A Mathematical Model of Spheroidal Weathering

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A mathematical model is developed to explain the geometrical patterns of spheroidal weathering. The model is then analyzed, and results of computer simulations for the weathering of spherical and ellipsoidal surfaces are presented. Ellipsoids weather initially into ellipsoids of greater or lesser eccentricity, depending on boundary conditions, and finally into spheres. This is in qualitative agreement with the geometry of observed weathering patterns. Some of these features would be difficult to explain by a diffusion model. The weathering of rectangles also is simulated, and they weather into ellipses or circles. These are also in qualitative agreement with observed weathering patterns.

KEY WORDS: Weathering, spheroidal, mathematical modeling, computer simulation.

INTRODUCTION

Spheroidal weathering structures are formed by differential chemical leaching and precipitation in rocks. Weathering starts from a network of fractures and fissures. Water percolates along these and penetrates the polygonal body from all sides, producing concentric ellipsoidal and spherical shells of decayed rock (Figs. 1–3). Weathering cells are typically 0.02–2.00 m in diameter. The weathering front migrates from the outside toward the center. Occasionally a core of unweathered rock is preserved. Microstructure analysis shows that minerals of the unweathered rock are dissolved, elements are mobilized, and some are reprecipitated. Commonly, alternating Fe-rich and Fe-depleted zones occur (Fig. 3). These concentric weathering structures are found in a variety of rock types including granite, basalt, gabbro, sandstone, bauxite, and others (Augustithis and Otteman, 1966; Singer and Navrot, 1970; Augustithis et al., 1980; Augustithis, 1982).

Alternating concentric precipitations were first described by Liesegang (1913). In his experiments, Liesegang produced parallel rings when potassium
Fig. 1. Typical spheroidal weathering structures. Measurements are made from the line drawing.

dichromate and silver nitrate reacted in gelatin. Silver dichromate precipitated in concentric rings alternating with areas of no precipitation. The rings form by diffusion of silver dichromate through gelatin which forms a barrier to the other salt solution. This phenomenon is called Liesegang diffusion. Liesegang (1913) relates these diffusion rings to Fe-rich banding in weathered rocks and suggests the process of formation might be similar. Carl and Amstutz (1958) experimentally show that Liesegang rings also are formed in three-dimensional bodies with 80-90% quartz grains and 5-10% gelatin; the rings either stop at grain boundaries or deviate around sand grains.

These findings are similar to observations made on natural rocks in which Fe-rich rings terminate at mineral grains or go around them. Carl and Amstutz conclude that the Fe-rich rings in weathered rocks are caused by diffusion and periodic precipitation in a colloidal matrix or intergranular film. Augustithis and Ottemann (1966) show an exchange of elements occurs between the Fe-rich and the Fe-depleted zones in weathered granite. The amount of Ca and Fe increases in brown, Fe-rich zones whereas Al, Si, K, Zr, Y, and Rb are enriched in Fe-depleted zones. They propose two opposing directions of element migration,