Stone degradation
using limestone as indicator
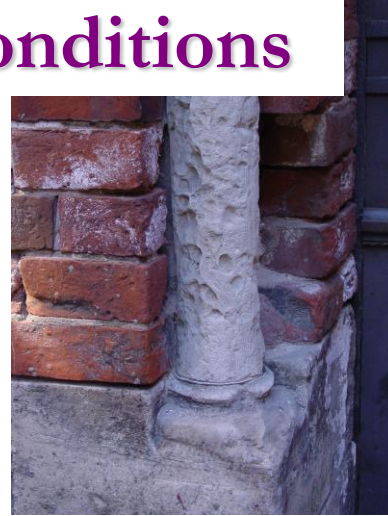
Deterioration of stone materials
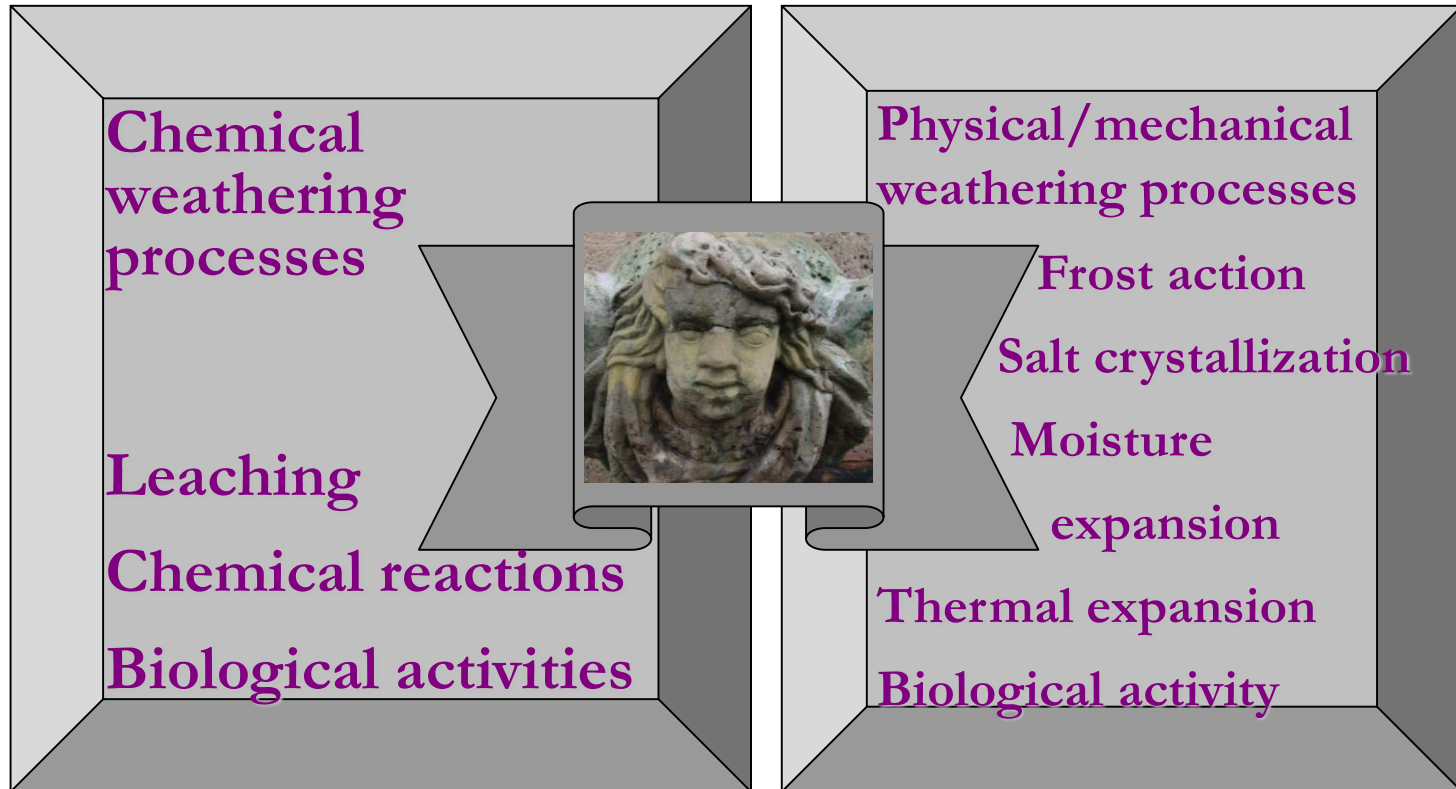
Chemical weathering processes

