Smithsonian American Art Museum

MARBLE OVERVIEW

WHAT IS MARBLE?

SOURCES OF MARBLE

- Metamorphic rock formed when limestone is exposed to extreme heat and pressure
  - Wikipedia "Metamorphic Rock": https://en.wikipedia.org/wiki/Metamorphic_rock
- Primarily composed of calcite crystals ($CaCO_3$). May also contain clays, micas, quartz, pyrite, ion oxides, or graphite.
  - Appearance and color vary with these minerals. The whitest marble forms from nearly pure limestone.
- Sourced from quarries. The stone's properties will vary based on the quarry.
  - Ex. Carrara marble: white or blue-grey marble quarried from Carrara Italy. This area has been mined since ancient Rome, and the highest quality marble was exhausted by the 20th century.

Michelangelo's unfinished *Awakening Slave*. Image: http://www.accademia.org/explore-museum/artworks/michelangelos-prisoners-slaves/

MATERIAL PROPERTIES

- Marble is…
  - Soft
  - Porous
  - Translucent
- These properties make marble well suited for art and architecture:
  - Easily carved
  - Takes polish and shine well
- *Consider:*
  - What about the microstructure of the rock make these features possible?
  - How does the geological formation of marble affect these properties?
  - How might these properties vary by quarry, or within an individual stone?

See more: Roberts, Caroline. 2011. "Stone" *American Institute of Conservation Wiki* http://www.conservation-wiki.com/wiki/Stone. Accessed July 2, 2020.

King, Hobart M. 2020. "Marble" *Geology News and Information*. https://geology.com/rocks/marble.shtml. Accessed July 2, 2020.

Doehne, Eric and Clifford A. Price. 2010. *Stone Conservation: An Overview of Current Research.* The Getty Conservation Institute, Los Angeles.

Created by Emily Brzezinski, July 2020. Updated 8/15 EB, 10/16 AO'C

DETERIORATION and CONDITION ISSUES

DETERIORATION

- Remember, stone deteriorates on a geologic time scale. Stone objects will erode with time and environmental factors, same as in nature.
- Marble is porous. Surface deterioration/damage may extend to the body of the stone, and vice versa.

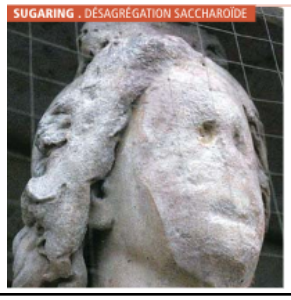
***See More**:* Torraca, Giorgio. 2008. "Part 3: Deterioration of Porous Building Materials" in *Lectures on Materials Science for Architectural Conservation.* The Getty Conservation Institute, Los Angeles.

CONDITION ISSUES

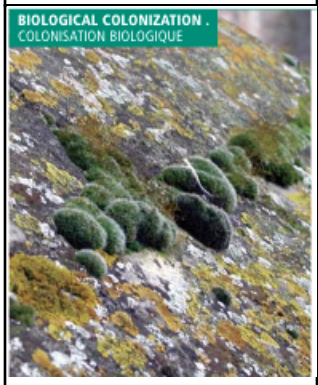
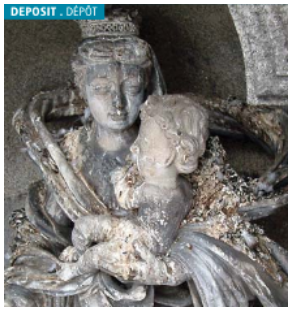
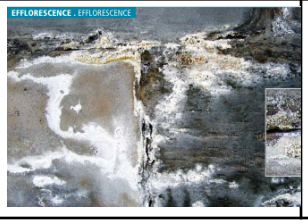
- The structure and material properties of marble predispose it to certain deterioration patterns. Therefore, there are some condition issues that are seen repeatedly in marble sculpture.
    - *Consider*: What properties of marble contribute to these issues? What about the object's intended use, or the environment it was kept in?
- The same terminology can be used in an examination or condition report.

