes that have accumulated surficial alteration crusts. We tried to document correlations between cracks and inclusion traces or grain changes, whenever it was possible to identify them, because these features may give clues to why the cracks occur where they do.

Some cracks on the volutes are definite openings, while others appear to be slight surficial indentations. The open cracks usually appear dark, and while they may be very fine, they permit the penetration of moisture, organisms, or salts into the stone. Indentations are shallower than open cracks, and do not appear darker than the surrounding marble. We recorded indentations because it is possible that with prolonged exposure to moisture and pollutants they may enlarge or eventually develop into open cracks.

Cracks in the volutes occur singly and in clusters. Some exposed volutes have inclusion rich areas that have developed clusters of cracks (Fig. 6). Of greatest concern are volutes where several cracks appear to be collinear, and appear at several points on the volute face, at approximately the same distance from the bottom of the volute (Fig. 7). In some cases, traces of cracks (often associated with inclusions) can be followed around the edge of the volute rim, or a slightly open inclusion trace on the back of a volute appears to be at approximately the same level as a small crack on the face of the volute. Any feature, or combination of features, that indicates the existence of a plane of weakness in the stone is likely to be significant because the volute may fail along such a plane.

Observations

Of the 126 volutes examined to date, 56 have some type of flaw (Table 1). We have identified type 1 flaws on 36 volutes, type 2 flaws on 22 volutes, and type 3 flaws on 12 volutes. Flaws are commonly clustered together: a volute may have more than one instance of a given type crack, and fourteen of the volutes we have examined have cracks of more than one type. Four capitals (40, 30, 29, 17) with pieces of volute missing have been completely examined. Each of these capitals also has cracks in the intact volutes. Three capitals with pieces of volute missing have been partially examined (10 -B-C-D, 12 -C, 4 -B-C); one of these has another volute with a crack in it.

We have grouped our observations by approximate severity in tables 2-4. For each volute where a flaw has been identified, the type of crack, its general location, a description of the crack, and a description of the surrounding stone features are given. Where more than one type of crack has been identified on a volute, the first type listed is the more prominent (usually more readily visible from approximately three feet away). The Location information identifies the features of the volute face in which the crack occurs (rims, recessed areas, edge, etc. see Fig. 2A); the features are described for an observer looking directly at the face of the volute. The Description column indicates the nature (and severity) of the crack; i.e. whether it is an opening or if it appears to be just a slight indentation. The last column of the table identifies, when possible, features in the stone such as inclusion traces or texture changes that may be related to the presence of the crack.

The volutes of greatest concern are the 32 listed in table 2; from 19 column capitals. The cracks in these volutes are either type 1 or type 2, and the crack is typically open and (or) appears extensive (occurs in several areas of the volute). Twenty five of these volutes have a type 1 crack and 12 of the volutes have a type 2 crack. Only 5 volutes in this group have both type 1 and type 2 cracks. Cracks are most common on the outward facing B and C volutes (14 and 15 cases, respectively). Only three cracks were found on inward facing volutes, one on an A volute, and two on D volutes. The volutes are grouped by their apparent severity in table 2. Eleven columns appear to have the most severe cracks, or are probably at the greatest risk for failure. These volutes meet several of the following conditions: 1- one volute on the column is already broken (missing), 2- more than one volute on the column has cracks that are open, 3- there are open cracks in recessed areas of the volute face, 4- there are clusters of cracks, the cracks occur in several features of the volute, or segments of cracks appear to be co-planar. Five columns have volutes that fall into an intermediate level of risk. These volutes have cracks in multiple volutes and (or) they have an open crack in a recessed area of the volute face. The last three columns included in table 2 are probably a lower risk for failure; only one volute on the column shows an open crack or has a pronounced fracture.

The 19 volutes, from 15 columns, that are listed in table 3 have minor cracks. Types 1 and 2 are about equally represented in this group, but all are cases where the flaw appears to be an indentation, or a surficial feature only. As with the volutes in table 2, we found more cracks on outward facing (B & C) volutes (15) than on inward facing (A & D) volutes (4). It is also common that more than one volute on a column is cracked. Ten of the columns represented by volutes in Table 3 are also included among the more severely cracked volutes in Table 2. Five volutes are listed in both Tables 2 and 3; in each case the crack listed in Table 3 appears to be only an indentation and is less extensive than the crack listed in Table 2 for the same volute.

Volutes with type 3 flaws are listed in table 4. In most cases these are where small pieces are missing from the abacus corner or from the egg and dart trim, where the loss is minimal and not likely to be related to future loss of large portions of the capital. Most of these flaws are on the sheltered side (A and D) of the column capital, where the marble surface is covered by a blackened alteration crust of gypsum plus dirt. Underneath the crust, the marble exposed by the break often appears to be loose, disaggregated grains.

We found unusual cracks on two column capitals, but we have not included them in the tabulations or our discussions because they appear to be unrelated to the problem of the broken volutes. Columns 19 C-D & 18 C-D both have a vertical crack that extends from the abacus into the scroll between the C and D volutes (Fig. 8). There is no inclusion trace or evidence of grain change at either place.[2] These cracks are unusual because of their vertical orientation; we have not seen cracks that trend in such a manner on any other capitals examined to date. It is possible that these cracks may be caused by structural problems (e.g., building settling). These columns are in the vicinity of column 54 which has a similar vertical crack in the top drum of the column shaft, and was monitored in a study by Hartman-Cox Architects (1991). The columns are also in an area of the Memorial that shows signs of settling.