Leaching

Chemical reactions

Biological activities

Physical/mechanical weathering processes

Frost action

Salt crystallization

Moisture expansion

Thermal expansion

Biological activity

General deterioration forms

unsheltered conditions

sheltered conditions

1st stage - black crusts

2nd stage - loss of material

St. Paul's Cathedral, London
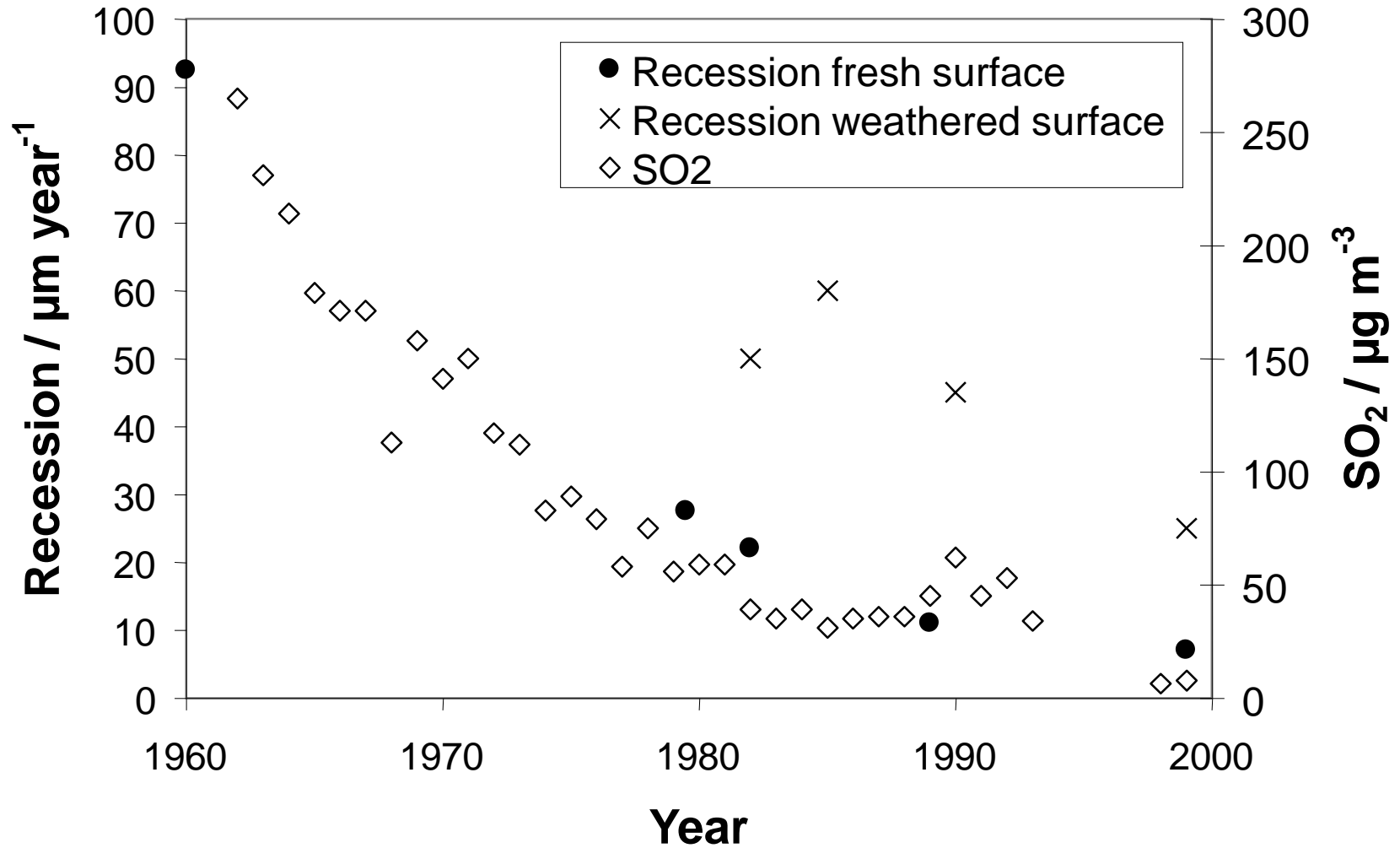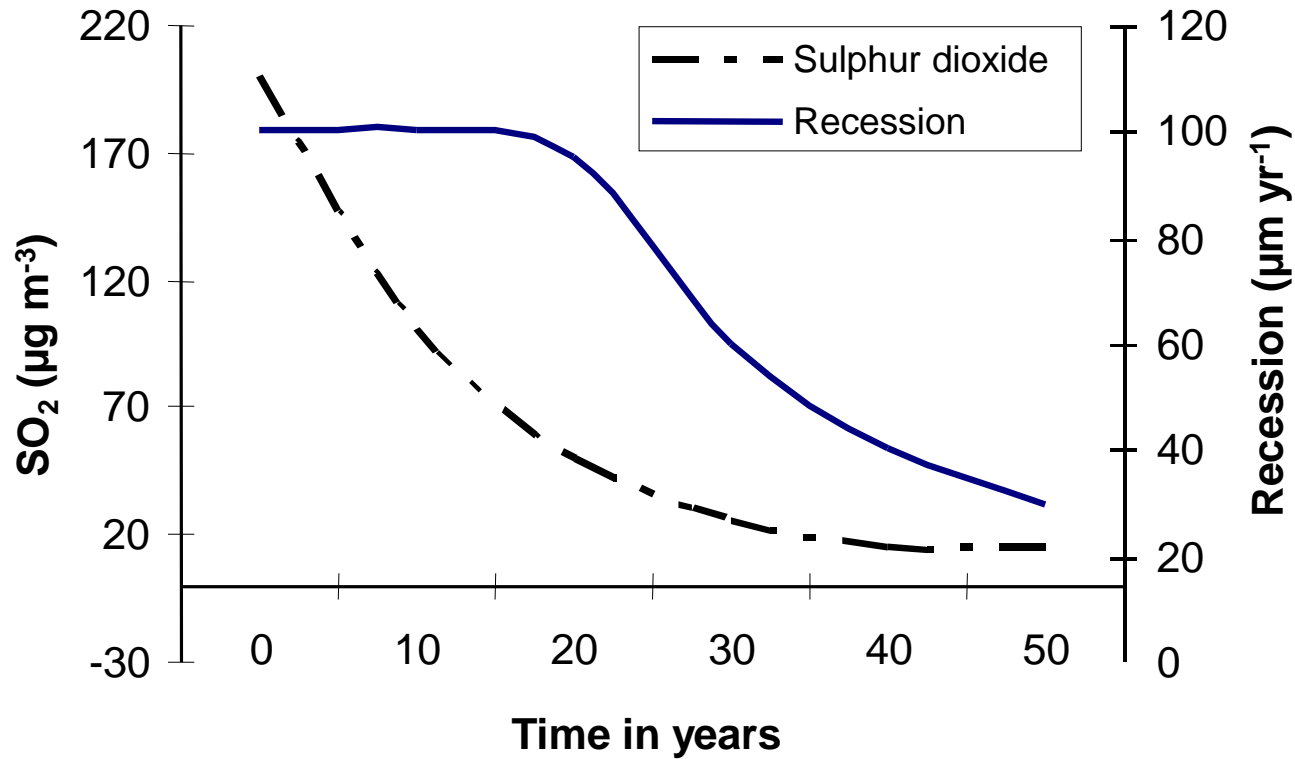
Bankside power station, London

