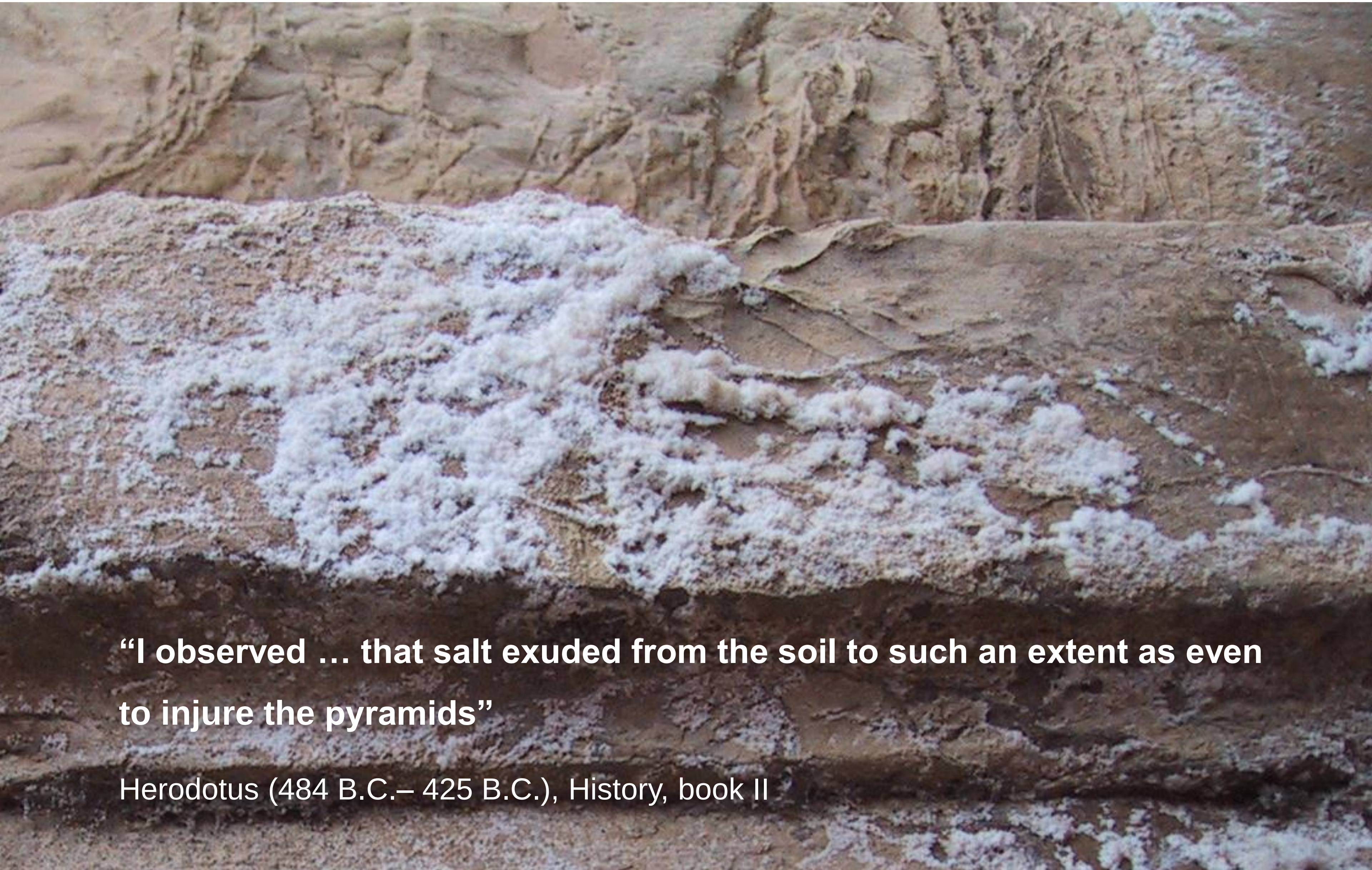
Salts as major decay agents

Teresa Diaz Gonçalves

Salts as major decay agents



“I observed … that salt exuded from the soil to such an extent as even to injure the pyramids”

Herodotus (484 B.C.– 425 B.C.), History, book II

Salts as major decay agents

Lecture contents

- Introduction

Salts as major decay agents

Lecture contents

- Introduction
- Salt decay pathology
    - Anomalies
    - Moisture
    - Soluble salts
    - Damage mechanisms
    - Influencing factors
    - Signs

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    - Signs
- Control and prevention
    - Working principles
    - Methods of control and prevention
    - Complementarity between methods
    - Possible approaches

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    - Signs
- Control and prevention
    - Working principles
    - Methods of control and prevention
        1) Mechanical removal of efflorescence
        2) Removal of contaminating materials
        3) Poultices
        4) Electrochemical removal of salts
        5) Microorganisms
        6) Crystallization modifiers
        7) Plasters and renders
        8) Environmental control
        9) Rising damp control
        10) Barium hydroxide method
    - Complementarity between methods
    - Possible approaches

Salts as major decay agents

Introduction

Salts as major decay agents

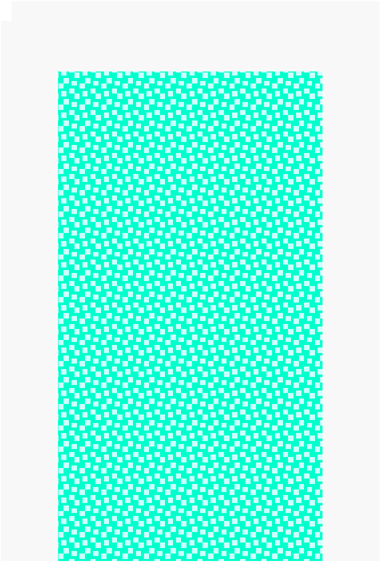
Introduction

water

Salts as major decay agents

Introduction

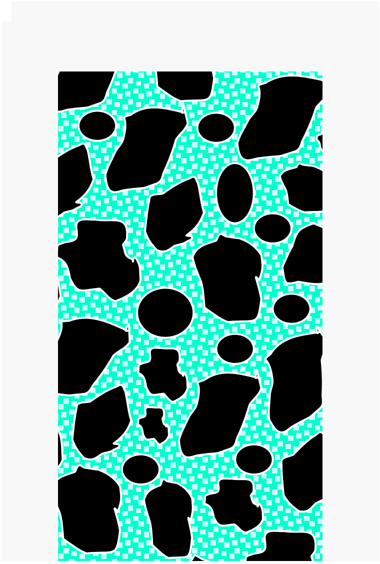
water + soluble salts



Salts as major decay agents

Introduction

water + soluble salts + porous material

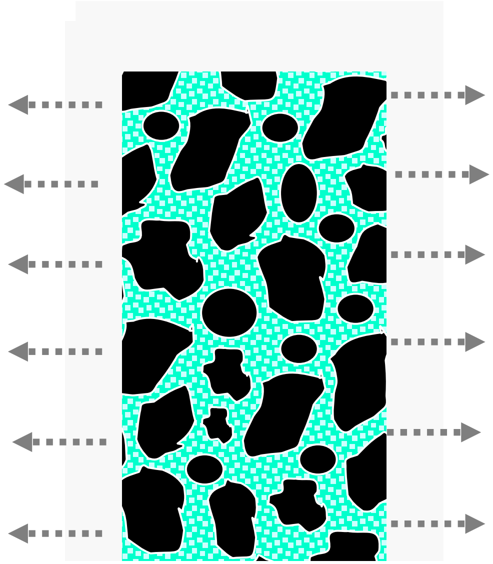


Salts as major decay agents

Introduction

water + soluble salts + porous material + environmental conditions

T / RH / air velocity



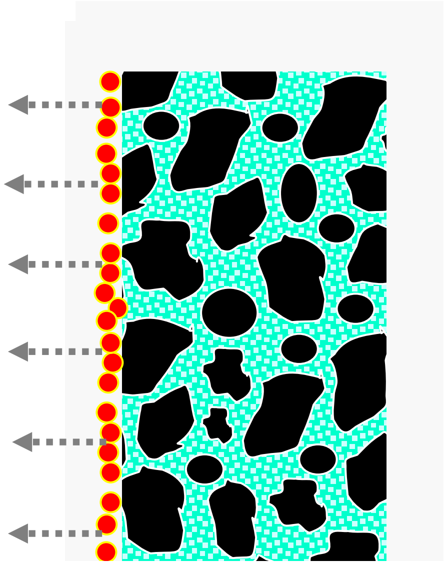
Salts as major decay agents

Introduction

water + soluble salts + porous material + environmental conditions

T / RH / air velocity

efflorescence

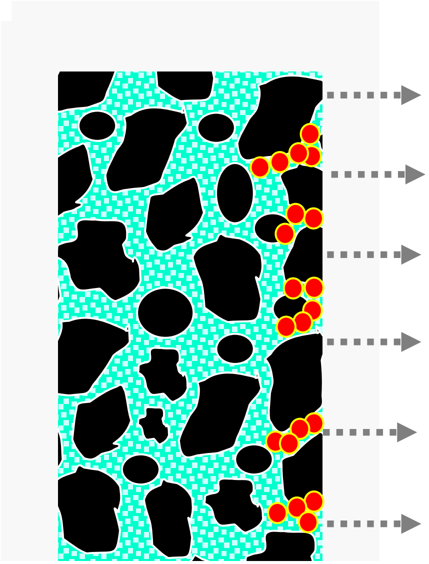


Salts as major decay agents

Introduction

water + soluble salts + porous material + environmental conditions

T / RH / air velocity



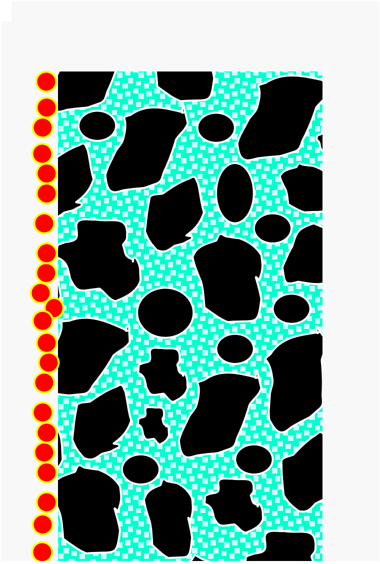
subflorescence

Salts as major decay agents

Introduction

water + soluble salts + porous material + environmental conditions

T / RH / air velocity



efflorescence

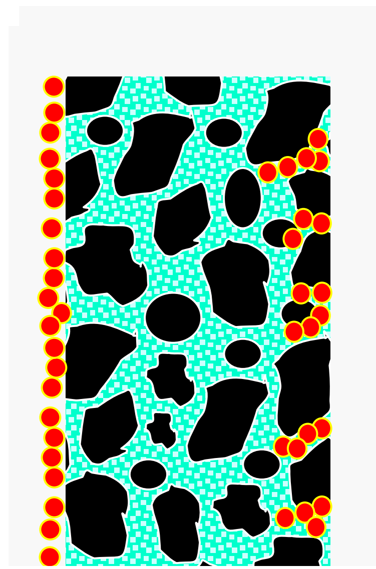
- aesthetic damage
- health problems
- high cost recurrent repairs

Salts as major decay agents

Introduction

water + soluble salts + porous material + environmental conditions

T / RH / air velocity



efflorescence

subflorescence

- aesthetic damage
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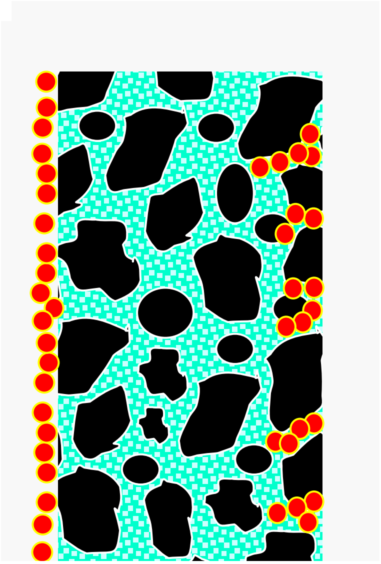
Salts as major decay agents