Common Condition Issues in Stone:

This list is NOT exhaustive, and not all issues may be present. Check with supervisors and ICOMOS Illustrated Glossary for additional terms. All images are from the ICOMOS Glossary.

	**Cracking**: Individual fissure, clearly visible with the naked eye, resulting in separation of one part from another ● There are different names depending on the location, pattern, or how large the crack is ● Fissure, craquelure (shown left), fracture, split (ICOMOS Glossary page 16) ● When in doubt, describe what you see as specifically as possible
	**Sugaring**: Loosening of calcite crystal on surface of the marble. The surface is gritty and powdering, with same texture of white sugar. ● Emily's informal definition: Sugaring marble feels and looks like a sugar cube. The material is a solid mass, but grains will rub off the surface and the whole thing is crumbly. ● More common in weathered marbles, such as those displayed outdoors

	**Discoloration**: Change of the stone's color (ICOMOS Glossary page 46) ● May be surface, or extend into the substrate ● Overarching term that includes bleaching and staining ● Stone may be darker, lighter (bleaching), or any other color it was not originally (coloration, shown left)
	**Staining**: A type of discoloration with a defined or limited area ● Generally considered unattractive or aesthetically undesirable ● Often caused by material held against the marble (corroding metals, coatings, biological growth, pollution), and often involves water ● Staining is a type of discoloration, or staining can cause discoloration
	**Loss**: Empty space, obviously in place of some formally existing stone part. ● Common in protruding elements (noses, arms of sculpture) ● General term. Refers to larger missing elements (shown left on sculpture's nose) or small losses with a more specific term (for example, chips along a crack or break are also losses) ● Specify the size, extent, and location of the loss.
	**Impact Damage**: Mechanical damage due to the impact ● Marble might also exhibit cracking, losses, and other mechanical damage in the area ● Impact damages may be from handling, installation, or tools. On outdoor or architectural marbles, they might be from projectiles, bullets, or shrapnel.

	**Scratching:** Mechanically induced superficial, line-like loss of material. Caused by a pointed object ● May appear accidental or intentional ● If possible, describe the location and depth of scratch ● Tool marks from manufacture may appear as scratches, but would not be considered damage
	**Biological Colonization**: Colonization of the stone by plants or micro-organisms. ● Examples includes moss, fungi, bacteria, lichen, algae ● Larger animals living on stone (page 70) ● Common in outdoor marble ● Porous nature of marble means that the biological mass (spores, hyphae, roots, etc.) may extend into the stone ● Could cause staining and/or discoloration ● Could cause structural issues
	**Deposits**: Accumulation of material of variable thickness (page 50) ● Deposits are can be thick and widespread depending on the level of build up ● Examples include splatters of mortar, build up from soot or atmospheric pollutants, animal droppings, marine growth (such as algae), etc.
	**Efflorescence**: Generally white-ish, powdering, or whisker like crystals on the surface. Often from salt crystals. ● Caused by salts in the stone reacting with water, as liquid or the air ● The physical characterizes of the crystals depend on the salt composition ● Appear similar to deposits

In the future, consider adding:

Deteriorated coatings
Human interaction
Abrasion
Detachment
Accretion

…and anything else you come across while examining marble.

See more: International Committee for Stone (ICSC). 2008 "Illustrated glossary on stone deterioration patterns" International Council on Museums and Sites (ICOMOS), International Committee for Stone (ICSC). Edition V. Paris, France

EXAMINATION

1. **GUIDELINES**
   - Begin with the major structural conditions and work "outward" to surface condition issues.
     - For example, describe major structural cracking, then any staining, then a discolored coating.
   - Be specific about the location, stability, and extent of the condition issue.
   - When in doubt, describe what you see as specifically as possible.
   - It may be helpful to describe what you DO NOT see.
     - For example, for a well-preserved marble sculpture, a report reading "The object is in good condition, with no cracking or other structural damage present" is more helpful than only listing "good condition"

The following questions offer guidelines for an examination or condition report of a marble object. The examination questions and condition issues are NOT exhaustive.