In use

At present modern art gallery

Portland Limestone, St. Paul's Cathedral, London, fresh and weathered surfaces
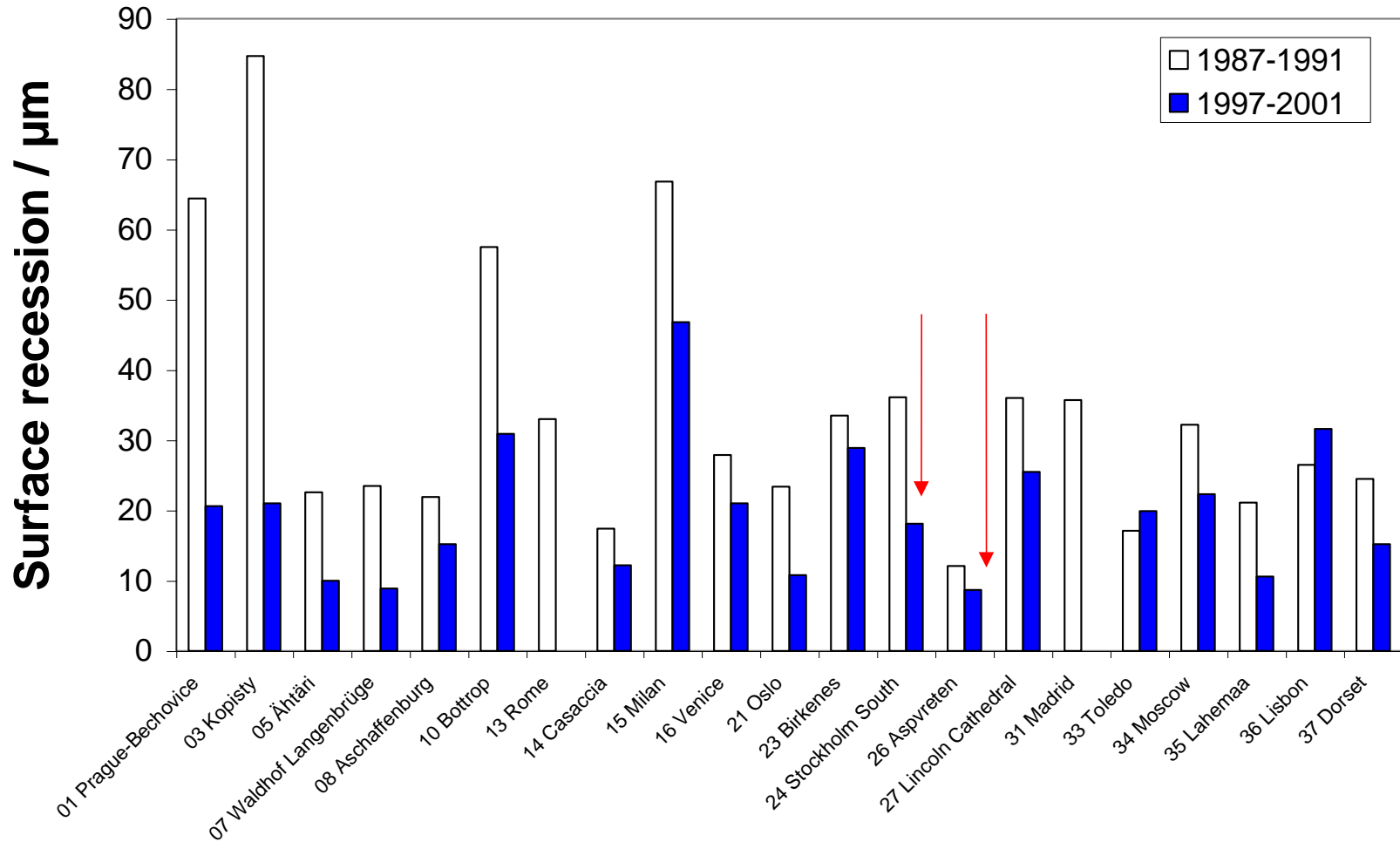
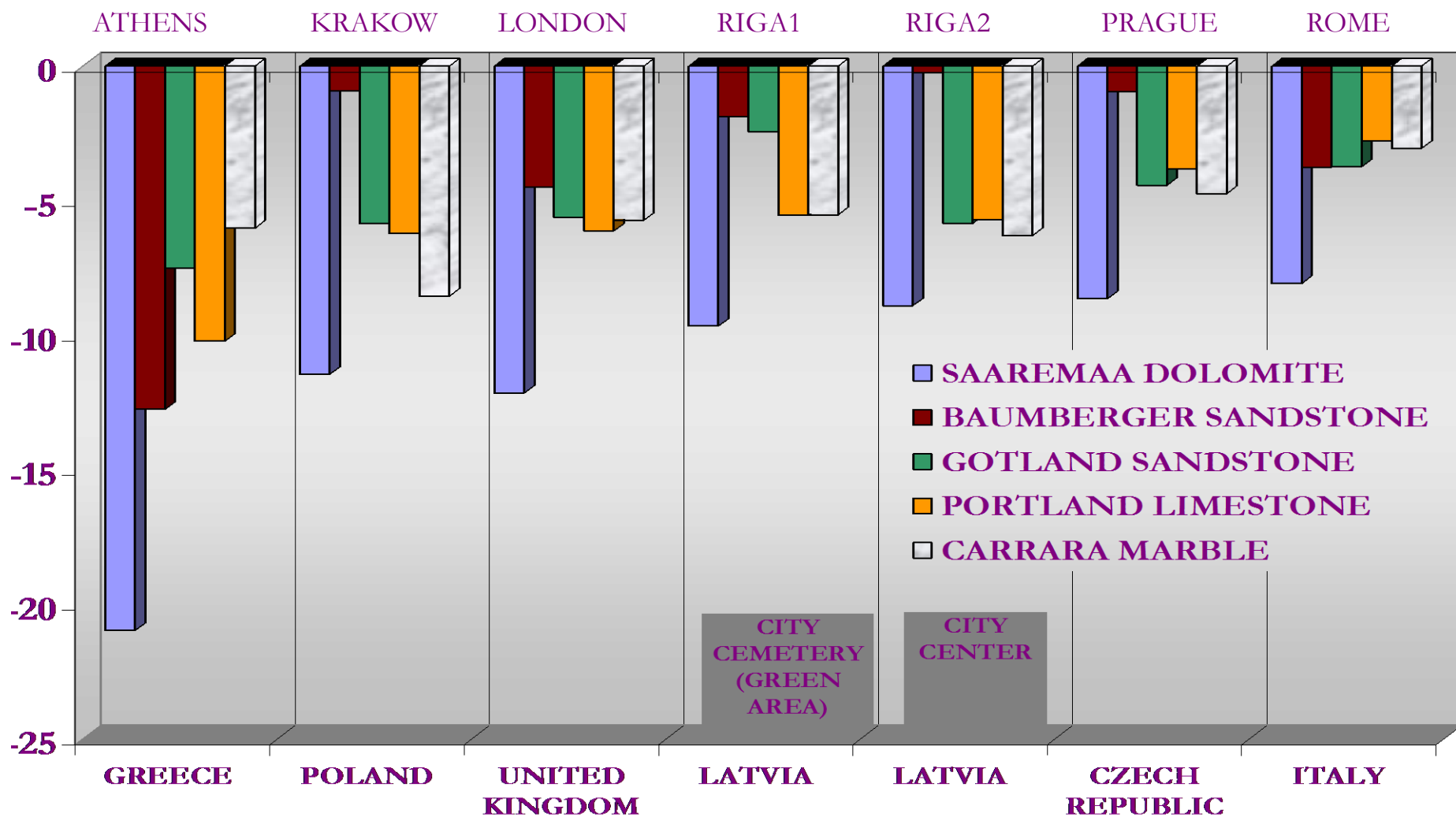# Schematic view of memory effect

