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A Geometric Study of Corroded Surfaces of Iron–Nickel Alloys

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It was conjectured that during very long-term corrosion of iron–nickel alloys in soils the metal/corrosion interface would show a self-similar (fractal) structure over interesting length scales. Examination of a number of corroded meteorites indicated that this conjecture is incorrect.

Introduction

As metal surface corrodes, the profile changes form; most profoundly in the case of a passive material undergoing local corrosion, but also in other cases (*1*). A quantitative understanding of this shape change would permit prediction of the deepest corrosion penetration as a function of time, now addressed entirely within the framework of extreme value statistics (*2*), and would also permit prediction of the change in deepest penetration over times which are experimentally inaccessible. Examination of data on iron alloys from a number of sources suggested that there might be merit in the hypothesis that, for specimens which corrode for hundreds or thousands of years, the metal/corrosion product interface when considered over length scales on either side of the grain size would approach a fractal structure with a fractal dimension (*3*) independent of the details of alloy chemistry and specimen environment. A test of this hypothesis was conducted using iron–nickel meteorites, and the results were found to contradict the hypothesis.

A summary of the data with supporting micrographs sufficient to demonstrate the failure of the hypothesis required more space than is appropriate for a negative result. Hence, this brief communication summarizes the analysis. A more comprehensive report is available on request from the authors.

Experimental Results

It was decided to test the hypothesis by study of iron–nickel meteorites. Nine meteorites were considered and two were selected for analysis. The selection criteria were that the meteorites should have substantial undisturbed corrosion products, that there be no significant evidence of dealloying, that substantial specimens were available, and that the specimens were free of severe fissuring or pitting. The two chosen were octahedrites, one from Henbury Craters and the other from Boxhole, Northern Australia. Both had less than 10% nickel.

Polished sections normal to the surfaces of the meteorites were prepared and photographed through a scanning electron microscope at magnifications varying from 100 to 5000×.

The distances between pairs of points on the metal/corrosion product were approximated by series of line segments varying in length from $L = 2$ μm to $L = 100$ μm and the distances between the points along the polygonal paths so defined were measured. If the metal/corrosion product interface were a fractal, the ratio of the distance between points measured along the interface along a polygonal path based on a particular size of segment should be identical for all pairs of points and should vary with segment length L as L^d, where d is the fractal dimension (*3*). If the hypothesis were correct, the data for all point pairs for both meteorites would scale with a single d value. Neither of these conditions were found even approximately to be fulfilled. Furthermore, visual observation of the interfaces showed that they have very different appearance at different magnification.

Since the meteorites measured were chosen to have no characteristics which would interfere with the formation of self-similar structures, the data must be taken as disproving the hypothesis for all meteorites, and by inference, all buried objects made of iron-nickel alloys.

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