Discussion of Possible Causes of Volute Failure

Our discussion will concentrate on the volutes in Table 2. These volutes have

---

[2] *In all of the column capitals examined so far, the general orientation of the bedding or inclusion traces is horizontal.*

the most severe cracks and probably pose a risk of failure before the other volutes examined. The features of these volutes may reveal characteristics that reflect problems that go beyond shallow or surficial features of the stone.

The cracked volutes are evenly distributed around the Memorial, as are the column capitals from which pieces fell or were removed (Fig. 9). It appears that open cracks are slightly more prevalent on the south side of the Memorial (columns 34 - 25), however the number of open cracks may just reflect a stronger contribution from weathering agents in this area. General observation suggests that outward facing volutes have rougher surfaces in this area of the Memorial compared to volutes on the east and west sides. In addition, the predominant local wind direction is from the south (oral communication, inquiry of National Oceanic and Atmospheric Administration (NOAA)), so the wind may have accentuated small surficial cracks or indentations resulting in more open cracks in this area.

The outward facing (B and C) volutes are more frequently cracked than the inward facing (A and D) volutes. Twenty nine of the volutes listed in table 2 are B or C volutes, while only 3 are A or D volutes. However, while it appears that the B and C volutes are more prone to develop cracks, the abundant cracks in B and C volutes may partly reflect the impact of exposure on the volutes. For the majority of the columns that we have examined to date, the B and C volutes are exposed to rain and wind, while all of the A and D volutes are sheltered from direct contact with weathering agents. The A and D volutes typically retain some of the original smooth surface finish, and many are partially covered by blackened surficial alteration that consists of gypsum plus dirt and particulates. In contrast, the exposed B and C volutes typically have roughened (sugared) surfaces, only rarely have surficial encrustation, and are much more likely to show preferential weathering around inclusions or reveal the textural characteristics of the marble.

Access to the exterior (B and C) column capitals, that became available in the present study, showed that cracks or possible weaknesses in the marble may be related to textural features of the marble as well as to areas of silicate inclusions. It is much easier to identify features associated with cracks on the volutes that have been exposed to weathering agents. On sheltered volutes, surface polish and accumulated surficial alteration crusts obscure grain texture features, and may even make recognition of inclusion traces difficult. During our examination of the volutes, we have assessed features such as inclusions or changes in the grain size or texture that occur in the vicinity of cracks and indentations. Such features in the marble might reveal why a crack appears at that particular location. Among the main cracks identified in table 2, changes in grain texture around cracks are more common than the presence of inclusions; 22 cracks are associated with grain changes, 11 are associated with inclusions, and in four cases no feature associated with the crack can be identified. While inclusion traces generally occur in clusters or cross several similar parts of a column capital, textural changes are subtle and thus harder to discern. Weathering of the exposed volutes shows textural differences in the marble as bands of coarse, slightly gray grains adjacent to less coarse, tan grains (Fig. 10). X-ray diffraction analysis of samples taken from these adjacent zones showed only calcite, without any appreciable component of another inclusion phase, despite the visible differences. However, small differences in the chemistry of the calcite may exist. These subtle differences in appearance may reflect an area where two bodies of marble (possibly different layers of limestone) were altered during formation of the marble. The interface between the two zones could have been a shear plane, along which the marble slid. It seems quite likely that a subtle characteristic, like the presence of a healed shear plane might lead to the "unexpected" fracturing of the volutes.

While we still do not know why the volutes failed at the Jefferson Memorial, this examination has helped to confirm some of our earlier ideas and has helped us recognize some important features. Weaknesses, like that which probably led to the failure of the volutes, appear to be planar features across single pieces of marble. We have found cracks in multiple volutes on one capital; often at approximately the same level. Capitals that are missing part of one volute, commonly have similarly located cracks in the other volutes. Although cracks may occur in several areas on a volute, cracks that are more than superficial are generally restricted to one plane or region in the stone. Two features of the marble that may be related to the volute failure, inclusions and texture changes, occur along horizontal planes across the column capitals.

Inclusions do not appear to be a major factor in the cracking and failure of the volutes. Inclusions are relatively abundant in the marble at the Memorial, and while some cracks are associated with inclusions, the inclusions are generally discontinuous and unlikely to extend across a block of marble as large as the column capital pieces where we see cracks in several volutes. The most severe cracks, with pronounced openings in recessed areas, are not necessarily related to the inclusion traces. If inclusions are present, they probably contribute to the development of cracks, but they are not necessarily the key weakness that leads to the eventual failure of a volute. Most likely, the inclusions mark the location of old shear planes in the marble.

Most of the volutes that were removed earlier were from sheltered areas, had blackened surfaces, and represented only one side of the failed crack, so we had few visible clues about grain or texture changes where the pieces failed. However, the fracture faces of the broken volutes typically have a blocky, stepped appearance that resembles slickenside surfaces in geologic faults where gradual slipping occurs along shear zones. Our examination of the exposed volutes has shown that open type 1 cracks are more commonly related to areas of textural or grain change than to inclusions. At this time it appears that such planes, which we identify by a change in grain size and texture, may be the most important feature contributing to the failure of the volutes. However, we have also observed grain change zones on many volutes where there are no openings (Fig. 10). This observation supports our earlier idea that external factors, like vibration (from nearby sources such as: planes, trains, automobiles, and especially low-flying helicopters) or penetration of moisture, combine with a weakness in the stone to form the cracks that we have observed.