The multi-pollutant programme

- ICP Materials exposure 1997 - 2001
- EU 5FP project MULTI-ASSESS incl. HNO_3 and particles 2002 - 2003
- Comparative exposure of different calcareous stone materials
- Assessment of threshold levels for pollution, deterioration and soiling

Limestone - trends in the multi-pollutant situation

Surface recession (µm-1year exposure)

ATHENS · KRAKOW · LONDON · RIGA1 · RIGA2 · PRAGUE · ROME

■ SAAREMAA DOLOMITE
■ BAUMBERGER SANDSTONE
■ GOTLAND SANDSTONE
■ PORTLAND LIMESTONE
□ CARRARA MARBLE

CITY CEMETERY (GREEN AREA)

CITY CENTER

GREECE · POLAND · UNITED KINGDOM · LATVIA · LATVIA · CZECH REPUBLIC · ITALY

RAPIDC
Regional Air Pollution InDeveloping Countries

Background to Portland Limestone

- The quarries are located on the Isle of Portland in Dorset, England.

- The tablets have been used in all recent UNECE, EU and SIDA programmes

- Portland has been quarried since the Roman period but became popular in the 17th century when Inigo Jones and Sir Christopher Wren used it in many buildings including St.Paul's Cathedral, London. Portland has remained popular with architects and builders because of its fine grain and good durability, and because it weathers very evenly.