2. **MATERIAL**
   - What is the overall appearance, grain, and color? Are there inclusions or veins?
   - How was the object created? Are there tool marks? Is it polished? Where?

3. **STRUCTURE / FABRICATION**
   - Is this object created from one piece of stone, or several? Where are the joins? How is it joined (pin, adhesive, lead putty, etc.)? What risks does this pose to handling that you should note for future?
     - **Important note for portrait busts: The join between the bust and the socle/base is especially important to check. This join is often weak and can fail if loose and improperly handled.
   - Do you see pointing marks? Is the object directly carved, or an enlargement/reduction/multiple? Depending on the time period, how can you tell? (Cool article on sculpture reproductions by SAAM sculpture curator Karen Lemmey: https://www.19thc-artworldwide.org/summer16/lemmey-on-from-skeleton-to-skin-the-making-of-the-greek-slave)
   - Any missing elements? Significant breaks, losses, structural instability?
   - Is there cracking? Where? Is there a pattern? Is the cracking stable?
   - Any other condition issues or deterioration? These may overlap with surface conditions (e.g. Flaking, pitting, sugaring)

4. **SURFACE**

- Any condition issues or deterioration? These may overlap with structural conditions. (e.g. Flaking, pitting, sugaring)
- Evidence of biological colonialization?
- Is it coated? With what? How can you tell, or how can you find out?
- Is there evidence of paint layers?
    - Check the recesses and hidden spaces – marbles were often painted

See more: Smithsonian Magazine https://www.smithsonianmag.com/arts-culture/true-colors-17888/
"Polychromy of Roman Marble Sculpture: https://www.metmuseum.org/toah/hd/prms/hd_prms.htm

- Any discoloration? Where is it in the marble structure?
- Staining? Ingrained dirt? Surface dust?
- What is the nature of the soiling? (greasy? Fluffy? Sooty?)

5. OTHER

- Is there evidence of past conservation treatment?
    - What, and where?
    - Are there repairs using another piece of marble? Is it a modern repair with plaster and paint? How is it attached – any metal pins? What does this tell you about the time period of the repair?
- Is there evidence of human interaction?
    - Especially graffiti, hand oils, etc.
- Is there a maker's mark, inscription, signature, or date? Where, and what does it look it?

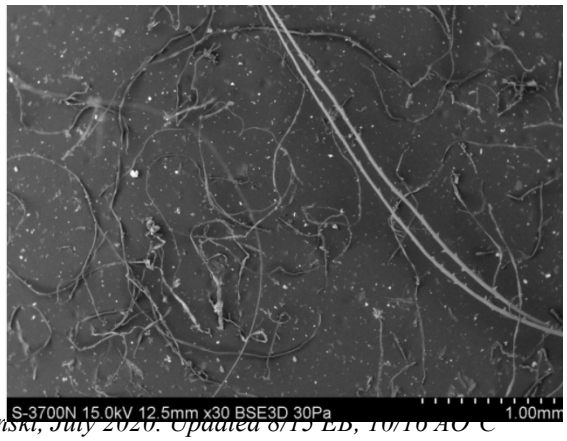
See more: International Committee for Stone (ICSC). 2008 "Illustrated glossary on stone deterioration patterns"

Leila Sabouni. 2018. Treatment Proposal for *Helen Louisa Phelps* (1856) by Chauncey Bradley Ives. Smithsonian American Art Museum.

OTHER STUFF YOU REALLY OUGHTA KNOW ABOUT

MARBLE AND SURFACE DIRT

- What *actually* is dirt?
    - Dirt is a mix of many, many materials. Museum dust is primarily human skill cells and hair brought in by visitors.
    - The composition of the dirt depends on the location and life the marble has led until this point.