Areas of Future Concern

Based on our examination to date, several characteristics may indicate that a volute could be at risk for future failure:

- If it is part of a column capital that already has a broken volute.
- If there are multiple cracks on a volute, especially if the cracks are co-planar or approximately collinear.
- If cracks cross several features (such as rims and recessed areas) or continue around the edge of the volute.
- If the volute has an open crack in a recessed area of the face.
- If the volute has open cracks in the type 1 area; especially if they appear to be unrelated to inclusion traces.

Many of the remaining volutes to be examined at the Memorial are sheltered from direct impact of rain and wind. When we examine these volutes, one important aspect of our examination will be to see if clues to the existence of texture changes can be detected where the surface features are more difficult to discern.

References

Hartman-Cox Architects, 1991, Preservation of the Lincoln and Jefferson Memorials Phase IIA Report 12 November 1991, 80% Draft. 65 p. (unpublished report to the National Park Service)

McGee, E.S., 1991, The contribution of marble characteristics to the failure of column capital volutes at the Jefferson Memorial Washington, D.C.. U.S. Geological Survey Open-File Report 91-432, 63 p.

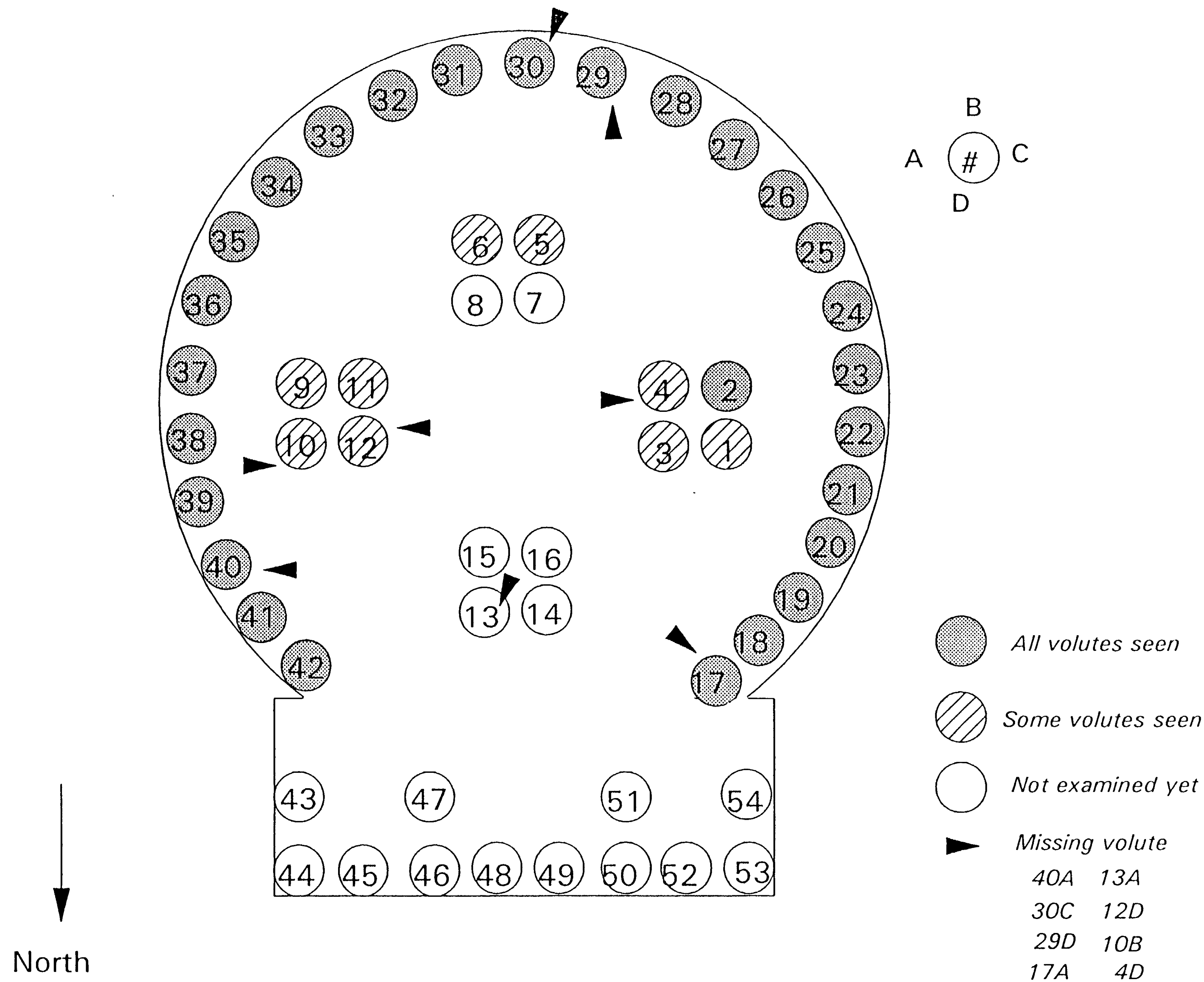

Figure 1. Schematic diagram of the columns at the Jefferson Memorial.