Introduction

water + soluble salts + porous material + environmental conditions

T / RH / air velocity



efflorescence

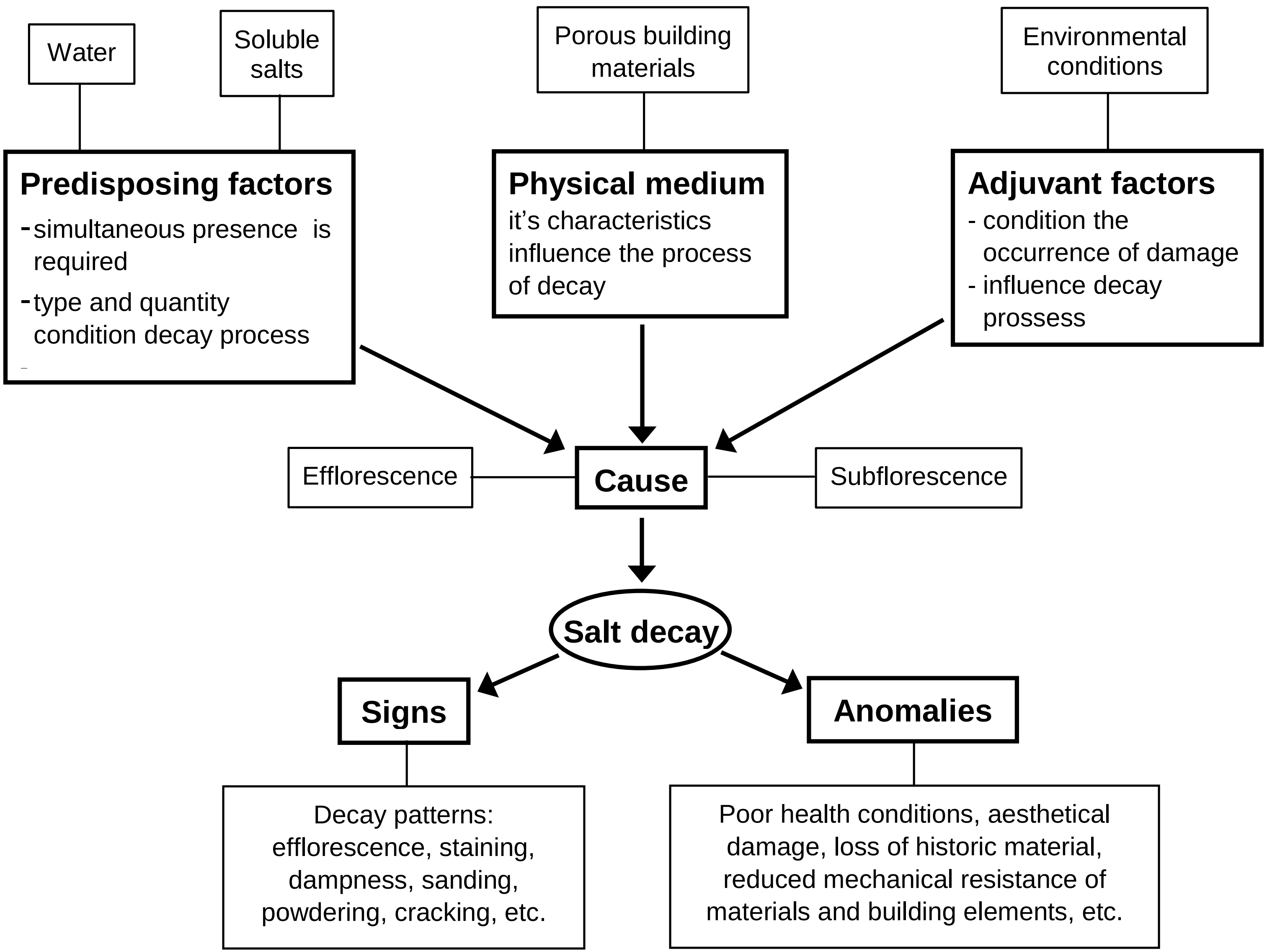
subflorescence

- aesthetic damage
- health problems
- high cost recurrent repairs

- loss of historic material
- structural damage

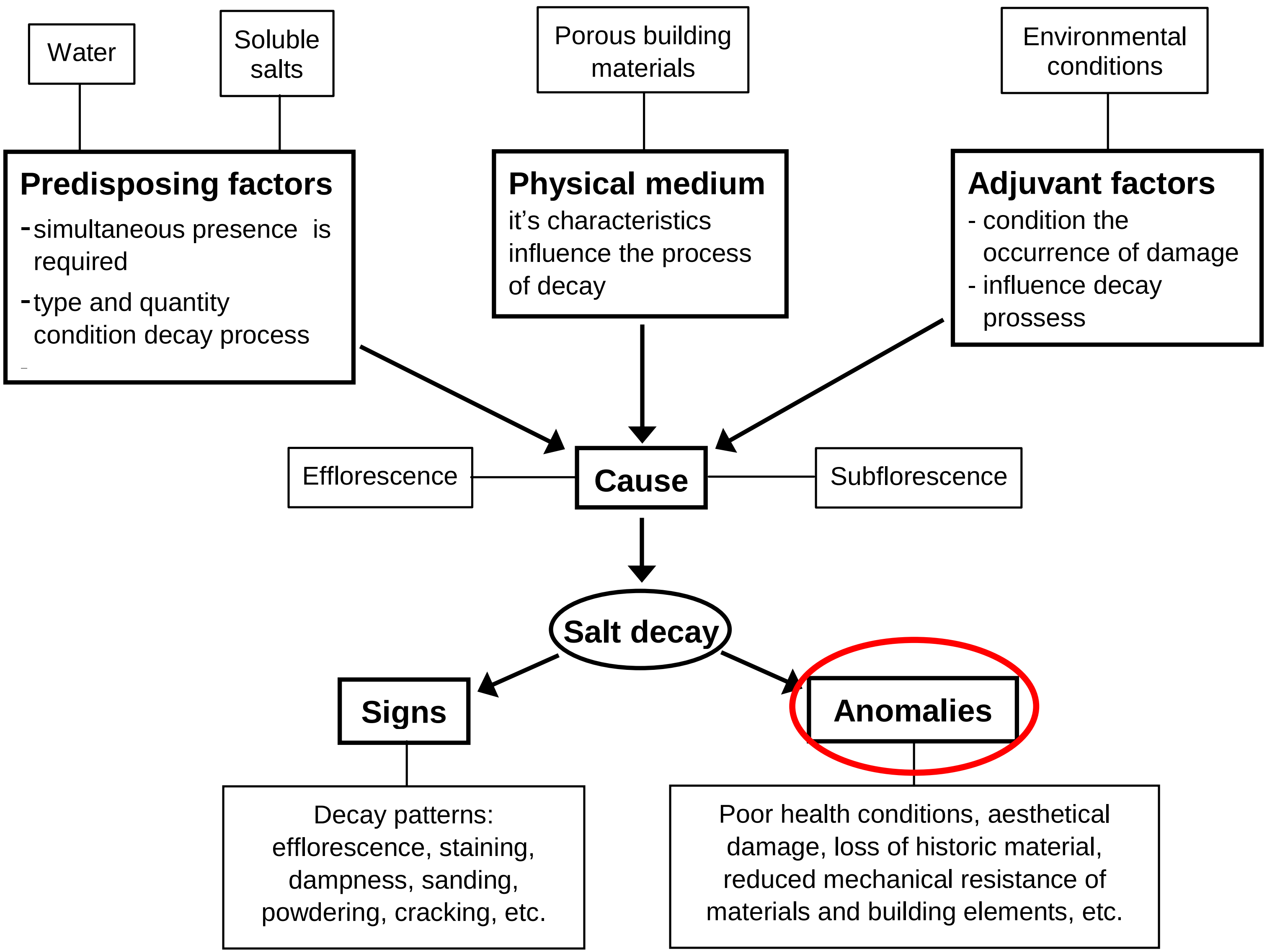
Salts as major decay agents

Salt decay pathology... can be summarized as follows:



Salts as major decay agents

Salt decay pathology



Salts as major decay agents

Salt decay pathology: anomalies

São João Baptista Church
Moura, Portugal – November 2002

- aesthetic damage
- health problems
- high cost recurrent repairs
- loss of historic material
- structural damage

Salts as major decay agents

Salt decay pathology: anomalies

Alcobaça Monastery,
Portugal – November 2002

- aesthetic damage
- health problems

Salts as major decay agents

Salt decay pathology: anomalies

Quinta do Rocio,
Torres Vedras, Portugal – April 2008

- aesthetic damage
- health problems
- high cost recurrent repairs

Salts as major decay agents

Salt decay pathology: anomalies

Santa Cruz Monastery
Coimbra, Portugal – June 2002

- aesthetic damage
- health problems
- high cost recurrent repairs
- loss of historic material

Salts as major decay agents

Salt decay pathology: anomalies

Paulistas tide-mill,
Corroios, Portugal – November 2004

- aesthetic damage
- health problems
- high cost recurrent repairs
- loss of historic material
- structural damage

Salts as major decay agents

Salt decay pathology: anomalies

Salt decay is especially relevant in old buildings:

Salts as major decay agents

Salt decay pathology: anomalies

Salt decay is especially relevant in old buildings:

- Salts and water – are more active
    - thick solid walls made of porous hydrophilic materials
    - walls built in direct contact with the ground
    - periods of constructive deterioration (roof damage, masonry cracking, etc.)

Salts as major decay agents

Salt decay pathology: anomalies

Salt decay is especially relevant in old buildings:

- Salts and water – are more active
  - thick solid walls made of porous hydrophilic materials;
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- Physical medium – mechanically weaker materials (lime mortars)

Salts as major decay agents

Salt decay pathology: anomalies

Salt decay is especially relevant in old buildings:

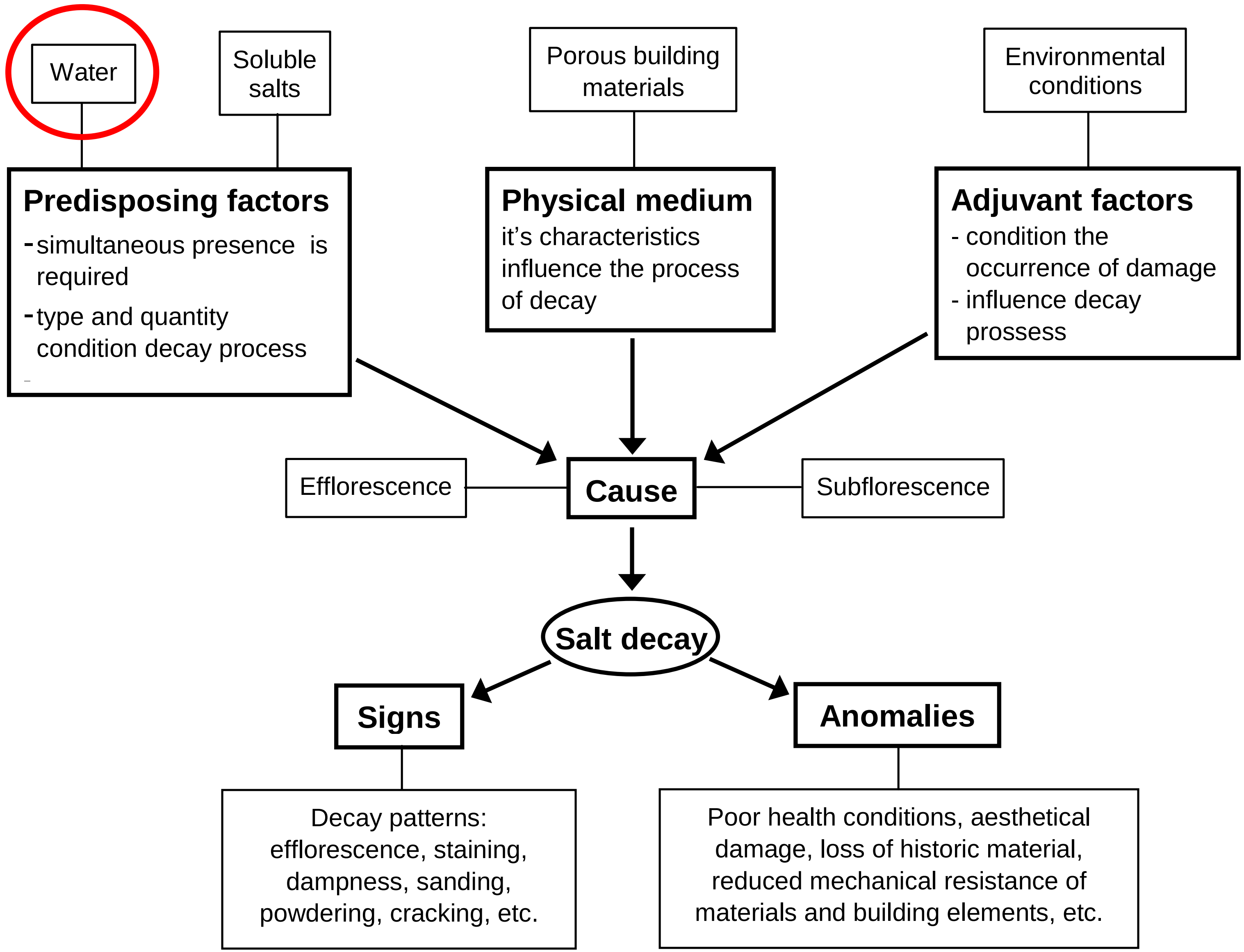
- Salts and water – are more active
  - thick solid walls made of porous hydrophilic materials;
  - walls built in direct contact with the ground
  - periods of constructive deterioration (roof damage, masonry cracking, etc.)

- Physical medium – mechanically weaker materials (lime mortars)

- Structural impact – walls with structural function
- Historic relevance – historic buildings should be preserved for future generations
- Artistic relevance – old buildings often include valuable sculptures, frescoes, etc.

