In situ discovery of shock-induced graphite-diamond phase transition in gneisses from the Ries Crater, Germany

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ABSTRACT

Reflected-light microscopy and fine-scale laser microRaman spectroscopy of shocked garnet-cordierite-sillimanite gneisses in suevites of the Ries meteorite impact crater, Germany, led to the discovery of impact diamonds in their pristine graphite-diamond assemblages. Graphite-diamond textural relations permit a clear determination of the solid-state nature of the formation of diamond from graphite, which is estimated to have occurred at a peak-shock pressure between 30 and 40 GPa. Shock-induced transformations were promoted only in unkinked and undeformed graphite booklets at the graphite-garnet, graphite-sillimanite, or graphite-rutile interfaces, where the difference in shock impedance is very high. Reverberations of shock waves with short wavelengths similar to the grain sizes at the phase boundaries are probably important constraints for dynamic graphite-diamond phase transformation. Raman spectroscopic investigations of hard transparent carbon platelets intercalated between fine-grained diamond and deformed graphite revealed the platelets to be Raman inactive. The platelets are either dense amorphous carbon or an unknown dense crystalline carbon phase that is Raman inactive.

INTRODUCTION

Impact diamonds in the Ries Crater in Germany were first found in glass bombs by Rost et al. (1978). Recently, they were also reported from impactite glass bombs and shocked rocks from different meteorite impact craters by Abbott et al. (1996), Hough et al. (1995), Koebeler et al. (1997), Langenhorst et al. (1998), Siebenschock et al. (1998, 1999), and Boudouelle et al. (1999). In every case, the impact diamonds recovered by all of these researchers and by Schmitt et al. (1999) and Hough et al. (1999), come from acid- or alkali-demineralized residues of glass bombs and shocked metamorphic rocks. Unfortunately, such enrichment procedures have disaggregated the graphite-diamond intergrowth and separated diamond crystals from the majority of their graphite precursors. The absence of graphite in mineral concentrates recovered by some researchers has been used as an argument for complete graphite-diamond phase transformation. In addition, a reliable delineation of the pristine graphite-diamond textural relationships through the study of the diamond residues was not feasible. The pristine textural relationships might provide valuable insights into the nature of the formation mechanism of diamond from graphite under natural shock-wave conditions. Furthermore, in the majority of these studies, an estimate of the degree of the shock-induced phase transformation could not be achieved. In addition, the majority of silicate and oxide minerals coexisting with the impact diamonds and graphite were destroyed during the cyclic chemical treatment. This chemical treatment has inhibited the possibility of a reliable peak-shock pressure calibration through estimation of the degree of shock deformation of the coexisting minerals. Both Masaitis et al. (1995, 1998a, 1998b) and Koebeler et al. (1997) reported the in-situ occurrence of transparent grains, which they believed to be diamonds, in a shock-metamorphosed granite-gneiss inclusion in suevite from the Ries crater, Germany, and from a shocked metamorphic rock from Popigai, Russia. However, the nature of these grains, whether diamond or another phase (e.g., monazite or zircon), was not verified in-situ by any physical method. Our investigations of transparent grains with the same habit and optical properties of a grain thought by Koebeler et al. (1997) to be diamond (Fig. 1a in Koebeler et al.) in Popigai Tagamites revealed that these grains are zircon. No information about the diamond-graphite textural relationships was given in any of the previous reports.

Shock-wave experiments of well-ordered graphite by DeCarli and Jamieson (1961) revealed only partial graphite-diamond phase transformation at 30 GPa. Hirai et al. (1995) suggested that the phase transformation under dynamic conditions is much easier at low graphite crystallinity and small crystal size of the graphite. In contrast to Hirai et al. (1995), DeCarli (1995) also indicated that the degree of phase transformation...