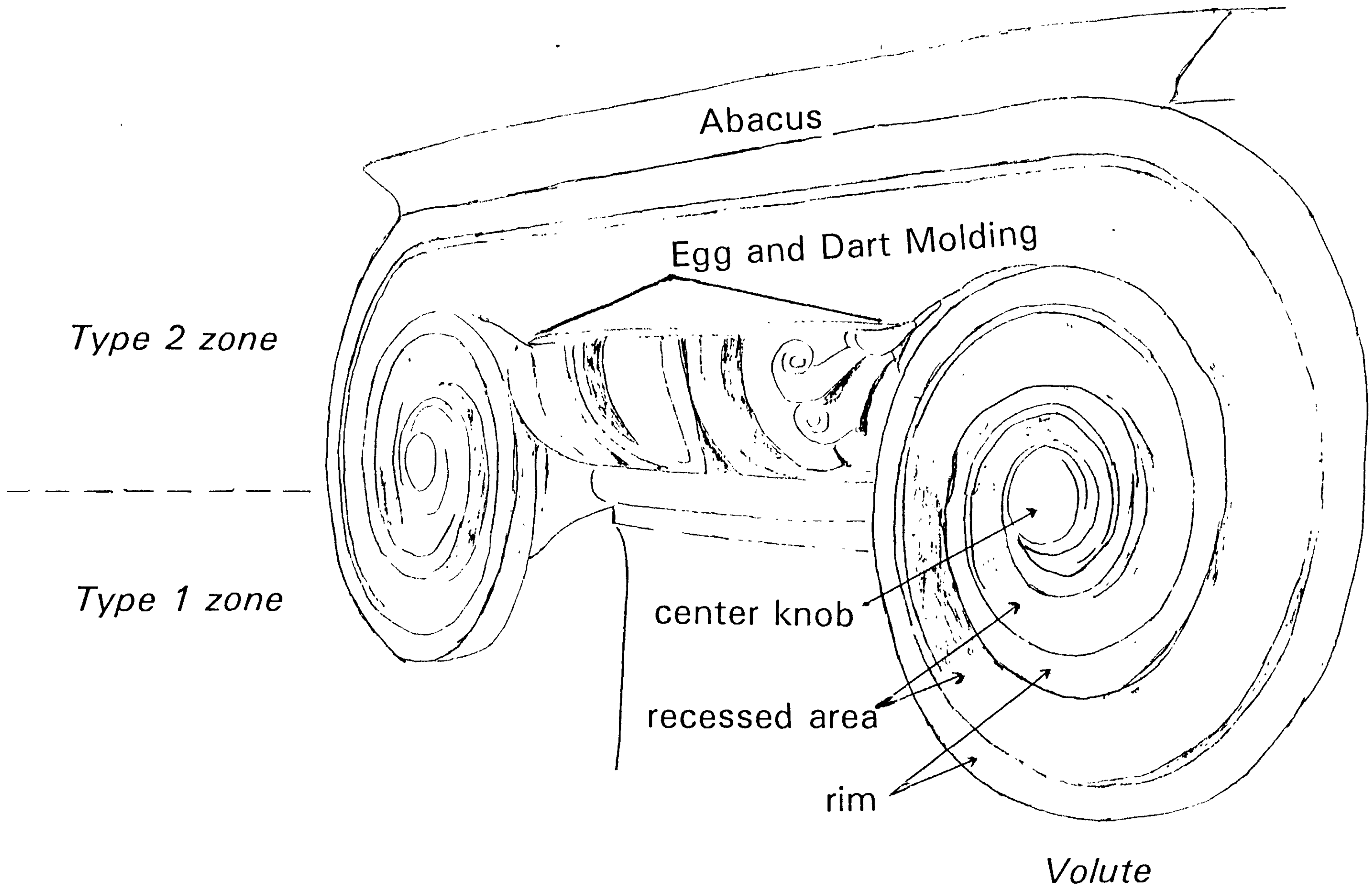

Figure 2A. Parts of a column capital and area of Type 1 and Type 2 cracks.

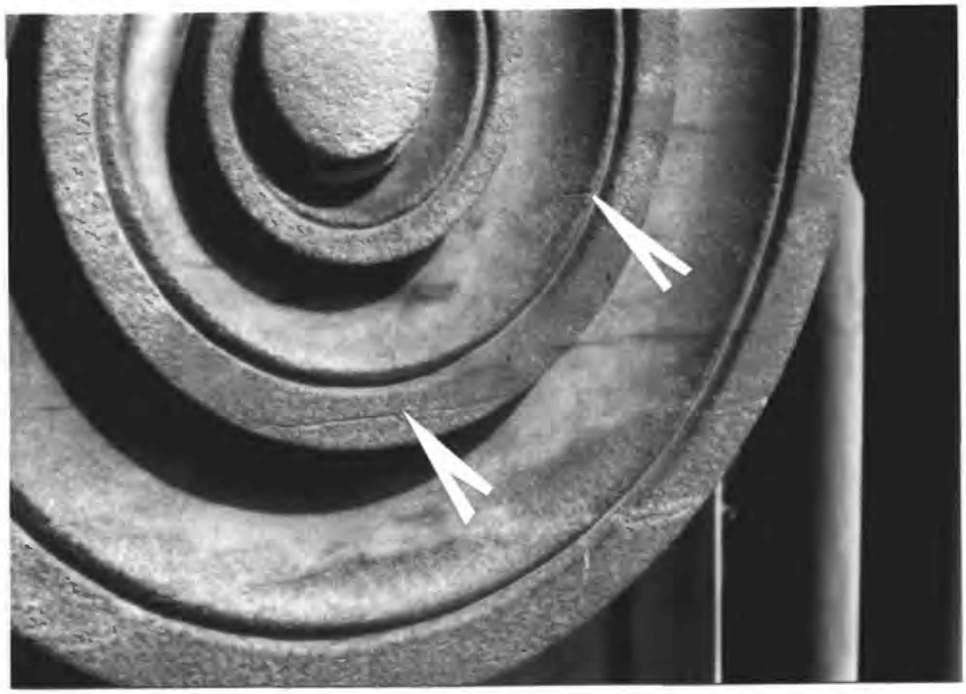

Figure 2B. Example of Type 1 cracks, volute # 33B.

