

## Victoria Memorial, Calcutta, India

### To the Editor:

Kevin J. Anderson's article "Granite and Marble" in Historical Note (*MRS Bulletin*, May 1993) was very interesting. Since he touched on the use of marble for the construction of a famous historical monument in India (the Taj Mahal), I would like to illustrate another Indian example—the Victoria Memorial—a landmark structure in the heart of Calcutta. The marble used to build its exterior is from the same source (from Makrana) as that used for the Taj Mahal. The interior of the Victoria Memorial, however, is made of sandstone blocks.

This impressive piece of Italian Renaissance architecture (see Figure 1), featuring curved colonnades, was designed by the well-known British architect Sir William Emerson. Its construction, which began in 1901, was completed in 1924. This magnificent edifice was built to commemorate the reign of Queen Victoria, which ended with her death in 1901.

The deterioration of the Victoria Memorial over the past decade has been alarming, and has become a cause of major concern (Figure 2). Having had the privilege of carrying out an investigation to determine the cause of its deterioration (UNDP TOKTEN Program<sup>1</sup>), I fully concur with Anderson's view that the widespread use of fossil fuels is, to a large extent, responsible for gypsum recrystallization in stone (Figure 3). This type of secondary gypsum is expansive in nature, and can cause severe damage to the stone. In addition, the city of Calcutta supports one of the highest urban populations (exceeding 10 million) in the world today. In this respect, reference is made to Fassina's report,<sup>2</sup> which posits that in industrial or urban areas, human activity results in the constant emission of sulfur-bearing compounds, which also contribute to the degradation process (Figure 3). Vehicular traffic in the city of Calcutta today totals nearly half a million.

The Memorial complex used to be dotted with large evergreen trees that in a very definitive way formed a green belt, and a protective cushion against environmental pollution. The indiscriminate chopping down of these trees during the

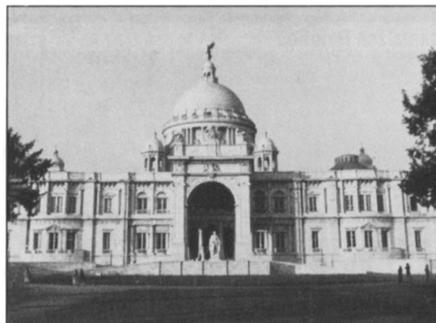


Figure 1. A view of Victoria Memorial, completed in 1924, a fine example of Italian Renaissance architecture undergoing deterioration due mainly to environmental pollution.

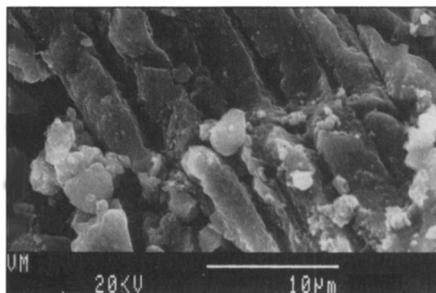


Figure 2. A scanning electron micrograph of a deteriorated calcite crystal (in marble), split open along its cleavage planes.

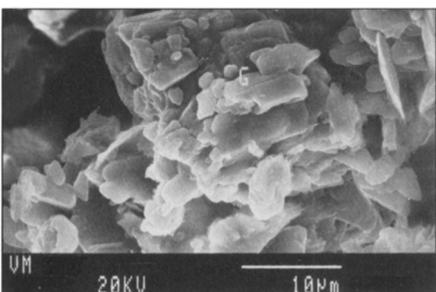


Figure 3. Recrystallized gypsum crystals in sandstone, viewed under a scanning electron microscope (SEM).

past decade, to introduce a "son et lumière" show on the memorial, has aggravated the problem still further.

Also of significant interest is the fact that parts of the sandstone blocks inside

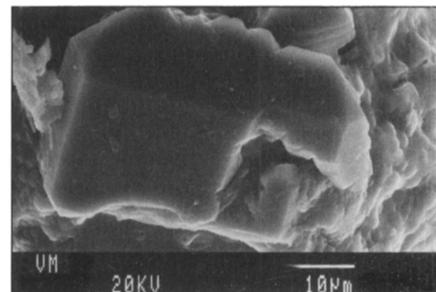


Figure 4. An affected quartz crystal in the sandstone. Its edges have been corroded, and part of it has decomposed.

the building have been even more severely affected. Large efflorescent patches due to the recrystallization of expansive salts, gypsum in particular, have resulted in spalling and exfoliation. The host minerals in the rock have also been damaged (Figures 3 and 4).

Absorption of salts by natural rocks depends on their porosity. Mercury porosimetry tests show that sandstone is porous, compared to marble. It is therefore more prone to chemical attack.

Calcutta is close to the Bay of Bengal, so the salt-laden sea breeze combines with the atmospheric sulfur dioxide, which penetrates the sandstone to precipitate as gypsum, thenardite ( $\text{Na}_2\text{SO}_4$ ), and its decahydrate form, mirabelite ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ). The high humidity (RH ranging from 90 to 98%) and warm temperature (15 to 35°C) promote the salification process.

Let us hope that the authorities will take note of the rapid deterioration now in progress, and act before it is too late.

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### References

1. S.L. Sarkar, A.K. Bhadra, and P.K. Mandal, "Microstructural investigation of mortar and stone deterioration in Victoria Memorial, Calcutta," submitted to *Materials and Structures* (RILEM, 1993).
2. V. Fassina, "Environmental pollution in relation to stone decay," in *Durability of Building Materials* 5 (1988) p. 317. □

1993 MRS FALL MEETING – See pages 66–68 for information.