Salts as major decay agents

Salt decay pathology



Salts as major decay agents

Salt decay pathology: moisture

Salts as major decay agents

Salt decay pathology: moisture

> Construction humidity

mixing of mortars, setting of bricks, materials exposed to rain, specific processes (water-jet cleaning)

Salts as major decay agents

Salt decay pathology: moisture

- Construction humidity
- Rising damp
    - ground moisture that rises up in the walls by capillarity
    - phreatic water or rain water in the soil surface layers

Salts as major decay agents

Salt decay pathology: moisture

- Construction humidity
- Rising damp
- Dew point condensation

  humid air => temperature drops => RH increases

  if the absolute saturation humidity is attained => condensation

  - on cold surfaces
  - inside materials subjected to a temperature gradient because the absolute saturation humidity varies with temperature

Salts as major decay agents

Salt decay pathology: moisture

- Construction humidity
- Rising damp
- Dew point condensation
- Hygroscopic moisture

  attracted from the air

  by common building materials (such as mortars, brick or stone) or soluble salts

  soluble salts are much more hygroscopic => salt damp

Salts as major decay agents

Salt decay pathology: moisture

> Construction humidity

> Rising damp

> Dew point condensation

> Hygroscopic moisture

> Penetration of rainwater

through cracks, construction joints, damaged roofs, etc.

Salts as major decay agents

Salt decay pathology: moisture

- Construction humidity
- Rising damp
- Dew point condensation
- Hygroscopic moisture
- Penetration of rainwater
- Moisture from accidental causes

  leaking of pipes, fouling of gutters, etc.

Salts as major decay agents

Salt decay pathology: moisture

- Construction humidity
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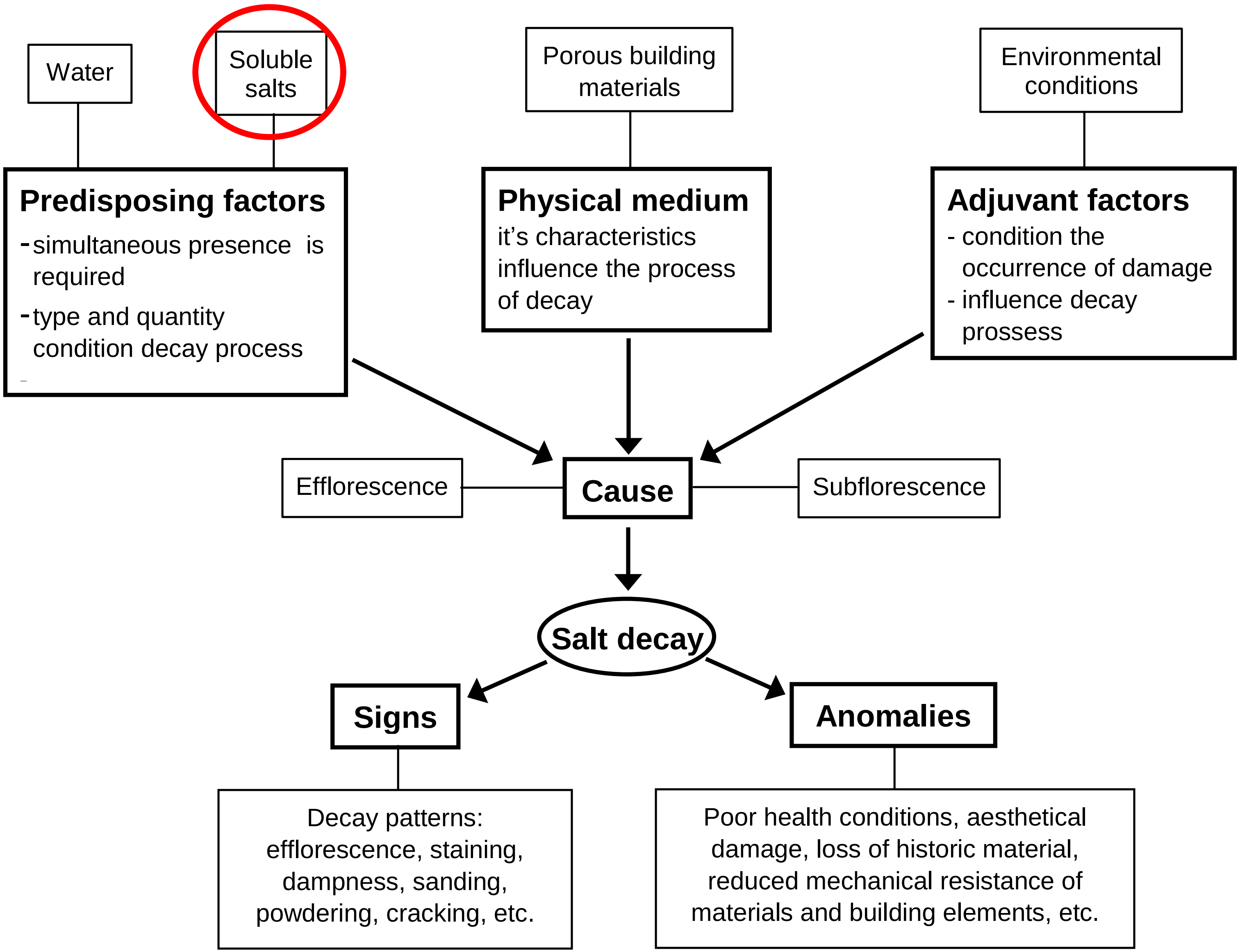
Salts as major decay agents

Salt decay pathology



Salts as major decay agents

Salt decay pathology: salts

Salts as major decay agents

Salt decay pathology: salts

- The type of salt is the best indicator of its origin

Salts as major decay agents

Salt decay pathology: salts

> The type of salt is the best indicator of its origin

Sodium chloride (NaCl)

- direct contact with seawater (marine fog, seawater spray or groundwater)
- salty goods once stored in the building or even
- from groundwater with domestic residues <= human consumption of sodium chloride

Salts as major decay agents

Salt decay pathology: salts

> The type of salt is the best indicator of its origin

Sodium chloride (NaCl)

Nitrates (NO_3)

decomposition of organic materials

- soils treated with organic fertilizers
- animal excrements and tissues
- microbiological activity

Salts as major decay agents

Salt decay pathology: salts

> The type of salt is the best indicator of its origin

Sodium chloride (NaCl)

Nitrates (NO_3)

Carbonates (CO_3) - alkali (sodium, potassium, magnesium) => soluble

- from high alkali content materials (ex: cement mortars)

- alkali hydroxides + carbonic acid (dissolution of CO2 in water) = alkali carbonates.

Salts as major decay agents

Salt decay pathology: salts

> The type of salt is the best indicator of its origin

Sodium chloride (NaCl)

Nitrates (NO_3)

Carbonates (CO_3)

Sulphates (SO_4)

- ceramic materials
- alkali hydroxides (or alkali carbonates) + sulphuric acid (air pollution) = sulphates
- gypsum (calcium sulphate dihydrate - $CaSO_4 \cdot 2H_2O$)
    - plasters
    - sulphuric anhydride (SO_3 in polluted air) + calcium carbonate ($CaCO_3$) of calcareous stones or lime mortars = calcium sulphate / gypsum

Salts as major decay agents

Salt decay pathology: salts

- The type of salt is the best indicator of its origin
- Solubility

Salts as major decay agents

Salt decay pathology: salts

> The type of salt is the best indicator of its origin

> Solubility … at a certain temperature

- ability of a salt to dissolve (in water)
- quantitatively = maximum amount of salt that can be dissolved at certain temperature
- maximum => saturated solution
- evaporation => concentr increases => max solubility => excess salt crystallizes
- can vary with temp => temp drops => max solubility => excess salt crystallizes

  NaCl – no ; Na_2SO_4 – yes

- supersaturation:

  non-equilibrium state

  can attain salt concentration higher than the maximum solubility

  NaCl – no ; Na_2SO_4 – yes

Salts as major decay agents

Salt decay pathology: salts

- The type of salt is the best indicator of its origin
- Solubility … at a certain temperature
- Relative equilibrium humidity (RHeq) … at a certain temperature

Crystal at RH < RHeq => solid crystal is in equilibrium with the air

Crystal at RH = RHeq => the salt dissolves => saturated solution

Crystal at RH > RHeq => the salt dissolves => dilute solution

the higher the RH, the lower the concentration of the solution

RH = 100% => solution infinitely dilute

Solution at RH < RHeq => the salt crystallizes (all of it)

Salts as major decay agents

Salt decay pathology: salts

> The type of salt is the best indicator of its origin

> Solubility … at a certain temperature

> Relative equilibrium humidity (RHeq) … at a certain temperature

> Phases

- some salts can crystallize as different hydrates (depending on the T and RH)

Salts as major decay agents

Salt decay pathology: salts

> The type of salt is the best indicator of its origin

> Solubility … at a certain temperature

> Relative equilibrium humidity (RHeq) … at a certain temperature

> Phases

- some salts can crystallize as different hydrates (depending on the T and RH)

Ex: for sodium sulfate, at 20º

thenardite (Na_2SO_4) is the stable phase below 77% RH

mirabilite ($Na_2SO_4.10H_2O$) is stable between 77% and 95.6% HR

Salts as major decay agents

Salt decay pathology: salts

> The type of salt is the best indicator of its origin
> Solubility … at a certain temperature
> Relative equilibrium humidity (RHeq) … at a certain temperature
> Phases
> Habits = shape of the crystals

Salts as major decay agents

Salt decay pathology: salts

- The type of salt is the best indicator of its origin
- Solubility … at a certain temperature
- Relative equilibrium humidity (RHeq) … at a certain temperature
- Phases
- Habits = shape of the crystals

depends on: internal crystal structure, environmental conditions, porosity and moisture content of the substrate, solution supply rate, etc.

sodium sulphate

powdery efflorescence

fluffy / hair-like efflorescence

Salts as major decay agents

Salt decay pathology: salts

- The type of salt is the best indicator of its origin
- Solubility … at a certain temperature
- Relative equilibrium humidity (RHeq) … at a certain temperature
- Phases
- Habits = shape of the crystals
- Distribution

  the distribution of salt across the material …

  .

Salts as major decay agents

Salt decay pathology: salts

- The type of salt is the best indicator of its origin
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- Phases
- Habits = shape of the crystals
- Distribution

the distribution of salt across the material depends on any factor that affects the ratio liquid flow / evaporation flow

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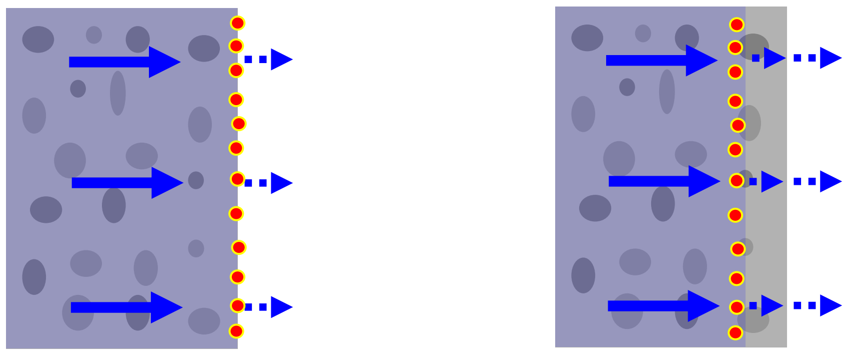

Stage I

Stage II

Salts as major decay agents

Salt decay pathology: salts

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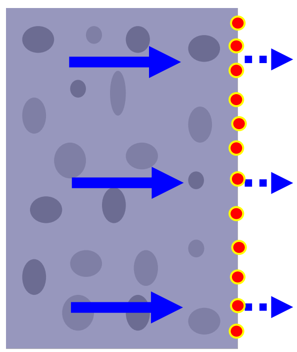
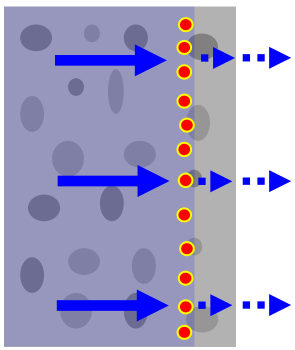