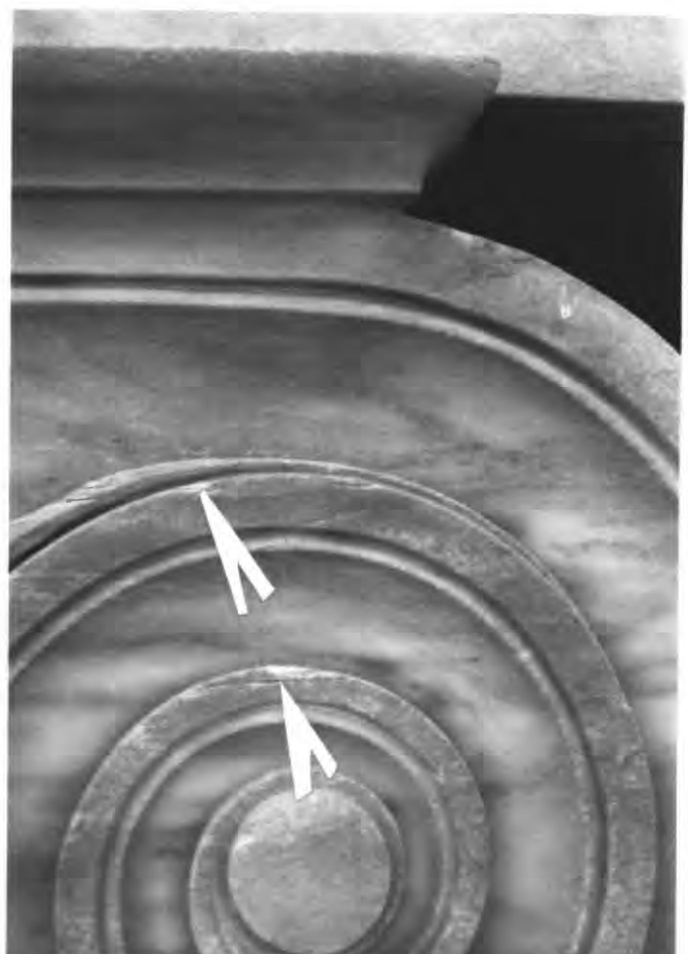

Figure 2C. Example of Type 2 cracks, volute # 26B.

Figure 2D. Example of Type 3 flaw, egg and dart near volute # 19A.

Figure 3. Crack along a mica inclusion, volute # 36B.

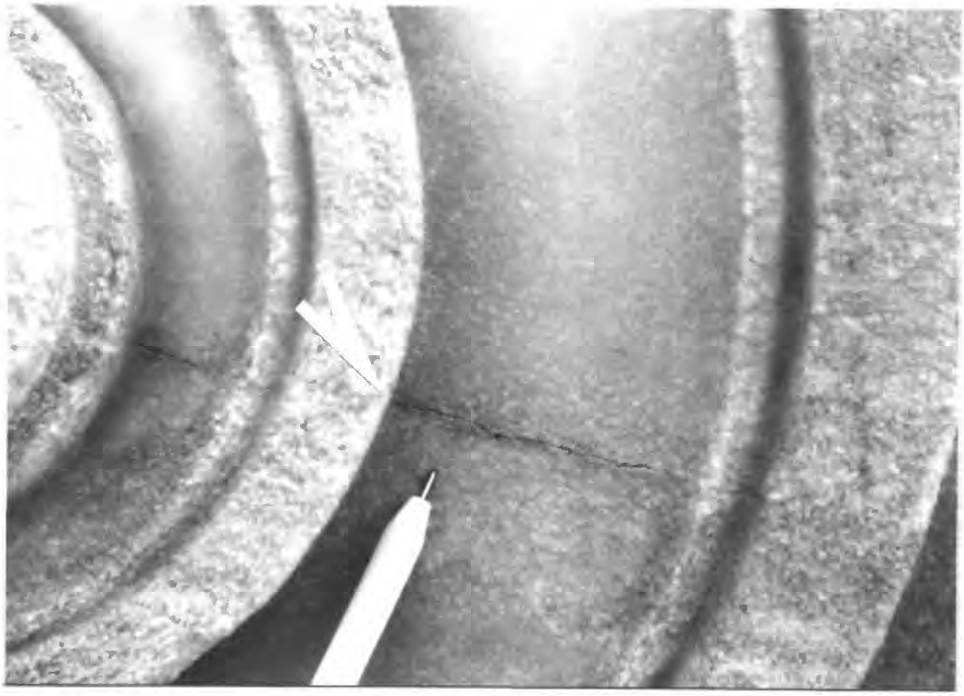

Figure 4. Crack associated with a texture or grain change, volute # 27B.

