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## Corrosion Resistance of the Delhi Iron Pillar — Scale Characterisation and Passive Film Growth Models

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### ABSTRACT

The corrosion resistance of the Delhi pillar iron has been reviewed. The corrosion products on several ancient Indian irons have been characterised. The role of entrapped slag particles in aiding passive film formation in ancient Indian iron has been analysed by mixed potential theory. The protective rust formation process has been elucidated and possible models proposed. After an initial period of high corrosion rate, the initial corrosion resistance is conferred by the formation of protective amorphous compact layer of  $\delta\text{-FeOOH}$ . The corrosion rate is further lowered by the formation of phosphates and their phase transformations.

### 1. Introduction

The Delhi pillar iron (Fig. 1) is testimony to the high level of skill achieved by the ancient Indian iron smiths in the extraction and processing of iron. The iron pillar at Delhi has attracted the attention of archaeologists and corrosion technologists as it has withstood corrosion for the last 1600 years. Several theories, which have been proposed to explain its superior corrosion resistance, can be broadly be classified into two categories; the environmental [1–3] and material [4–7] theories. These theories have been critically reviewed in detail in [6,7]. The proponents of the environment theory state that the mild climate of Delhi is responsible for the corrosion resistance of the Delhi pillar iron as the relative humidity at Delhi does not exceed 70% for significant periods of time in the year, which therefore results in very mild corrosion of the pillar. It is known from the classic researches of Vernon [8–10] that atmospheric rusting of iron is not significant for humidity levels less than 70%. Moreover, the climatic conditions of Udayagiri, where the pillar was originally located before it was brought to Delhi in the 11th century [11], should also be analysed in detail. On the other hand, several investigators have stressed the importance of the material of construction as the primary cause for its corrosion resistance. The ideas proposed in this regard are the relatively pure composition of the iron used [4], presence of phosphorus and absence of S/Mn in the iron [3], its slag enveloped metal grain structure [3], passivity enhancement in the presence of slag particles [5,7] and formation of phosphate film [5–7]. Other theories to explain the corrosion resistance