Stage I

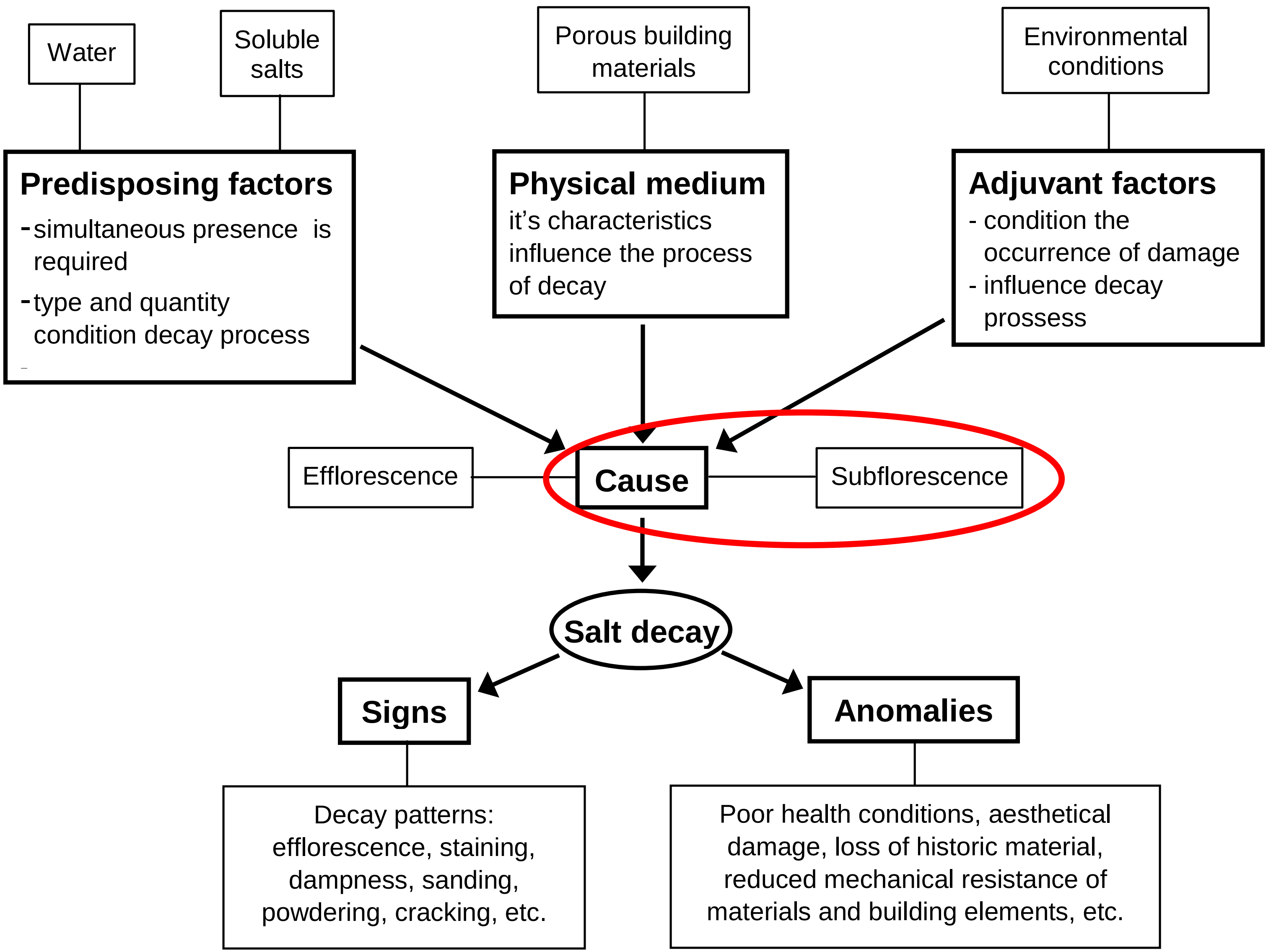


Stage II

Note: stage I conditions are as common as the occurrence of efflorescence (base of the walls, etc.)

Salts as major decay agents

Salt decay pathology



Salts as major decay agents

Salt decay pathology: damage mechanisms

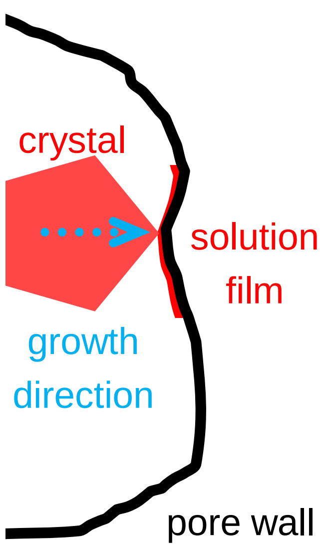
- Linear crystallization pressure
- Hydration pressure
- Hydrostatic pressure
- Shear stress
- Differential thermal dilation
- Hydric dilation

Salts as major decay agents

Salt decay pathology: damage mechanisms

> Linear crystallization pressure

- linear growth of the crystals against the pore wall
- the salt doesn't fill the pore
- repulsion crystal / material => solution film between the crystal and the pore wall



<u>Corren's (1949):</u>

$$\Delta p = p_{cr} - p_l = \frac{R\,T}{V_c} \ln\left(\frac{c}{c_s}\right)$$

Δp (MPa) is the crystallization pressure
p_{cr} (MPa) the pressure on the loaded face of the crystal
p_l (MPa) the ambient pressure
T (K) the absolute temperature
V_c (cm^3. mol^{-1}) the molar volume of the solid crystal,
R (8.3145 $MPa.cm^3.mol^{-1}.K^{-1}$) the ideal gas constant
c_s the solute concentration in a saturated solution
c the solute concentration in the supersaturated solution

Salts as major decay agents

Salt decay pathology: damage mechanisms

> Linear crystallization pressure

> Destructiveness

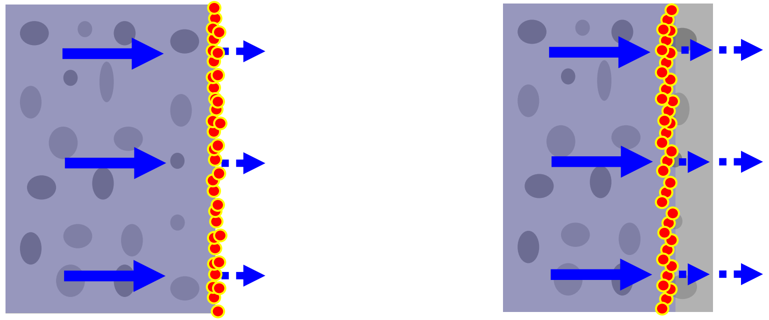
crystallization pressure + mechanical resistance + salt distribution

Salts as major decay agents

Salt decay pathology: damage mechanisms

- Linear crystallization pressure
- Destructiveness

crystallization pressure + mechanical resistance + salt distribution



Stage I   Stage II

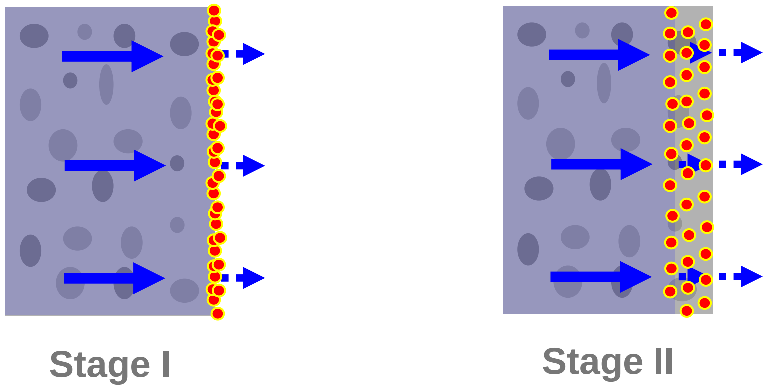
the distribution of salt across the material depends on any factor
that affects the ratio liquid flow / evaporation flow

Salts as major decay agents

Salt decay pathology: damage mechanisms

- Linear crystallization pressure
- Destructiveness

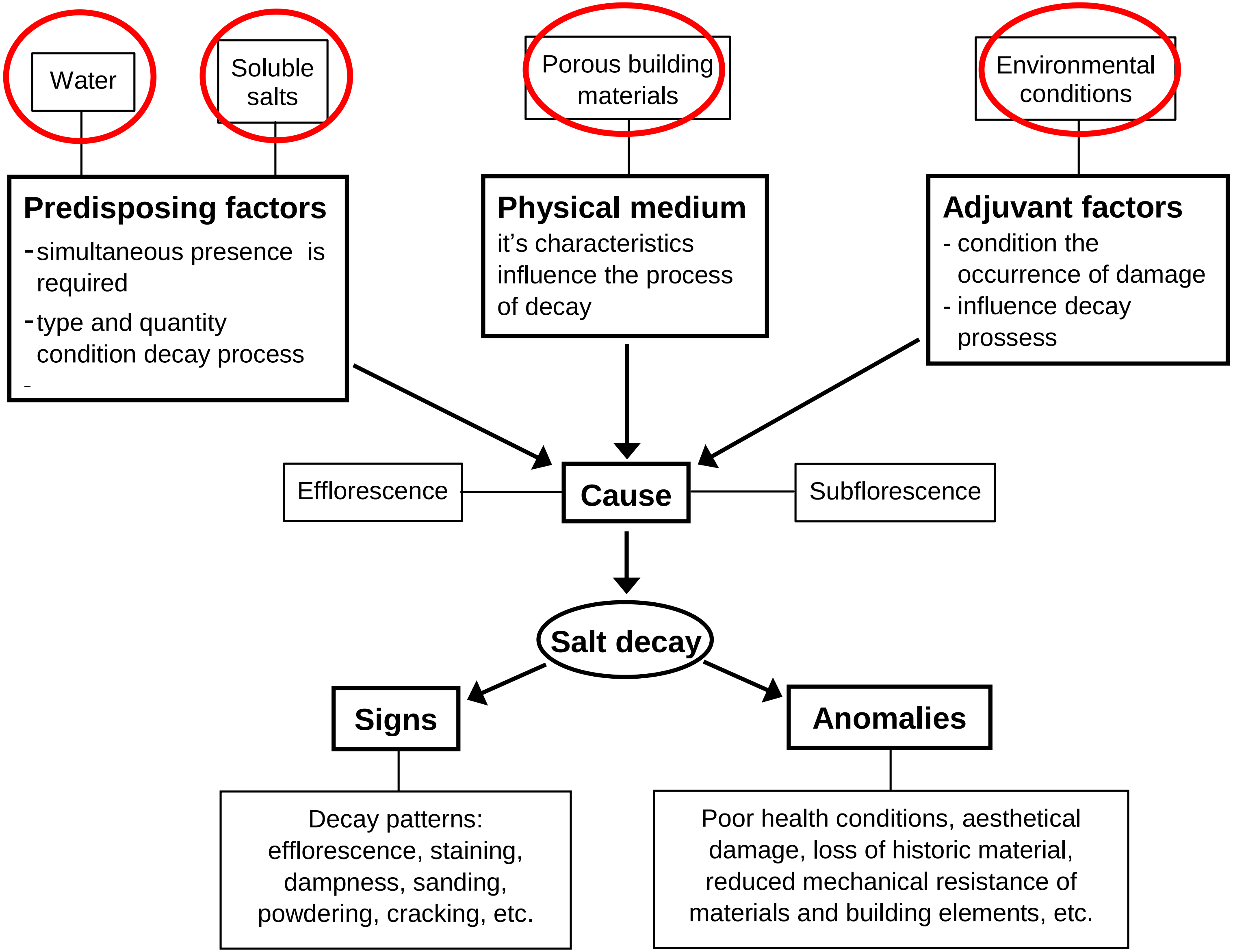
crystallization pressure + mechanical resistance + salt distribution



the distribution of salt across the material depends on any factor that affects the ratio liquid flow / evaporation flow

Salts as major decay agents

Salt decay pathology: influencing factors



Salts as major decay agents

Salt decay pathology: influencing factors

Complex group of interrelated factors …

> Environmental conditions

air T and RH, solar radiation, air velocity

- evaporation rate:
  - subflorescence instead of efflorescence
  - higher supersaturation => higher crystallization pressure
  - different habits: (Chatterji 2005) => more damaging needle-like crystals

faster evaporation

- crystal phases with higher crystallization pressure

Na_2SO_4 above 32.4ºC => thenardite

Salts as major decay agents

Salt decay pathology: influencing factors

Complex group of interrelated factors …

> Environmental conditions

> Porous material

- porosity, porometry, mechanical resistance
    - Influence the liquid flow + the evaporation flow
    - crystallization pressure
    - susceptibility of the material
- other (constructive factors)
    - paint layer
    - surface treatments
    - cracking
    - Etc.

Salts as major decay agents

Salt decay pathology: influencing factors

Complex group of interrelated factors …

- > Environmental conditions
- > Porous material
- > Salt solution
    - type and concentration of salt
        - crystallization pressure
        - temperature-dependent solubility => temperature-induced crystallization
        - distinct phases => crystallization when water contacts pre-existing crystals
        - viscosity, surface tension, contact angle => kinetics of liquid flow
        - vapour pressure => evaporation flow
        - etc.