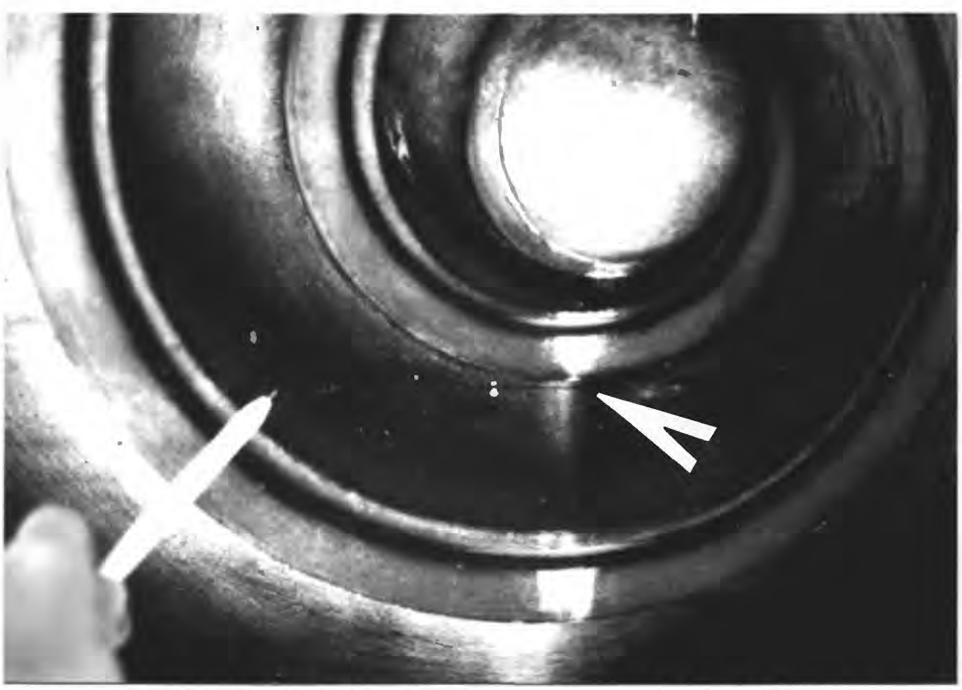

Figure 5. The blackened alteration crust on volute # 10C obscures grain and inclusion features that might be associated with the crack.

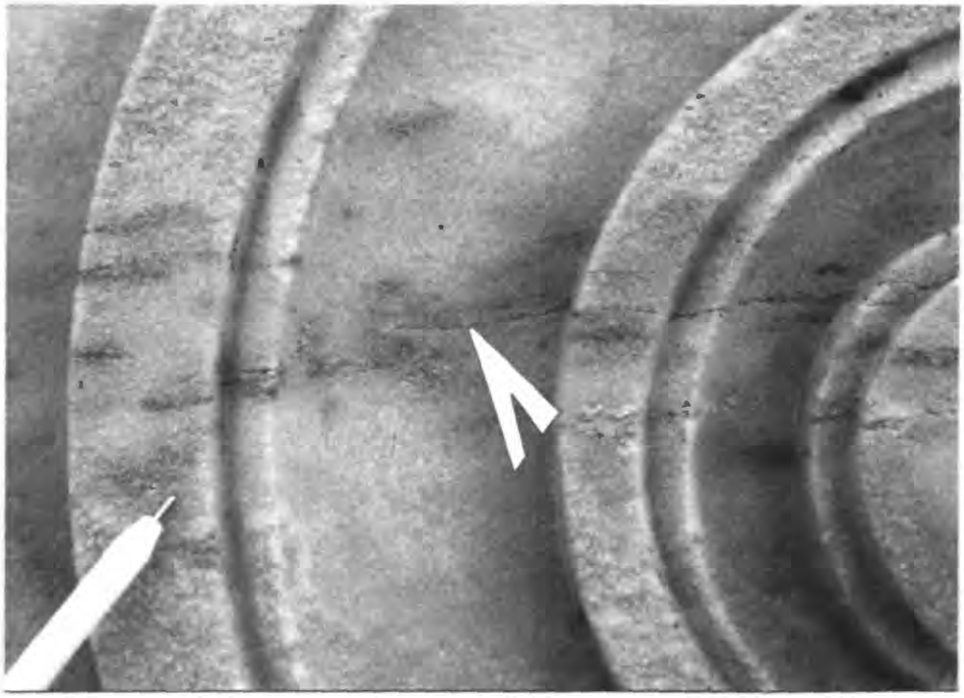

Figure 6. Some cracks are clearly associated with inclusion rich areas; volute # 18C.

Figure 7. Collinear cracks cross both the B and C volutes on column # 33. Note that the cracks are difficult to see even from a small distance (compare with Figure 2B).

Figure 8A. Vertical crack on column 19, between C and D volutes.

Figure 8B. Detail of the crack on 19 C-D; the crack continues along the bottom of the groove to the right of the pen tip.