- Dust is hydroscopic, so it attracts water, and proteinaceous, so it attracts insects or mold.
- Dirt/dust can become ingrained when it is repeatedly rubbed into a surface or remains on a surface for a long period of time, especially on a porous surface.

SEM image of museum dust, magnified 30 times
Image c/o British Museum "What lurks under the microscope?", link on the following page

See more: Portoni, Fabiana et al. 9 March 2020. The British Museum blog "What lurks under the microscope?" https://blog.britishmuseum.org/what-lurks-under-the-microscope-dust-detective-work/. Accessed August 11, 2020.

Gorence, Amanda. May 23, 2013. "Microscopic Photos of Dust Collected from the World's Best Art Museums" Feature Shoot. https://www.featureshoot.com/2013/05/microscopic-photos-of-dust-collected-from-the-worlds-best-art-museums/. Accessed August 11, 2020.

- Where did the dirt come from?
  - This can give you clues to the properties of the dirt, and how to approach cleaning it.
- How does the nature of the dirt affect the marble?
  - Where is it in the marble's structure? On the surface? Ingrained? Staining?
  - Is there anything in the dirt that will interact with the calcium in the marble, such as metal ions or oils?
- How does this affect your treatment choices?
  - How does the type of dirt change your method of removal?
  - Can removing one layer of dirt or dust affect the layers below? How?
    - Can it scratch? Smear?

Consider:
- How old is the sculpture?
- What locations has it been, and for how long?
  - Outside? Underwater? Could there be biological growth or sensitive, weathered surfaces?
  - Inside? Was the room heated with coal? Fire? Near a HVAC vent? Was it exhibited? For how long?
- Has the marble been near people? Will there be hand oils? Nicotine residues?
- What does the source tell you about the properties of the dirt?
- Would the dirt layer affect any paint layers? Coatings?

***Important Note: Cleaning is NOT REVERSIBLE
- What is lost if you remove the dirt?
- Could this dirt layer be historic or significant? Why? Why would you choose to clean it, or leave it in place?

- Does your approach change depending on the collection or provenance of the object (for example, would you treat an archeological marble differently that decorative arts? Why?)

See more: Melissa King. 2019. "The Dangers of Dust". https://www.youtube.com/watch?v=pFHnGWy_9oA. Accessed July 25, 2020.

Nancy Odegaard. February 11, 2016. Artificial Dust Preparation. *Ice Cold: Solid Carbon Dioxide Cleaning Session 2, Smithsonian American Art Museum* https://youtu.be/P4gOPpNgdWQ?t=689 Accessed October 16, 2020.

MARBLE AND PH

- What is pH?
  - pH scale: Scale from 1-14 used to specify the acidity or alkalinity of an aqueous solution (https://en.wikipedia.org/wiki/PH)

- How does pH affect marble?
  - How would an acidic solution affect marble? Why?
  - How would a basic solution affect marble? Why?
  - How would a neutral solution (water at pH 7) affect marble? What if the water is pH 6.8? 7.3, etc.?
  - Would the marble react differently if it was polished? Unpolished? Coated? Deteriorated? Why?

Activity Corner! The Tile Test (*originally by Terry Weisser, via Ariel O'Connor)*

1. Find a highly polished marble tile
2. Take a picture
3. Add rounded drops of water to the surface (label each)
   a. Tap water (measure the pH first!)
   b. DI water buffered to basic range via sodium citrate (pH 10ish, but try a few)
   c. DI water buffered to acidic range (pH 4ish, but try a few)
4. Allow to dwell until the end of the day, then wipe off the water.
5. Examine in normal and raking light and compare to your BT photo. What happened? Why?

*Add photo of tile test

- How does pH affect treatment choices?
  - Why might you choose a pH-adjusted or "buffered" water solution for marble cleaning?
    - How are you choosing to raise the pH? (sodium citrate? Ammonium citrate?) What are the working properties of your material? What ions are you introducing to the surface?