Salts as major decay agents

Salt decay pathology: influencing factors

Complex group of interrelated factors …

> Environmental conditions

> Porous material

> Salt solution

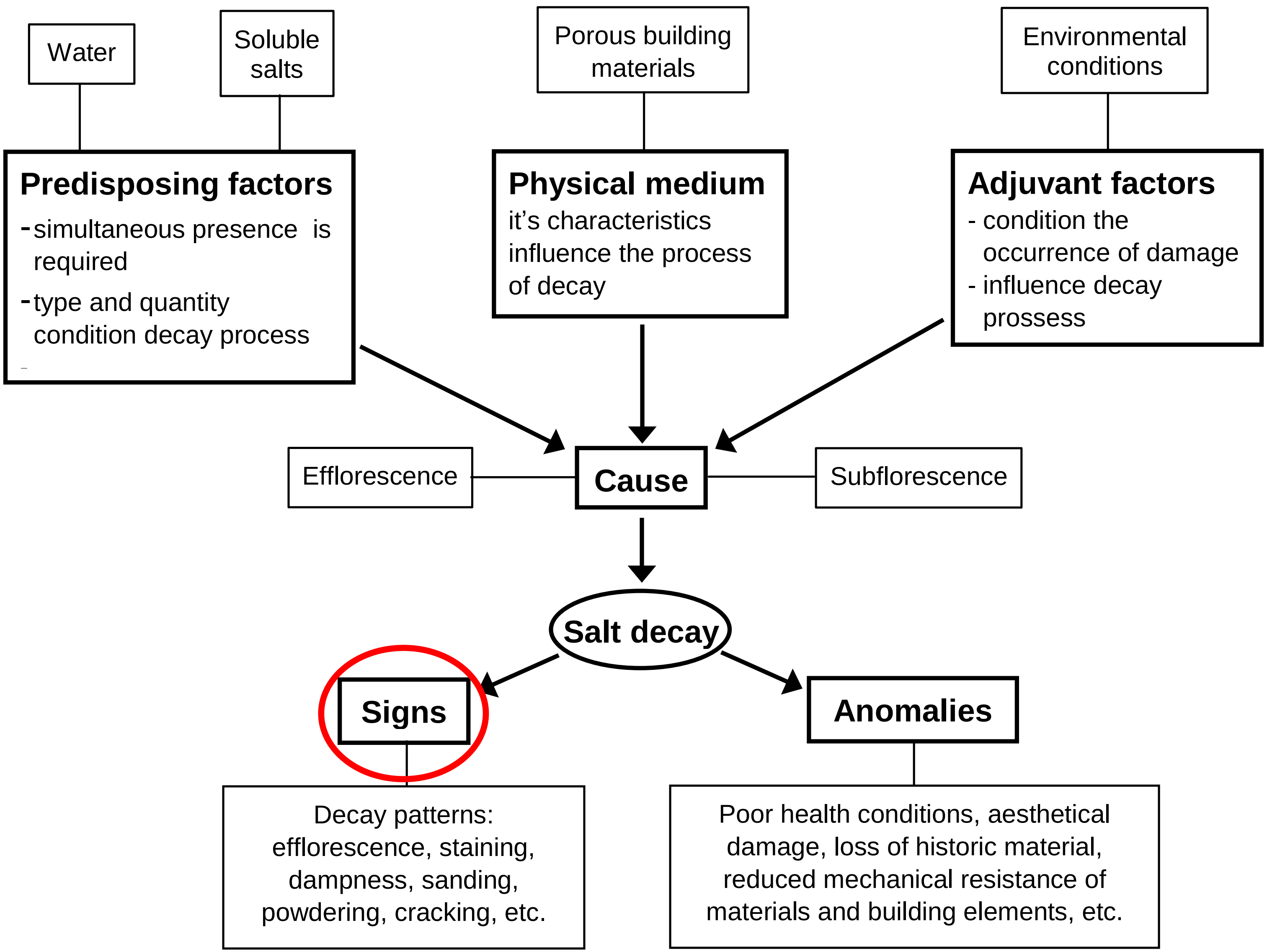
> Moisture

- moisture content; moisture supply rate

  - liquid flow
  - habit of the crystals

Salts as major decay agents

Salt decay pathology



Salts as major decay agents

Salt decay pathology: signs

Peeling of an ordinary vynil emulsion paint

> Material damage

- peeling of paints

Salts as major decay agents

Scaling of the lime-wash/ lime render system

> Material damage

- peeling of paints
- scaling

Salts as major decay agents

Salt decay pathology: signs

Delamination (layering of material with laminated structure)

- Material damage
  - peeling of paints
  - scaling
  - delamination

Salts as major decay agents

Salt decay pathology: signs

Sanding of mortars

> Material damage

- peeling of paints
- scaling
- delamination
- sanding of mortars

Salts as major decay agents

Salt decay pathology: signs

Powdering of ceramic bricks

> Material damage

- peeling of paints
- scaling
- delamination
- sanding of mortars
- powdering of ceramic bricks

Salts as major decay agents

Salt decay pathology: signs

Erosion

> Material damage

- peeling of paints
- scaling
- delamination
- sanding of mortars
- powdering of ceramic bricks
- erosion, etc.

Salts as major decay agents

Salt decay pathology: signs

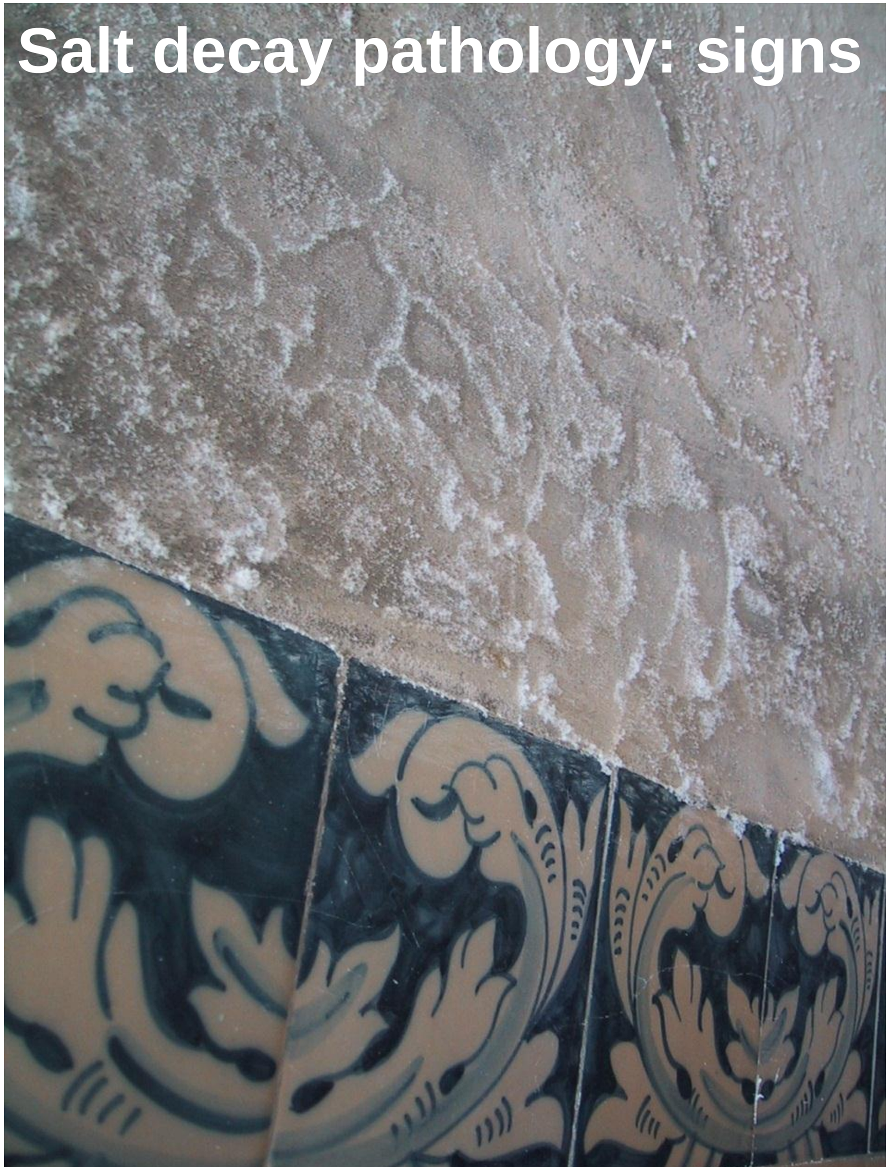
Salt damp

> Material damage
- peeling of paints
- scaling
- delamination
- sanding of mortars
- powdering of ceramic bricks
- erosion, etc.

> Salt damp

Salts as major decay agents

Salt decay pathology: signs



Efflorescence

> Material damage

- peeling of paints
- scaling
- delamination
- sanding of mortars
- powdering of ceramic bricks
- erosion, etc.

> Salt damp

> Aesthetical / health -related alterations

- efflorescence

Salts as major decay agents

Salt decay pathology: signs

Salt damp and staining

> Material damage
  - peeling of paints
  - scaling
  - delamination
  - sanding of mortars
  - powdering of ceramic bricks
  - erosion, etc.

> Salt damp

> Aesthetical / health -related alterations
  - efflorescence
  - staining, etc.

Salts as major decay agents

Salt decay pathology: signs

> Material damage

- peeling of paints
- scaling
- delamination
- sanding of mortars
- powdering of ceramic bricks
- erosion, etc.

> Salt damp

> Aesthetical / health -related alterations

- efflorescence
- staining, etc.

- *material damage*
- *salt damp*

Salts as major decay agents

Control and prevention

Salts as major decay agents

Control and prevention

- natural weathering

Salts as major decay agents

Control and prevention

- natural weathering
  - slow

Salts as major decay agents

Control and prevention

- natural weathering
  - slow
  - functionally coherent

Salts as major decay agents

Control and prevention

- natural weathering
  - slow
  - functionally coherent

- pathological decay
  - fast

Salts as major decay agents

Control and prevention

- natural weathering
  - slow
  - functionally coherent
- pathological decay
  - fast
  - functionally disruptive

Salts as major decay agents

Control and prevention

- natural weathering
  - slow
  - functionally coherent

- pathological decay
  - fast
  - functionally disruptive
  - inadequate solutions

Salts as major decay agents

Control and prevention

- natural weathering
  - slow
  - functionally coherent
  - maintenance
- pathological decay
  - fast
  - functionally disruptive
  - inadequate solutions
  - control intervention

Salts as major decay agents

Control and prevention

- natural weathering
  - slow
  - functionally coherent
  - maintenance

    ↓

    prevention

    ↓
- pathological decay
  - fast
  - functionally disruptive
  - inadequate solutions
  - control intervention

Salts as major decay agents

Control and prevention

- natural weathering
  - slow
  - functionally coherent
  - maintenance

    ↓

    prevention

    ↓

- pathological decay
  - fast
  - functionally disruptive
  - inadequate solutions
  - control intervention

The frontiers between the two types of decay have changed / are changing:

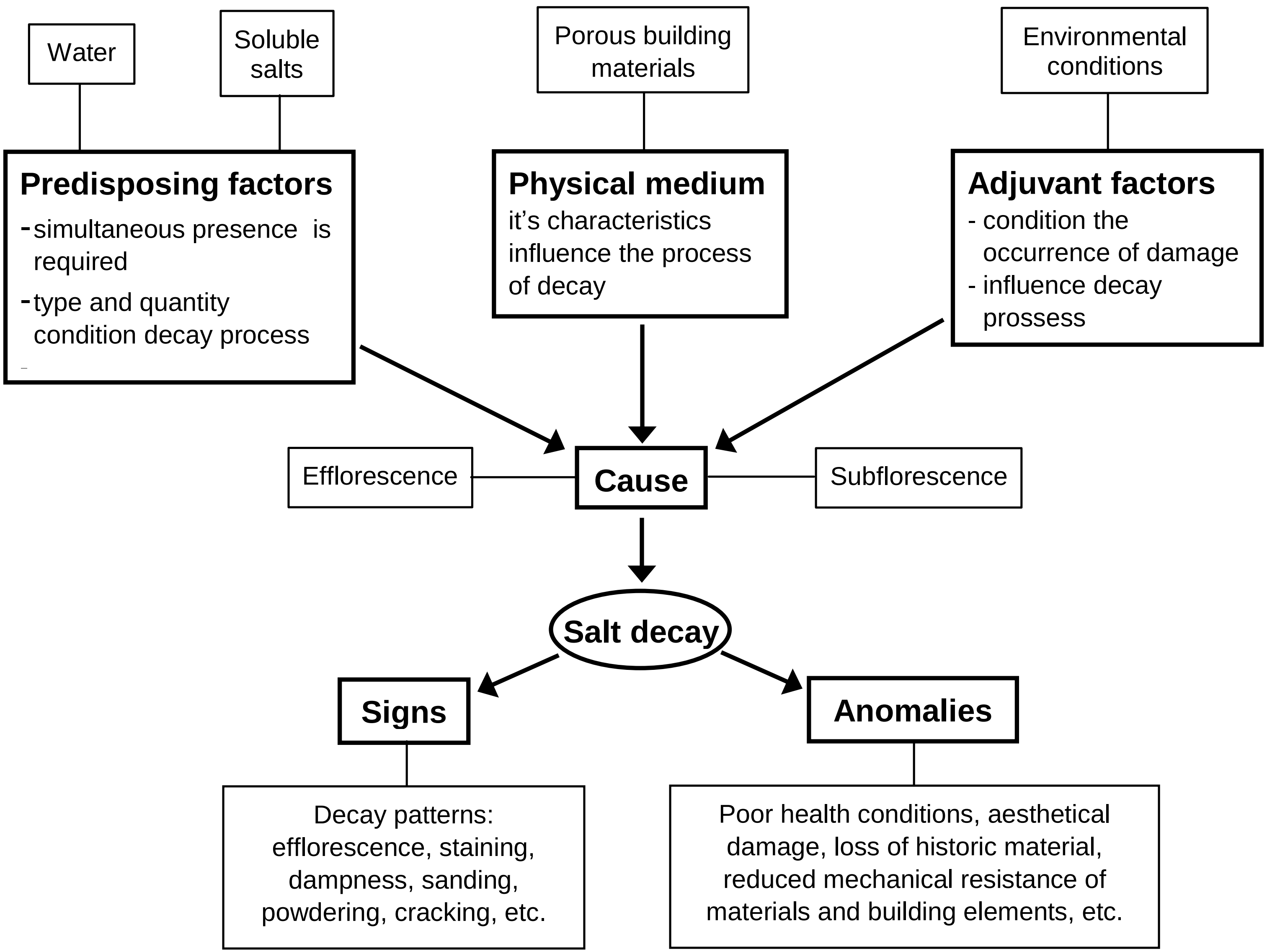
- Modern materials
- More demanding requirements
  - higher living standards
- Higher labour costs