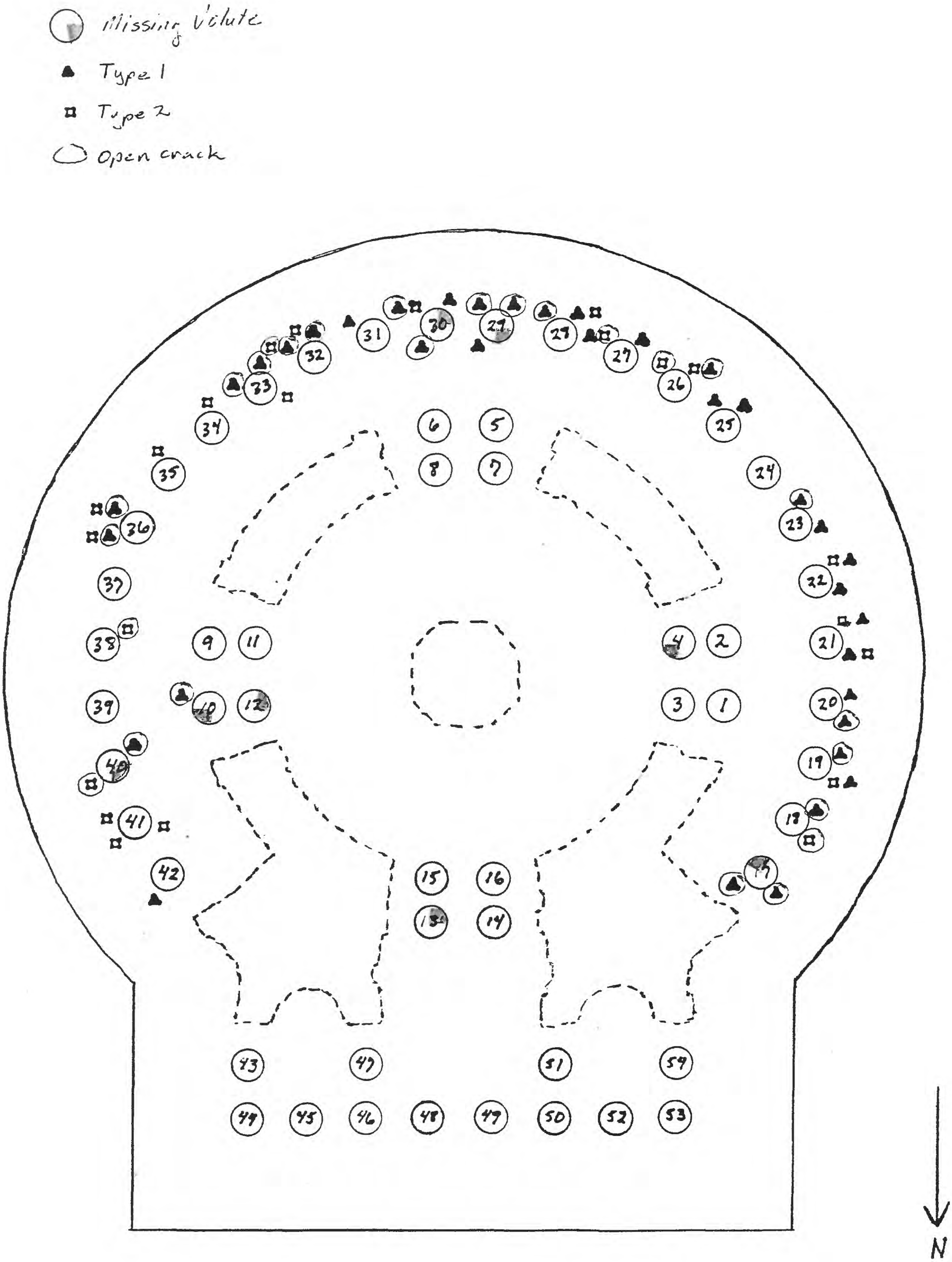

Figure 9. Map of the type 1 and type 2 cracks identified to date.

Figure 10. Textural changes on an exposed volute (# 24B) without any cracks.

Table 1. A. Types of cracks identified on fully examined column capitals.

Column #	A	B	C	D
42		1		
41	2	2, 3	2	
40	★	2		1
39				
38				2
37				
36		1, 2	1, 2	
35			2	
34			2	
33	3	1	1	2
32		1, 2	1, 2	
31		1, 3		
30	1	2, 1	★ 1	
29	1	1	1	★
28		1	1, 2	
27		2, 1	1	3
26		2	2, 1	
25		1	1	
24				
23	3	1	1	3
22	3	2, 1	1	3
21	3	2, 1	1, 2	
20	3	1	1	
19		1	2, 1	3
18		1	2	
17	★ 3		1	1
2				

★ This volute is partially missing.

Type 1: linear opening, lower half of volute.
Type 2: fine opening at the center knob or above.
Type 3: loss of small pieces anywhere on the capital.

Table 1 (con't). B. Types of cracks identified on partially examined column capitals.

Column #	A	B	C	D
12	xxx	xxx		★ xxx
11	xxx		xxx	xxx
10	xxx	★	1	
9				xxx
6	xxx			xxx
5	xxx			xxx
4	xxx			★ xxx
3	xxx		xxx	xxx
1				xxx

★ This volute is partially missing.
xxx This volute face not examined yet.

Type 1: linear opening, lower half of the volute.
Type 2: fine opening at the center knob or above.
Type 3: loss of small pieces anywhere on the capital.

Table 2. Volutes with Main Cracks

C #	V	Type	Location of Feature	Crack Description	Stone Characteristic
40★	B	2	outer rim & recessed - upper left middle rim; egg & dart	opening opening	grn chg? grn chg?
40★	D	1	outer rim & recessed - left middle rim & edge	opening opening	??, incl? ??, incl?
36	B	1	outer rim & recessed - lower, sides	opening	incl
36	C	1	outer rim & edge - lower	opening	incl
33	B	1	middle rim - lower outer rim & recessed - side & left back	opening opening, indent opening?	grn chg grn chg & incl incl
33	C	1	outer rim & recessed - lower & right middle rim - lower back	opening opening opening	incl? ?? incl
32	B	1 2	outer rim & recessed - lower, left middle recessed middle rim - top	opening opening opening	grn chg? grn chg? grn chg
32	C	1	outer rim, recessed, & edge - left	opening (slight)	grn chg
30★	A	1	outer recessed - lower r	opening (slight)	?? (incl)
30★	C	1	outer recessed - right back	opening opening	grn chg ??
29★	B	1	middle rim - lower outer rim & recessed - lower inner rim curve - lower	opening opening opening	incl incl ??