Now the demonstration…

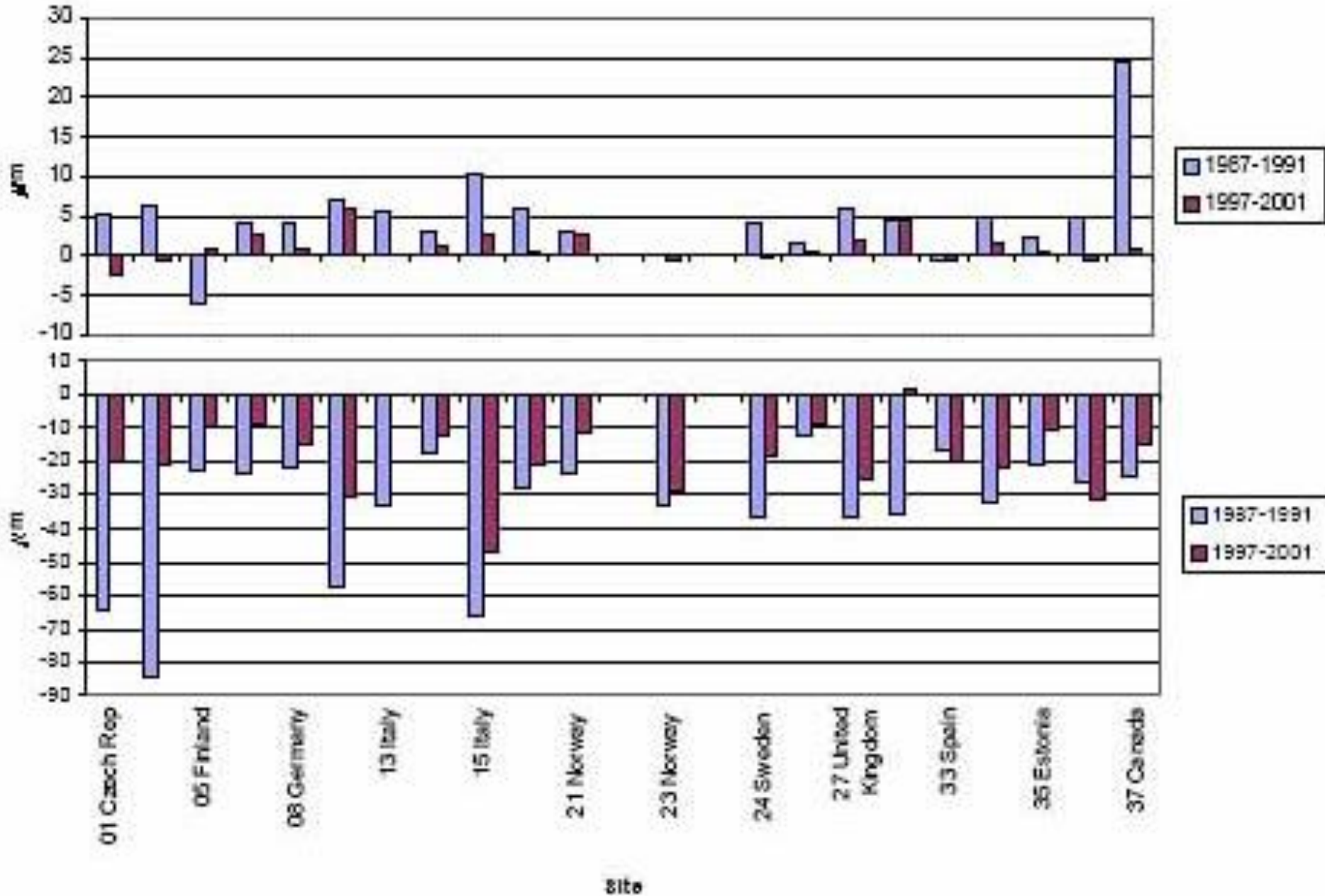# General deterioration forms

unsheltered conditions
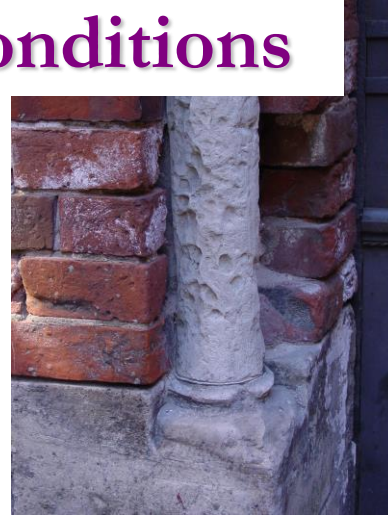
sheltered conditions

1st stage - black crusts

2nd stage - loss of material

Comparison of surface loss on sheltered (top) and unsheltered (bottom) limestone samples

Exposure in sheltered position

- Weight incerase is presumed to arise from the conversion of calcium carbonate into calcium sulphate (gypsum) that is not dissolved by rain as is the case for open exposure.

- The concentration of sulphates is found to be greatest in the top 1 mm of the tablets but there will still be small increases to a depth of 3 mm in some cases.

- The crust thickness can be estimated by using a gypsum density of 2.5, a weight gain factor of 0.36 from the stoichometry and the face area of the tablets giving

- μm crust $= \dfrac{\text{Weight gain (mg)}}{0.36 \times 2.5 \times 5}$

The distribution of soluble material

- A powder sample is obtained by drilling at four places on a 50 x 50 mm surface. Samples are obtained initially at 1 mm depth from the surface at 2 diagonally opposed locations on the tablet.

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- The concentrations of the major cations (Na^+, K^+, Ca^{2+} Mg^{2+}) and anions (Cl^-, NO_3^- SO_4^{2-}) are obtained by de-ionised water extraction (20 ml for 30 minutes) and measured by ion chromatography or some other appropriate method.