Salts as major decay agents

Control and prevention: working principles of control methods

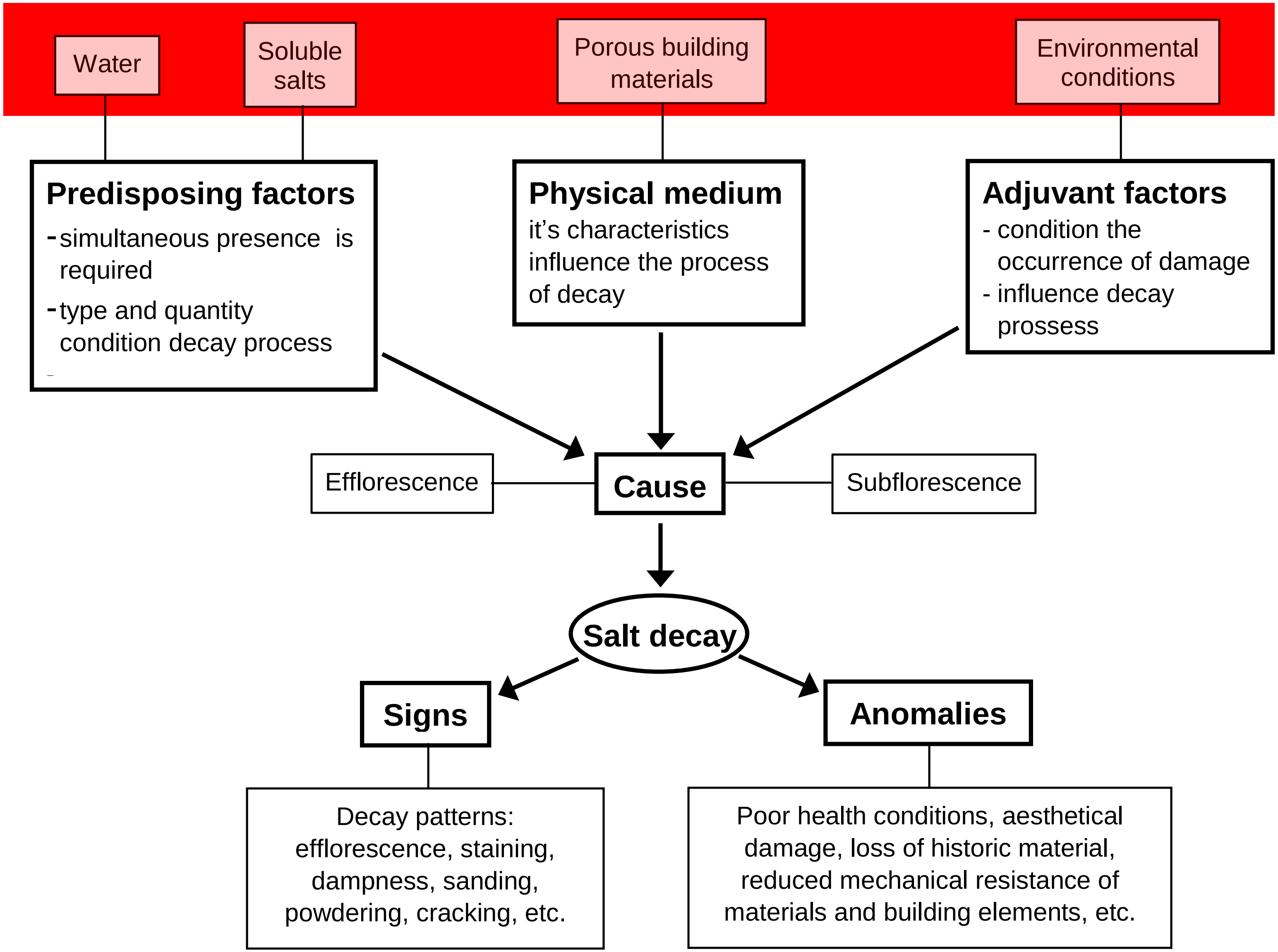
Salts as major decay agents

Control and prevention: working principles of control methods



Salts as major decay agents

Control and prevention: working principles of control methods



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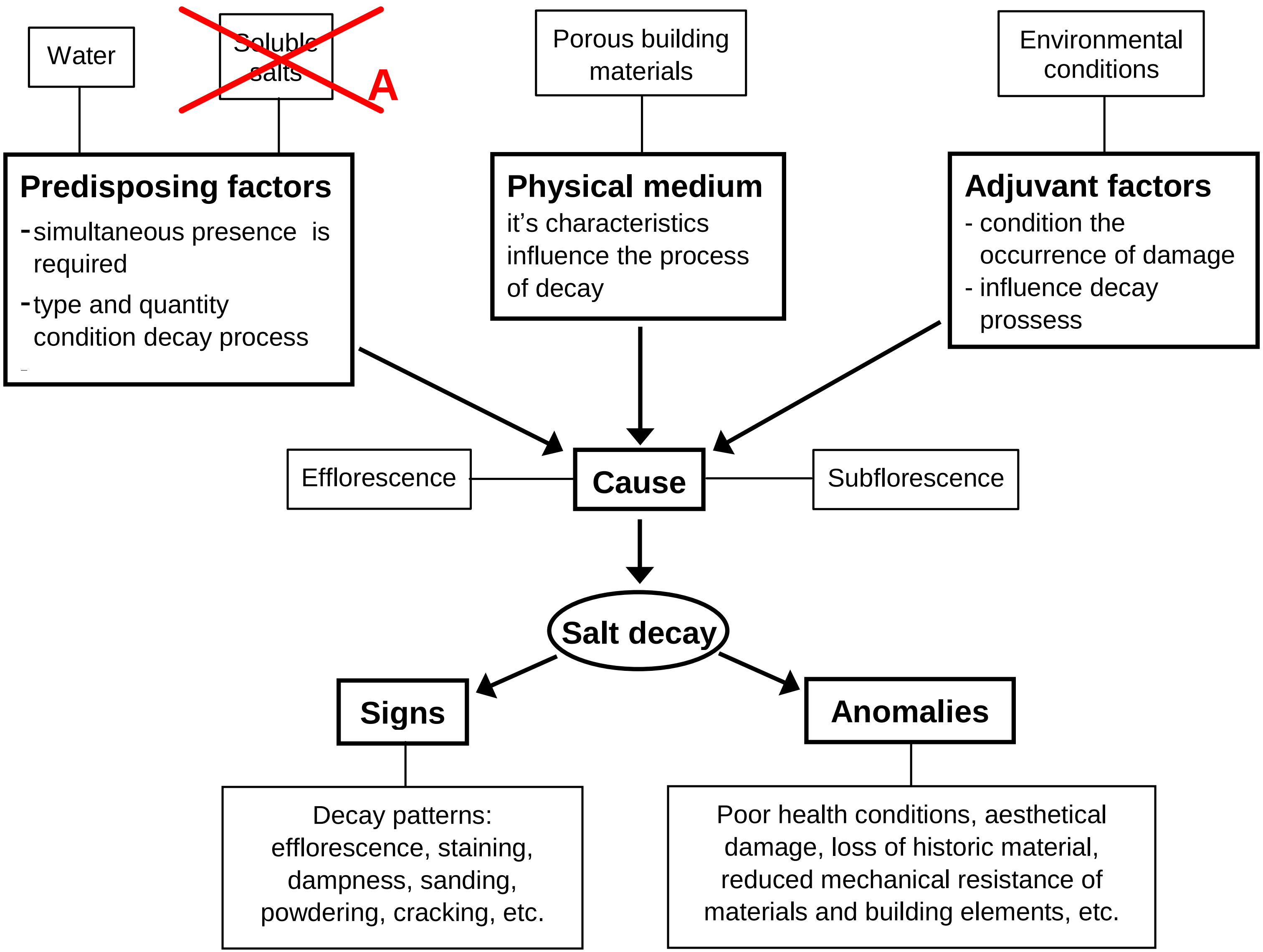

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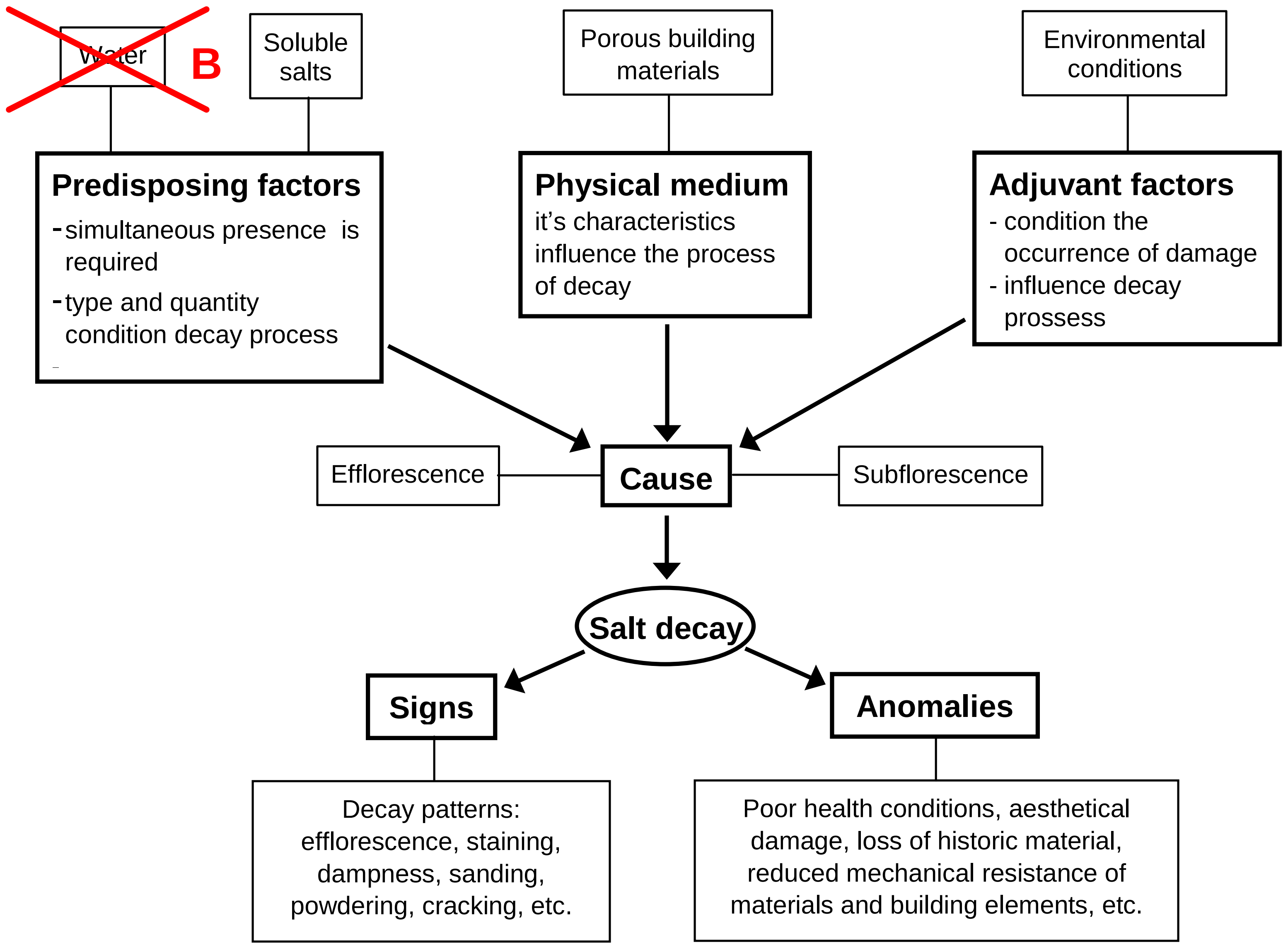