- Why might you add $CaCO_3$ to your aqueous cleaning solution? What could happen to the marble surface if you do not?

See more: Page 87- 95 of Torraca, Giorgio. 2008 "Part 3: Deterioration of Porous Building Materials" in *Lectures on Materials Science for Architectural Conservation.* The Getty Conservation Institute, Los Angeles.

COMMON CONSERVATION TREATMENTS

1. SURFACE CLEANING

- Dry cleaning:
  - Methods:
    - Vacuuming
    - Cosmetic sponges
    - Erasers
  - *Consider*:
    - What is the nature of the dirt are you cleaning? Where is it?
    - Will your method risk abrasions?
    - In what direction should you work? (For example, top to bottom? *See the "Approaching Cleaning" section, below)*
    - Is there biological colonization?
    - How far should you clean? When and where do you stop, or consider another method?

- Aqueous cleaning:
  - Cleaning Methods:
    - **Saliva**: Human saliva contains a wide variety of enzymes meant to break down food and are therefore can be effective at reducing organic soiling. Sometimes called "mild enzymatic cleaning solution."
      - **See more**: Roach, Mary. *Gulp: Adventures on the Alimentary Canal*, Chapter 6 "Spit Gets a Polish" p. 107-130.
    - **$CaCO_3$ saturated water**: Water with $CaCO_3$ dissolved in it, until the solution is super saturated. Adding $CaCO_3$ to the water prevents your solution from leaching calcium from the marble matrix. A solution is super saturated when some solute ($CaCO_3$, in this case) remains undissolved.
    - **pH – adjusted water/buffered water**: Water (pH neutral, DI, distilled, or tap. Test yours! It should be around 7.0 but may not be) made slightly basic or acidic. Adjusted water is used when neutral water might damage your marble or isn't effective. Matching the pH of the water to the material you are trying remove might make it more effective. *See Tile Test.*
    - **Chelators**: Binds with metal ions, such as copper or iron staining.

        - **Surfactants**: A mild detergent that removes hydrophobic material from a hydrophilic environment, therefore effective at removing oily or greasy material.
        - **Agar**: Gelatinous powder derived from algae that acts as a thickener for aqueous solutions. Can be added to cleaning solutions when you want to avoid drips.

    - Application Methods
        - **Agar**: Gelling or thickening your solution can keep solution on surface, give a longer dwell time, and avoid drips and the liquid solution pulling dirt into the stone.
        - **Swabs, Webril pads, and other traditional applicators**
        - **Silicon solvents**: Silicon-based solvents are extremely non-polar and can prevent water from penetrating into the porous marble. Areas can be pre-soaked with these solvents if water penetration is a risk.

    - *Consider:*
        Can aqueous cleaning drive any soiling further into the stone?
        Will it affect any staining? How?
        What is the nature of the dirt are you cleaning? Where did it come from?
        How can you target a specific type of soiling?
        What is the stone sensitive to? (See "Stuff to Be Aware of Before Treating Marble")

- Other Cleaning Methods
    - **Steam cleaning:** High pressure steam at a heated, controlled temperature, usually from a hand-held machine. Use caution with small cracks and sugary marble, as this can damage the loose stone.
    - **Laser cleaning**: A method of micro thermal ablation (Emily's informal definition: vaporizing very small stuff with heat and steam) that can target very thin surface deposits. There are several variations and specification of lasers used in conservation.

- RECIPES
    - CaCO3 -saturated, pH adjusted water/buffered water
        - 100 mL deionized water
        - Supersaturated with calcium carbonate ($CaC0_3$ added and stirred until some solid $CaC0_3$ still visible)
        - pH adjusted to 10 with ammonium hydroxide, dropwise

    - Surfactant- recipe needed!

