Medical mineralogy as a new challenge to the geologist: Silicates in human mammary tissue?

JILL DILL PASTERIS,1,* BRIGITTE WOPENKA,1 JOHN J. FREEMAN,1 V. LEROY YOUNG,2 AND HAROLD J. BRANDON2,3

1Department of Earth and Planetary Sciences, Washington University, Campus Box 1169, St. Louis, Missouri 63130-4899, U.S.A.
2Washington University School of Medicine, Division of Plastic Surgery, 1040 North Mason Road, Suite 206, St. Louis, Missouri 63141-6366, U.S.A.
3Department of Mechanical Engineering, Washington University, Campus Box 1185, St. Louis, Missouri 63130-4899, U.S.A.

INTRODUCTION

The current project illustrates some of the challenges faced by both pathologists and mineralogists who attempt to identify and to understand the occurrence of non-cellular materials in human tissue. Some of those materials are indigenous crystalline solids, or “biominerals.” The latter are biologically precipitated phases that, except for their biological genesis, would be called minerals, e.g., apatite in bone and weddellite in kidney stones. In addition, due to increasing concern about the health effects of inhaled particles (e.g., Guthrie and Mossman 1993; Goldsmith 1994; Hardy and Weill 1995; Beckett 1997; Murphy et al. 1998) and to the widespread medical and cosmetic use of prosthetic devices and other implants, pathologists now are also called upon to recognize foreign materials within human tissue, including the products of interactions between tissue and inhaled particles or implants (e.g., Bérubé et al. 1998). Two questions are discussed here. (1) What are the compositions and structures of the non-cellular materials that are found in human tissue? This is more a mineralogic and materials-science issue than a medical one. (2) Why are certain crystalline materials found in human tissue? This is a biological and medical issue, but materials and earth scientists can provide helpful insights based on their knowledge of the stability, solubility, and precipitation of natural inorganic crystalline materials (e.g., Skinner et al. 1988; Guthrie 1992; Guthrie and Mossman 1993; Werner et al. 1995; Poggi et al. 1998).

ABSTRACT

Medical questions surrounding the toxicity of “silica” and other silicon-containing materials introduced into the body can be answered only through use of microanalytical techniques that provide chemical and structural analyses of microscopic and submicroscopic particles. A useful approach to the study of minerals and other foreign substances associated with silicone breast implants is to use polarized-light optical microscopy to pinpoint the materials of interest in the tissue and to follow that observation with analysis by Raman spectroscopy. Silicone breast implants contain both the organic polymer silicone and particles of amorphous silica. We studied the breast tissue from six women who had silicone breast implants and from three controls who never had implants to address questions about post-implant alteration, such as to “crystalline SiO2.” Optical analysis of the mammary tissue sections revealed a variety of birefringent and non-birefringent, non-cellular materials. Raman spectroscopic analyses of those substances identified many similar materials in tissue from women with and without silicone implants: calcite, apatite, starch, lipid, and β-carotene. We also spectroscopically identified silicone (only in breast tissue from patients recognized to have had ruptured implants) and paraffin (only in one sample that had been embedded in paraffin and subsequently “deparaffinized”). In tissue sections of 5 µm thickness (standard thickness of pathology sections), it is impossible to detect optically the birefringence of quartz (or any other form of crystalline SiO2), even though it may be possible to image such thin crystalline SiO2 grains in polarized light due to light-scattering phenomena. Moreover, neither crystalline nor amorphous silica was identified by Raman spectroscopy in the tissue sections. Review of the pathology literature on such materials-based issues as silicosis and calcification revealed some misapplication of the optical microscopy term “birefringence” and misleading identifications of minerals in tissue sections. Our conclusion is that useful collaborations can be developed between (1) pathologists who observe foreign materials in tissue sections and understand the medical context of their findings and (2) mineralogists who routinely use optical, chemical, and structural analyses to characterize micrometer-sized crystalline materials and who understand materials properties.