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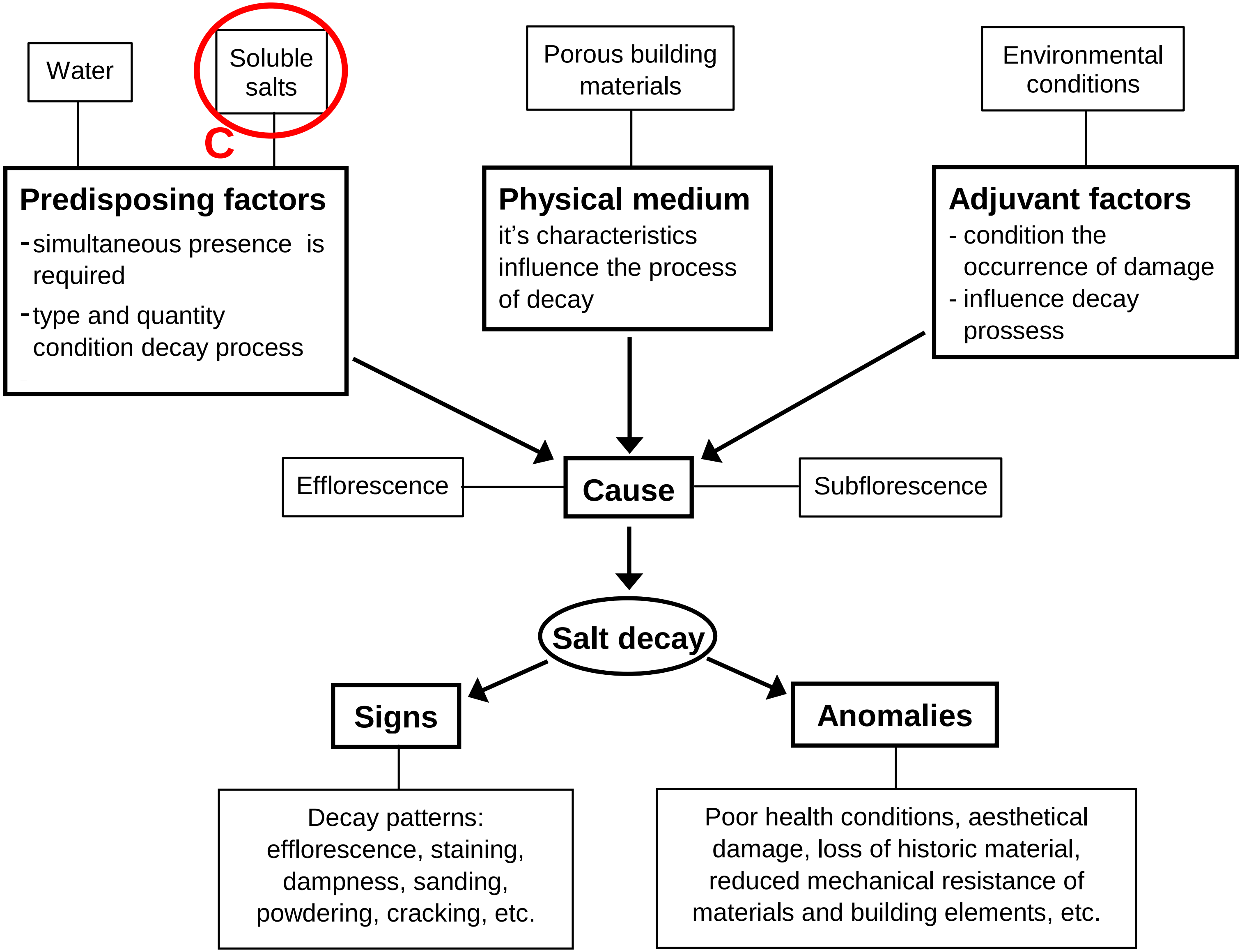

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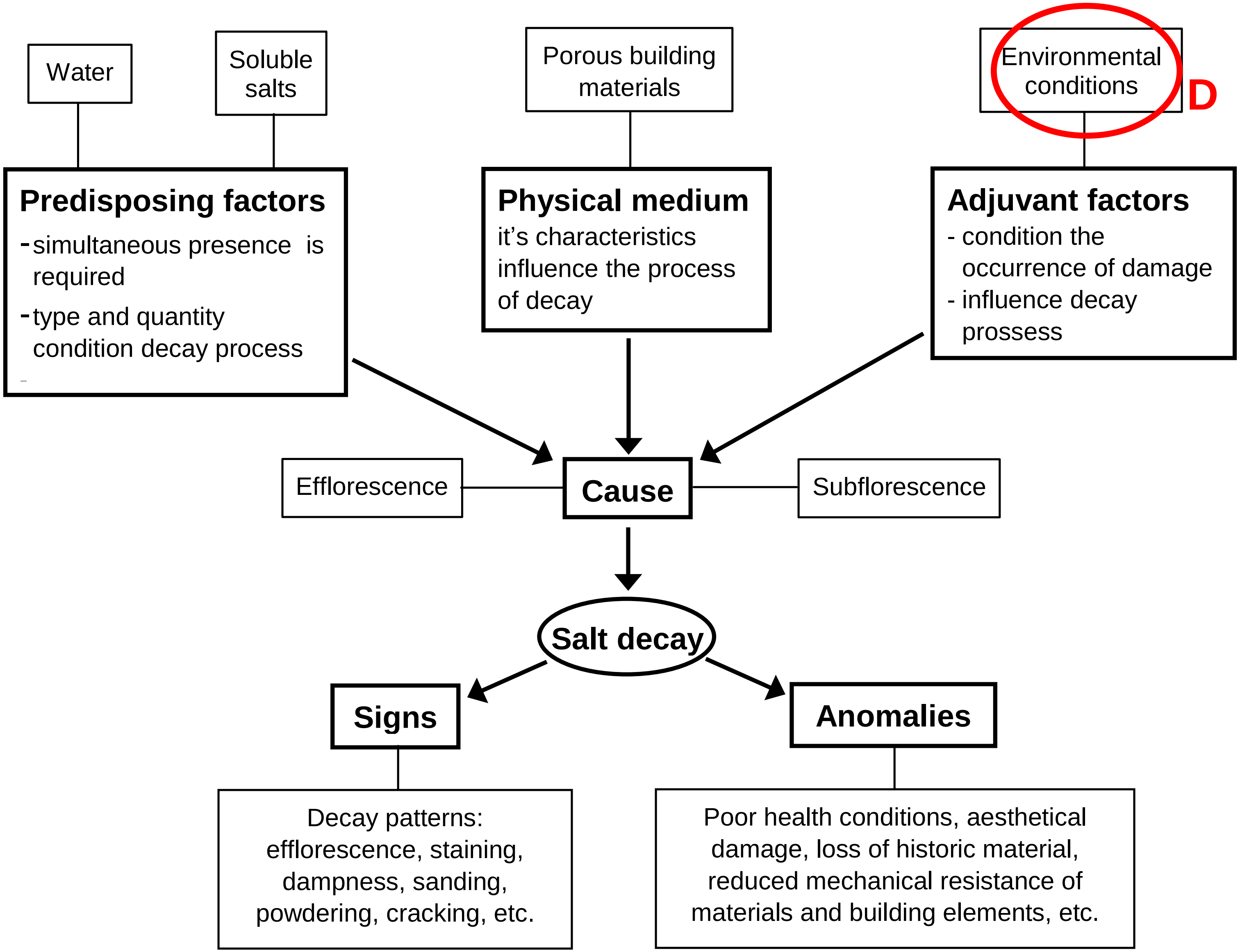

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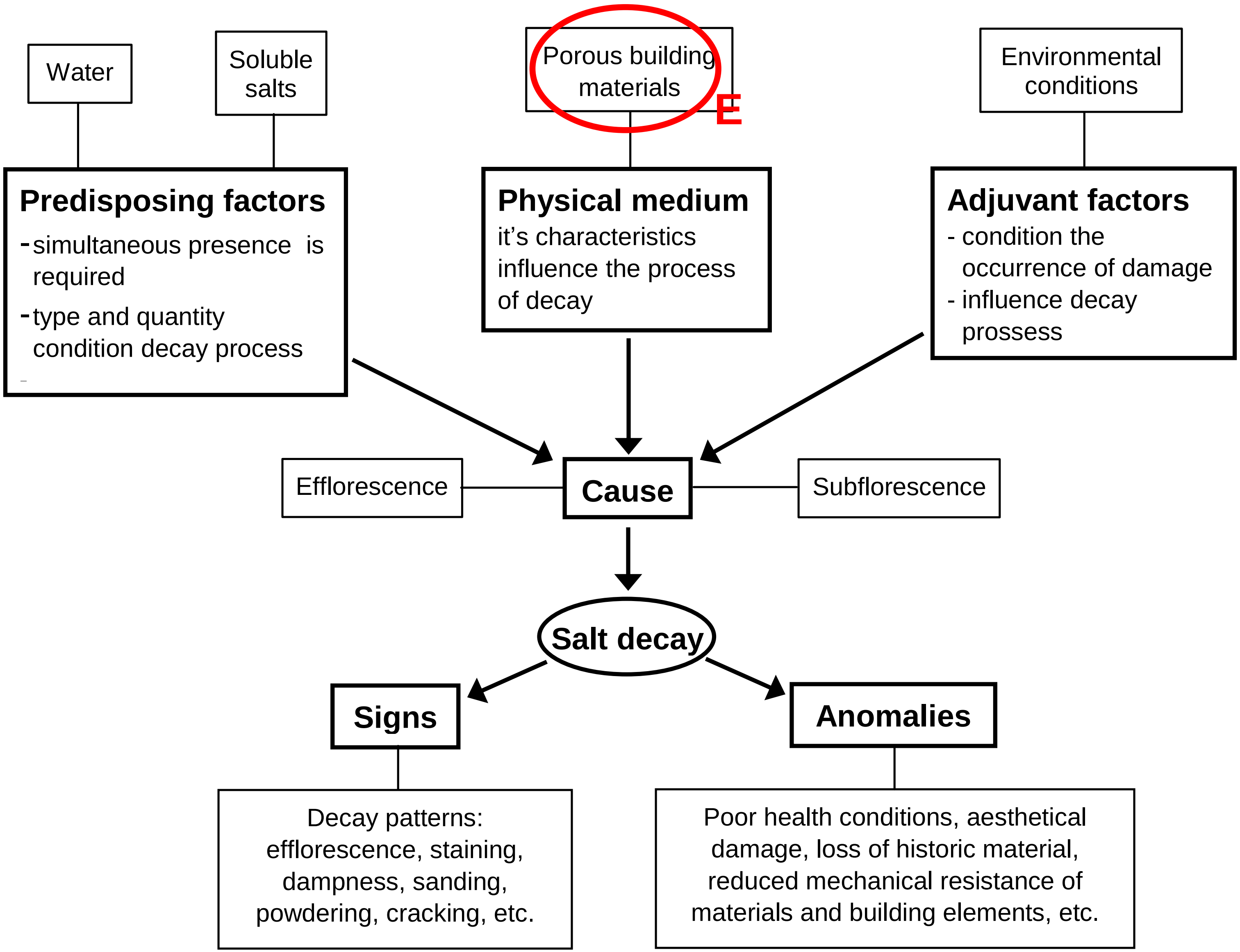

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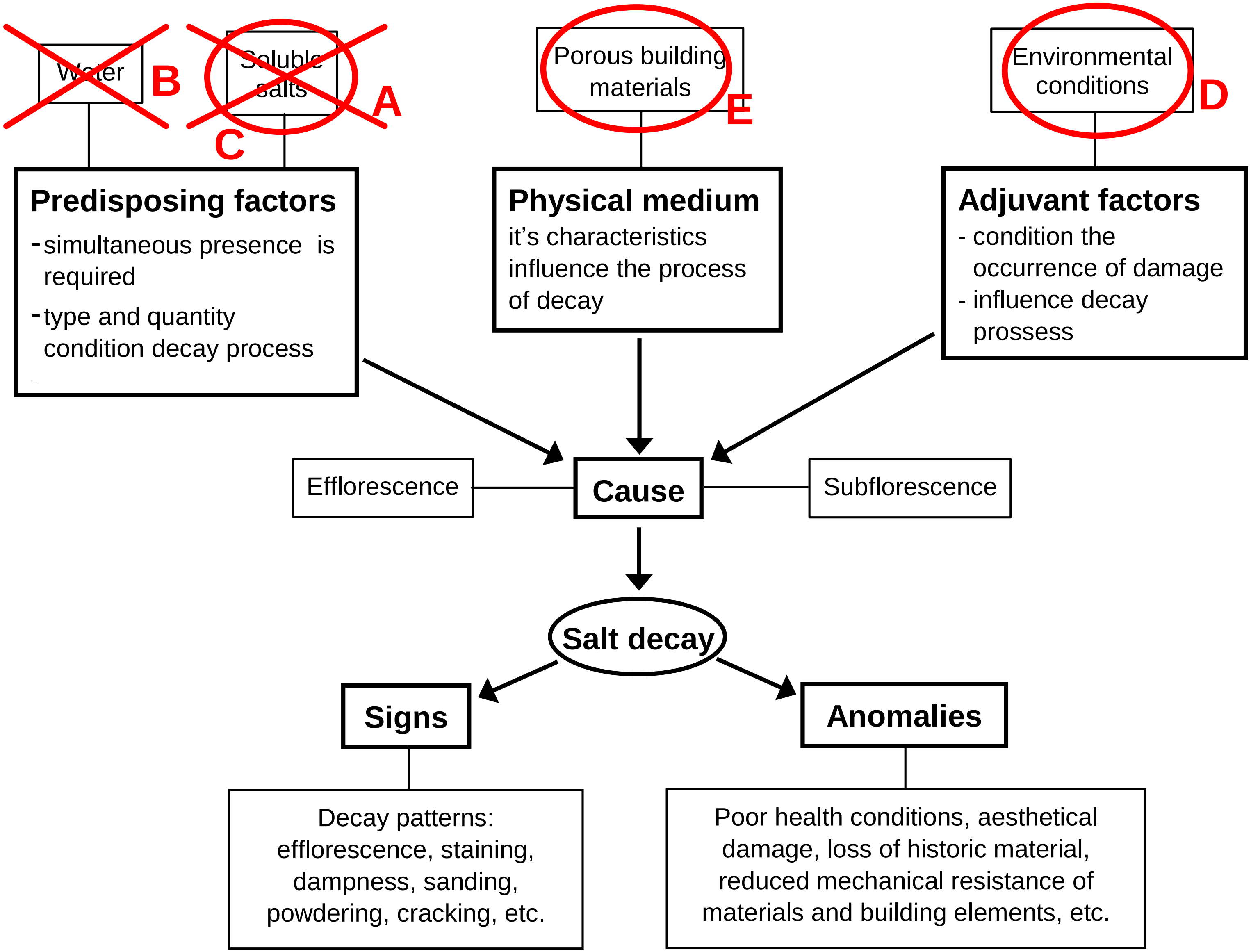

Salts as major decay agents

Control and prevention: control methods

1) Mechanical removal of efflorescence
2) Removal of contaminating materials
3) Poultices
4) Electrochemical removal of salts
5) Microorganisms
6) Crystallization modifiers
7) Plasters and renders
8) Environmental control
9) Rising damp control
10) Barium hydroxide method

Salts as major decay agents

Control and prevention: control methods

Mechanical removal of efflorescence

Working principle: A – Elimination of soluble salts

Description: Carried out by brushing (or a similar technique). The fallen efflorescence has to be eliminated, to avoid its re-absorption.