Table 2 con't.

C #	V	Type	Location of Feature	Crack Description	Stone Characteristic
29★	C	1	curve of rims - lower inner rim - lower left middle rim - lower left	opening opening opening	?? ?? ??
27	B	2	middle rim & recessed - right inner recessed - right	opening opening	grn chg grn chg
27	C	1	middle rim - lower, left outer rim - sides	indent indent	grn chg grn chg
23	B	1	outer recessed & rim - lower & sides	opening	grn chg
18	B	1	middle recessed outer rim & recessed	opening opening (indt?)	?? (grn chg) grn chg?
18	C	2	recessed (mid, in) inner rim	opening opening	incl? incl?
17★	C	1	inner rim - left outer recessed - lower	opening opening	grn chg grn chg
17★	D	1	outer rim, edge & recessed - left	opening	??
10★	C	1	middle recessed - lower	opening	??
			Intermediate Risk		
28	B	1	inner rim - lower right middle rim - lower r	opening indent (slight)	grn chg (incl) grn chg
28	C	1 2	outer rim - right middle rim - right inner rim - right center knob	indent indent indent indent	grn chg grn chg incl grn chg
26	B	2	middle rim - top outer rim - top	opening opening	incl incl
26	C	2 1	center knob middle rim	indent opening	grn chg incl? (grn chg)

Table 2 con't.

C #	V	Type	Location of Feature	Crack Description	Stone Characteristic
21	B	2	inner rim - top center knob	indent (open?) indent	grn chg grn chg
21	C	1 2	outer rim - left middle rim - top	indent indent	grn chg grn chg?
20	C	1	outer recessed - lower r middle rim	opening (slight) opening (slight)	?? ??
19	B	1	outer rim - lower outer recessed	opening opening (slight)	grn chg ?? (grn chg)
19	C	2 1	center knob middle rim - right	indent indent	grn chg grn chg
			Lower Risk		
41	B	2	middle rim - top	indent (open?)	incl
34	C	2	center knob middle rim - left outer rim - sides & edge	opening (slight) indent/open? indent/open?	incl incl incl
31	B	1	middle rim - lower	indent	grn chg

★ Volute is partially missing on this capital.

C # = Column Number
V = Volute Letter
incl = inclusion trace; grn chg = grain (texture) change; ?? = can't determine

Cracks cross the volutes along a horizontal plane. Two minor exceptions were found (29B, 29C) where a crack followed the curve of a rim on the volute; these are indicated with "curve" in the location description.

Table 3. Volutes with Minor Cracks

C #	V	Type	Location of Feature	Crack Description	Stone Characteristic
42	B	1	middle rim - right	indent (slight)	grn chg
41	A	2	outer rim - left, upper	indent	incl
41	C	2	middle rim - upper left outer rim - upper left	indent (slight) indent (slight)	?? ??
38	D	2	back	indent/opening	incl
36	B	2	knob	indent	grn chg
36	C	2	center knob	indent	grn chg
35	C	2	center knob outer rim - left	indent indent	grn chg grn chg?
33	D	2	middle recessed back	indent indent	incl incl
32	C	2	center knob	indent	grn chg
30★	B	2 1	rims: all - right outer rim - lower, right	indent (slight) indent	grn chg? grn chg
29★	A	1	outer rim - right back	indent indent	incl incl
27	B	1	outer rim, middle rim - left, lower	indent	grn chg
25	B	1	outer rim - lower	indent (slight)	grn chg
25	C	1	inner rim - lower outer rim - sides back	indent indent opening (slight)	grn chg grn chg incl
23	C	1	middle rim - lower	indent	grn chg
22	B	2 1	center knob middle rim outer rim - lower	indent indent opening (slight)	grn chg grn chg grn chg (incl)

Table 3 con't.

C #	V	Type	Location of Feature	Crack Description	Stone Characteristic
22	C	1	middle rim & edge - lower & right outer rim - lower	indent indent (slight)	incl (grn chg) grn chg
21	B	2 1	middle rim - top, right outer rim - right outer & middle rims	indent indent indent (slight)	grn chg grn chg grn chg?
20	B	1	outer rim - lower	indent (slight)	??

★ Volute is partially missing on this capital.
C # = Column Number
V = Volute Letter
incl = inclusion trace; grn chg = grain (texture) change; ?? = can't determine

Table 4. Volutes with Type 3 Flaws:

C #	V	Type	Location of Feature	Crack Description	Stone Characteristic
41	B	3	abacus corner	opening	incl
33	A	3	back, lower edge	piece missing	??
31	B	3	abacus corner	opening	incl
27	D	3	scroll between C & D egg & dart	piece missing pieces missing	?? ??
23	A	3	abacus corner	piece missing	??
23	D	3	egg & dart	pieces missing	??
22	A	3	abacus corner	piece missing	??
22	D	3	abacus corner	piece missing	??
21	A	3	abacus corner	piece missing	??
20	A	3	abacus corner	piece missing	??
19	D	3	egg & dart	pieces missing	??
17★	A	3	egg & dart	pieces missing	??

★ Volute is partially missing on this capital.
C # = Column Number
V = Volute Letter
incl = inclusion trace; grn chg = grain (texture) change; ?? = can't determine