See more: Chao, Raina. 2017. "Practical Evaluation and Application of Cleaning Techniques for Marble Sculpture" *Objects Specialty Group Postprints,* Volume Twenty-Four, 207–234.

2. STAIN REDUCTION

- Methods:
    - **Gels**: Aqueous and solvent solutions can be "gelled" with the addition of a gelling agent, such as agarose or xanthan gum. Gels control the level the solvent

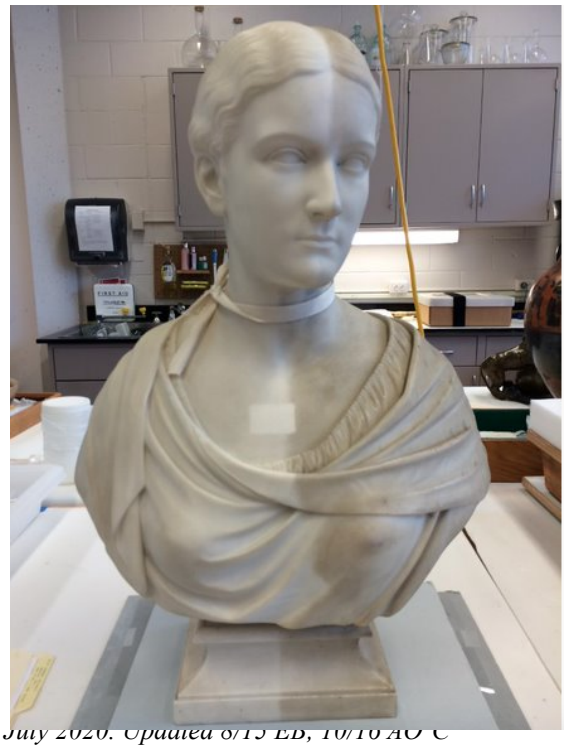
penetrates into the marble and holds the solvent on the surface for longer period of time. May or may not dry be allowed to dry on the surface.
        - **Poultices**: Application method, such as cotton, blotter, Webril pads, etc. Like gels, poultices hold the chosen solution to the surface longer and control penetration, solubilizing the stain. However, as they dry poultices "pull" the stain out of the material. May or may not be allowed to dry on the surface.
        - **Cotton swabs:** Application method, coupled with aqueous or solvent cleaning solution. May also use Webril cotton pads, cosmetic sponges, or other application technique.
        - **Solvents**: The specific solvent will depend on the properties and nature of the stain (ie what is the stain made of, how did it get there, how deep is it, and how do you dissolve it)
    - *Consider*:
        - What is the nature of the stain?
        - What method do you need to remove it, and why? (See "Aqueous cleaning")

- Recipes:
    - Xanthan gum gel with NTA chelator
        - 0.5% (weight/volume) nitrilotriacetic acid (NTA)
        - 0.5% (weight/volume) sodium borate
        - In deionized water. Adjusted to pH 9.5 with NaOH.
        - Gelled with 2% (w/v) Xanthan gum
    - Citric acid chelator
        - 1-3% (weight/volume) citric acid
        - In deionized water
        - Adjusted to pH 10 with NaOH

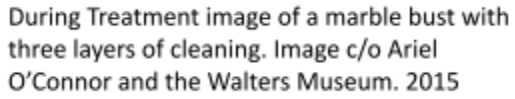
2.5 APPROACHING CLEANING

- Have a game plan before you start, DO NOT jump right in. Cleaning is easy to take for granted since we 'clean' things all the time, both professionally and privately.

- *Consider:*
    - How clean should the sculpture be? *(This decision is made by both the curator and conservator)*
    - How can you make your cleaning even?
    - What is the game plan? Where should you start cleaning? If using aqueous cleaning, how do you consider run off, and what direction should you work in?
    - What problems could be caused by leaving a clear line between cleaned/not cleaned areas (image on the right)
    - Are you risking leaving residues on the surface? Do you need to rinse any of your solutions away?
    - What is your plan if you cannot finish cleaning in a day? How will you avoid a line?