Possibilities / advantages:

- Improves the aesthetics / health conditions
- Very simple method
- Progressively eliminates the soluble salts (dessalination)

Limitations / risks:

- Unviable on surfaces with a low mechanical resistance or very valuable, which may be damaged
- Only removes the salt that crystallizes on the surface
- Temporary effect, if the supply of salt / water is not deactivated

Salts as major decay agents

Control and prevention: control methods

Removal of contaminating materials

Working principle: **A – Elimination of soluble salts**

Description: **Removal of materials identified as the source of soluble salts.**

Possibilities / advantages:

- **erradication of the problem, if well diagnosed**
- **simple method for certain materials (ex: plasters and renders in general)**

Limitations / risks:

- **removal of certain materials may by unfeasible (ex: the bedding mortar of a stone masonry)**
- **salts that have been transported to adjacent elements may persist**

Salts as major decay agents

Control and prevention: control methods

Poultices

Working principle: A – Elimination of soluble salts

Description: Application of a temporary layer (clay- or cellulose-based) on the surface of the material. The salts are removed by capillary suction (dry poutices) or liquid diffusion (wet poultices – they retain the water used in their preparation).

Possibilities / advantages:

- **non-intrusive method (may be used in some types of mural paintings, for ex.)**

Limitations / risks:

- **the surface has to remain covered with the poultice during a certain period**
- **usually implies introducing water in the material, to dissolve the salts => salt may penetrate further into the material or reach adjacent materials**
- **salts with a low solubility may be hard to dissolve / remove**
- **only removes salts up to a few cm depth**
- **successive applications may be necessary**
- **reduced effectiveness on surfaces with a low absorption (ex: painted)**
- **temporary effect, if the supply of salt / water is not deactivated**

Salts as major decay agents

Control and prevention: control methods

Electrochemical removal of salts

Working principle: A – Elimination of soluble salts

Description: Application of an even number of electrodes (positive and negative pole), generating an electric field in the material that induces the migration of the ions (of opposite charge) in the solution to the electrodes, where they are retained and accumulated.

Possibilities / advantages:

- **allows in-depth reduction of the salt content**

Limitations / risks:

- **possible need to wet the masonry, to dissolve the salts**
- **salts with a low solubility may be hard to dissolve / remove**
- **risk of change in pH in the surrounding electrodes**
- **temporary effect, if the supply of salt / water is not deactivated**
- **method that <u>has yet to be tested</u> in buildings, given the small number of case studies**

Salts as major decay agents

Control and prevention: control methods

Microorganisms

Working principle: A – Elimination of soluble salts

Description: Microorganisms capable of consuming the salt in their metabolic activity are applied (by spray, brushing, poultices, etc.) to the surface of the material. An appropriate vehicle is used (carbogel, sepiolite, for ex., have been tested).

Possibilities / advantages:

- **method compatible with the environment**
- **non-aggressive to the surface => suitable for valuable elements / weak materials**

Limitations / risks:

- **only removes the salts that crystallize close to the surface**
- **limited number of salts types (nitrates, sulphates)**
- **temporary effect, if the supply of salt / water is not deactivated**
- **method still lacks practical application in buildings (case studies)**

Salts as major decay agents

Control and prevention: control methods

Crystallization Modifiers

Working principle: **C – Alteration of the behaviour of soluble salts**

Description: **Products that interact with saline solutions, preventing the crystallization or making it happen in a less harmful way. There are four main specific working principles:**

- **crystallization inhibitors – prevent or delay nucleation, allowing the salt solutions to reach a higher supersaturation and, thus, preventing crystallization or delaying the growth rate of the crystals**
- **nucleation promoters – promote nucleation, increasing the number of crystals formed but reducing their average size; lower supersaturations => lower tensions generated inside the pores**
- **habit modifiers – adsorbed in specific faces of the crystal => reduction or increase of the growth rate on those faces; crystal expected to have less damaging habits**
- **efflorescence promoters – some modifiers alter the thermodynamic properties of the solution => change the balance liquid / evaporation flow during drying => expected to promote the formation of (more innocuous) efflorescence instead of (more destructive) sub-efflorescence**

Salts as major decay agents

Control and prevention: control methods

Crystallization Modifiers

Working principle: C – Alteration of the behaviour of soluble salts

Possibilities / advantages:

- **nonintrusive method**
- **some types of modifiers promote can desalination of construction elements, in view of promoting the formation of efflorescence over subflorescências**

Limitations / risks:

- **only a reduced number of products/salts was tested (ex: DTPMP and ATMP with sodium sulphate, potassium iron-cyanide with sodium chloride)**
- **still lacks (a lot of) research + practical application in buildings (case studies)**
- **potential toxicity problems of some substances are not fully understood**
- **temporary effect, if the supply of salt is not desactivated**

Salts as major decay agents

Control and prevention: control methods

Plasters and renders

Working principle: A – Elimination of soluble salts; E – Alteration of the physical medium

Description: Generally used as a way to live with the problem (working principle D), case in which they can obey the following specific working principles:

- Moisture sealing – neither liquid nor vapour can pass => may "push" the solutions to other zones
- Salt blocking – only vapour can pass => crystallization at the interface plaster/substrate (ex: hydrophobic)
- Salt transporting – transport of solutions to the surface => efflorescence forms (ex: lime plasters)
- Salt accumulating – the solutions penetrate but do not reach the surface => crystallization in the mass of the plaster/render (industrially designed products)

Plasters and renders can also be used as a method of desalination (working principle A) => sacrificial

Possibilities / advantages:

Depending on the specific working principle:

- Protection of the support (salt transporting; salt accumulating)
- Good health conditions (salt accumulating, salt blocking)
- Protection of adjacent elements (salt transporting)

Salts as major decay agents

Control and prevention: control methods

Plasters and renders

Working principle: **A – Elimination of soluble salts; E – Alteration of the physical medium**

Limitations / risks:

In general:

- **periodic replacement (especially for traditional sacrificial plasters) if the salt/moisture source is not deactivated**
- **possible complexity in choosing the most appropriate type of coating (site trials…)**
- **high cost of some industrial systems**
- **obvious impossibility of application in the case of uncoated walls**

Depending on the specific working principle:

- **surface degradation of the plaster (salt transporting)**
- **deterioration of the support (salt blocking)**
- **detachment of the coating (salt blocking, moisture sealing)**
- **degradation of adjacent elements or increase of the level of capillary rise (moisture sealing)**

Salts as major decay agents

Control and prevention: control methods

Environmental control

Working principle: D – Control of the environmental conditions

Description: Implementation, in interior spaces, of optimized conditions of temperature and HR, so as to prevent or minimize the occurrence and frequency of the crystallization / dissolution cycles.

Possibilities / advantages:

- does not involve a direct intervention on the contaminated elements => suitable for the preservation of valuable elements

Limitations / risks:

- the prediction of the optimal environmental conditions can be complex
- for high HR, there is the risk of biological development
- the method is feasible only inside buildings
- partition of the interior of a building/room may be necessary for the control of specific areas
- high cost (equipment and maintenance)
- possible environmental disadvantages due to energy consumption

Salts as major decay agents

Control and prevention: control methods

Control of rising damp

Working principle: B – Elimination of the moisture

Description: Eradication or reduction of ingress of moisture. There are several techniques: reduction in the absorbent section, introduction of watertight barriers, injection waterproofing products, peripheral trenches, etc.

Possibilities / advantages:

- **in some cases will solve the problem permanently**
- **simultaneous elimination of the source of salt (when this source is the soil)**

Limitations / risks:

- **possible difficulties of implementation, depending on the characteristics of the building, masonry materials and adjacent terrain**
- **high cost of some techniques**

Salts as major decay agents

Control and prevention: control methods

The barium hydroxide method

Working principle: C – Alteration of the behaviour of soluble salts

Description: inhibits the occurrence of cycles of crystallization / dissolution of gypsum (calcium sulphate), by converting it into a virtually insoluble salt (barium sulphate). Includes the sequential application of two compounds, using impregnated poultices:

(1) ammonium carbonate (+ gypsum = soluble ammonium sulphate + insoluble calcium carbonate)

(2) barium hydroxide (+ ammonium sulphate = insoluble barium sulphate)

Possibilities / advantages:

- **non intrusive method**
- **successful experiences in several cases of preservation of mural paintings**

Limitations / risks:

- **applies only to a specific type of salt (gypsum)**
- **only treats the surface**
- **high toxicity of barium hydroxide**

Salts as major decay agents

Control and prevention: complementarity between methods

Salts as major decay agents

Control and prevention: complementarity between methods

Some examples …

- Promotion of efflorescence (crystallization modifiers, transporting plasters/renders) + mechanical removal of efflorescence
- Removal of contaminating materials + dessalination method (sacrificial plasters/renders, poultices, electrochemical removal of salts, microorganisms)
- Poultices + plasters / renders
- Control of rising damp + dessalination method (sacrificial plasters/renders, poultices, electrochemical removal of salts, microorganisms) or environmental control
- Control of rising damp + accumulating plasters/renders
- Poultices used as impregnation method + crystallization modifiers or barium hydroxide method or microorganisms

Salts as major decay agents

Control and prevention: prevention

Salts as major decay agents

Control and prevention: prevention

Main risk factors:

> Use of inapropriate materials

- contaminated with soluble salts (ex: sea sand)
- with reactive constituents (ex: cement mortars with high alkali content)
- which alter the liquid or vapour flows (ex: rich cement mortars, impermeable paints)

Salts as major decay agents

Control and prevention: prevention

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> Water penetration

- deteriorated window frames, roofs, exterior walls, etc.
- poor condition of drainage systems (rain water / domestic supply or residual waters)
- incorrect drainage of surrounding terrains (ex: direct water towards the walls)

Salts as major decay agents

Control and prevention: prevention

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> Alteration of the internal environmental conditions

- heating / air conditioning / dehumidification systems
- doors and windows: activation of new / desactivation of old
- new use of the building / room (ex: people => water vapour + heat)

Salts as major decay agents

Control and prevention: possible approaches

Salts as major decay agents

Control and prevention: possible approaches

Often → choice between several “imperfect” solutions:

- different control methods, possibly more than one
- no intervention

benefits / limitations, disadvantages

Salts as major decay agents

Control and prevention: possible approaches

- **Prevention** – reduce the risk that degradation happens
- **Control**
  - **Correction** – permanent elimination of the problem by deactivating at least one of the predisposing factors:
    - **A** – Elimination of soluble salts
    - **B** – Elimination of the moisture

    } totally

  - **Mitigation** – "living with the problem" = reduce, alter or suspend the degradation by:
    - **A** – Elimination of soluble salts
    - **B** – Elimination of the moisture

    } partially

    - **C** – Alteration of the behaviour of soluble salts
    - **D** – Control of the environmental conditions
    - **E** – Alteration of the physical medium

Salts as major decay agents

Control and prevention: possible approaches

Prevention

- Selective choice of construction materials used in maintenance or in the recovery of old constructions
- Regular maintenance of the construction in order to avoid water penetrations.
- Analysis of potential risks of degradation due to alterations on the climate conditions (temperature and RH) inside buildings, because of interventions in the construction.

Control

Correction

- Removal of contaminating materials
- Control of the rising damp

Mitigation

- Control of the rising damp
- Mechanical removal of efflorescence
- Poultices
- Electrochemical removal
- Microorganisms
- Plasters and Renders
- Climate Control
- Crystallization modifiers
- Method of Barium Hidroxide

Salts as major decay agents

Thank you!