- What do you do if/when your cleaning system is no longer effective? Why?



During Treatment image of a marble bust with three layers of cleaning. Image c/o Ariel O'Connor and the Walters Museum. 2015

- Example Treatment:

Layer 1 – Powdery dust from open display. Removed via vacuum.
Layer 2 –Surface dirt overall. Reduced with cosmetic sponge, followed by saliva swabs.
Layer 3 – Heavy layer of greasy ingrained dirt, heavier on the upper surfaces, possibly from long-term exposure to coal smoke and nicotine. Reduced with surfactant solution.
Layer 4 – Iron staining from the metal rod attaching sculpture to plinth. Reduced with chelating gel.

**Important Notes:

- The sculpture MAY NOT clean evenly, different regions may respond differently to your cleaning.
- Consider the sculpture's "overall dirt level" while cleaning. If you clean one area very thoroughly first, you will either have to clean the entire surface to that level (which might not work) or end up with a bright spot, like the square on the chest of the image above. Instead, start with the "worst first", bring everything to the same level, and work with the whole surface in mind.

See more: Leila Sabouni. 2018-2019. Cleaning Notes on *Helen Louisa Phelps*. SAAM.

Ariel O'Connor. 2015. Treatment Report of Bust of Mrs. J. Edward Farnum (Eliza Leiper Smith, 1849-1912), by William Henry Rinehart. The Walters Art Museum.

3. STABILIZATION and STRUCTURAL REPAIRS

- Methods
  - Adhesive or pinned repairs to separated elements
  - Stabilization of cracks or delamination with adhesive
  - Consider if your repair is stronger or weaker than the original, and what that means during potential future damage
  - Adhesive recipe used by Carolyn Riccardelli for the Tullio Lombardo structural marble treatment at the Metropolitan Museum of Art
    - "3:1 blend" is a 40% solution and is made as follows:
    - Make one batch of each. Then, combine by volume 3 parts B-72 and 1 part B-48N:

40 g B-72	40 g B-48N
54 g Acetone	54 g Acetone
6 g Ethanol	6 g Ethanol

See more: Riccardelli, Carolyn et al. 2010. "An examination of pinning materials for marble sculpture". Objects Specialty Group Postprints, Volume Seventeen. Page 95-112.

4. **SURACE TREATMENTS**
    - Methods
        - Application of protective coating
        - Surface cleaning (see above)
        - Aesthetic fills
        - Inpainting

5. **PREVENTIVE MAITENANCE**
    - Methods:
        - Monitoring condition issues (such as crack propagation)
        - Regularly scheduled maintenance (dusting, washing, graffiti monitoring)
        - Environmental control (prevention of efflorescence and salts)

See more: Roberts, Caroline. 2011. "Stone" *American Institute of Conservation Wiki* http://www.conservation-wiki.com/wiki/Stone. Accessed July 2, 2020.

OneDrive sources on interventive treatments

Marble Resources – Drive Folder

**Recommended sources indicated with an asterisk*

GENERAL

*Doehne, Eric and Clifford A. Price. 2010. *Stone Conservation: An Overview of Current Research*. The Getty Conservation Institute, Los Angeles.

- Full book, good reference of general concepts of stone decay, characterization, and conservation. Contextualized conservation research and links to specific studies.

*International Committee for Stone (ICSC). 2008 "Illustrated glossary on stone deterioration patterns" International Council on Museums and Sites (ICOMOS), International Committee for Stone (ICSC). Edition V. Paris, France

*Torraca, Giorgio. 2008 "Part 3: Deterioration of Porous Building Materials" in *Lectures on Materials Science for Architectural Conservation.* The Getty Conservation Institute, Los Angeles.
[full text:
https://www.getty.edu/conservation/publications_resources/pdf_publications/pdf/torraca.pdf]

CLEANING

Berrett, Kory, Virginia Naude, and Richard Wolbers. 2007. "A New Method for Cleaning Marble". Objects Specialty Group Postprints, Volume Fourteen, 197-211

- Cleaning coated marble using Vanzan NF-C gelling agent and nitrilotriacetic acid (NTA) chelator, effective for staining caused by coatings, detergents, and soaps.

*Chao, Raina. 2017. "Practical Evaluation and Application of Cleaning Techniques for Marble Sculpture" Objects Specialty Group Postprints, Volume Twenty-Four, 207–234.

- Overview of published marble cleaning techniques and materials, with several case studies that look at use different cleaning protocols or have different cleaning goals. Gives recipes and references.

Die, L. et al. 1996. "Aging Effects of Ammonium Carbonate/Acetone Solutions and Cleaning of Works of Art" Studies in Conservation, Vol. 41, No. 1, pp. 9-18.

- Study that found that ammonium carbonate and acetone can leave residues, stain or discolor marble. Helpful to know, although the article is from 1996 and I haven't heard about this technique.

Goldber, Lisa A. 1989. "A Fresh Face for Samuel Gompers: Methyl Cellulose Poultice Cleaning" JAIC, Volume 28, Number 1, Article 2 (pp. 19 to 29).

- Case study of a methyl cellulose poultice cleaning. Authors adjusted the properties of the methyl cellulose with propylene glycol and fumed silica. The problem-solving discussion is helpful, but the materials and presentation may be out of date.

Toreno, Georgia, et al. 2018. “Biological colonization on stone monuments: A new low impact cleaning method” Journal of Cultural Heritage, Vol 30, page100–109.

- Examines DMSO for cleaning biological growth as alternative to biocides. Advocates that DMSO is more environmentally friendly and health conscious, although I have heard the opposite.

Tserevelakis, George J. et al. 2018 “On-line photoacoustic monitoring of laser cleaning on stone: Evaluation of cleaning effectiveness and detection of potential damage to the substrate” *JAIC* Vol 35, 108-115.

- Discussion of laser cleaning to remove graffiti from marble. Authors define degrees of laser cleaning, including surface ablation, effective cleaning, and damage to the substrate. Does not give much background on laser cleaning and how it works.

Wheeler, George. 2008. “Slow and Steady Does Not Always Win the Race: Intermittent Water Washing of Carbonate Stones in Sculpture, Monuments, and Buildings”. *AIC News* Vol 33, No 6. Page 1, 8-10.

- Discussion of removing gypsum from calcite objects via water washing. Authors compared intermittent washing with continuous cleaning, finding that the volume of water, not the frequency, controls the dissolution of gypsum.

Williams, Jane and Julie Lauffenburger. 1995. “Testing erasers used to clean marble surfaces.” Objects Specialty Group Postprints, Volume Three, page 118-124.

- Assesses if the mechanical action of electric erasers abrades or affects stone surfaces. Helpful discussions on the composition of erasers and issues of residue. Older article, but discussions are still relavent helpful.

COATINGS

*Kubick, Laura and Jennifer Giaccai. 2012. “A comparative study of protective coatings for marble sculpture”. Objects Specialty Group Postprints, Volume Nineteen. Page 45-69.

- Testing commonly used protective coatings (especially Renaissance and cosmoloid wax), looking at reversibility, efficacy, and aging. Focuses on interior display. Introduction gives helpful overview on coatings and current research (as of 2012).

STRUCTURAL REPAIR

Jorjani, Mersedeh, George Wheeler, Carolyn Riccardelli, Wole Soboyejo, and Nima Rahbar. “An Evaluation of Potential Adhesives for Marble Repair” [publication info not included]

- Overview and mechanical testing for various adhesives

Riccardelli, Carolyn et al. 2010. “An examination of pinning materials for marble sculpture”. Objects Specialty Group Postprints, Volume Seventeen. Page 95-112.