A shock-induced polymorph of anatase and rutile from the Chesapeake Bay impact structure, Virginia, U.S.A.

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ABSTRACT

A shock-induced polymorph (TiO₂ II) of anatase and rutile has been identified in breccias from the late Eocene Chesapeake Bay impact structure. The breccia samples are from a recent, partially cored test hole in the central uplift at Cape Charles, Virginia. The drill cores from 744 to 823 m depth consist of suevitic crystalline-clast breccia and brecciated cataclastic gneiss in which the TiO₂ phases anatase and rutile are common accessory minerals. Electron-microprobe imaging and laser Raman spectroscopy of TiO₂ crystals, and powder X-ray diffraction (XRD) of mineral concentrates, confirm that a high-pressure, α-PbO₂ structured polymorph of TiO₂ (TiO₂ II) coexists with anatase and rutile in matrix-hosted crystals and in inclusions within chlorite. Raman spectra of this polymorph include strong bands at wavenumbers (cm⁻¹) 175, 281, 315, 342, 356, 425, 531, 571, and 604; they appear with anatase bands at 397, 515, and 634 cm⁻¹, and rutile bands at 441 and 608 cm⁻¹. XRD patterns reveal 12 lines from the polymorph that do not significantly interfere with those of anatase or rutile, and are consistent with the TiO₂ II that was first reported to occur naturally as a shock-induced phase in rutile from the Ries crater in Germany. The recognition here of a second natural shock-induced occurrence of TiO₂ II suggests that its presence in rocks that have not been subjected to ultrahigh-pressure regional metamorphism can be a diagnostic indicator for confirmation of suspected impact structures.

Keywords: Phase transition, anatase, rutile, polymorph, shock metamorphism, Chesapeake, impact, crater

INTRODUCTION

The common forms of titanium dioxide (TiO₂) in the Earth’s crust are rutile, anatase, and brookite. The first natural occurrence of an unnamed dense polymorph of TiO₂ (TiO₂ II) attributed to shock metamorphism was found in the Ries impact crater in Germany (El Goresy et al. 2000, 2001a–2001c). TiO₂ II has an orthorhombic structure similar to that of α-PbO₂. We have found a second shock-induced occurrence of this TiO₂ polymorph co-existing with anatase and rutile in the Chesapeake Bay impact structure.

The buried, late Eocene Chesapeake Bay impact structure formed about 35 million years ago when an asteroid or comet nucleus struck what is now the Atlantic margin of Virginia in a layered target of seawater, sediment, and rock (Powars and Bruce 1999; Poag et al. 2004; Horton et al. 2005c). The 85 km structure consists of a central crater, having a broad central uplift surrounded by an elliptical moat, and a surrounding annular trough of slumpfed sediments (Horton et al. 2005b, 2005c). Pre-impact chloritization in granites that underlie the outer part of the Chesapeake Bay impact crater, and pervasive post-impact albitionization and chloritization in breccias over the central uplift have been described (Horton et al. 2005a, 2005b).

In 2004, the United States Geological Survey (USGS) drilled an 823 m test hole into the central uplift of the Chesapeake Bay impact structure near Cape Charles, Virginia (Sanford et al. 2004). Three main lithostratigraphic intervals were delineated in the test hole based on cuttings and cores, as well as geophysical logs (Horton et al. 2004, 2005b; Sanford et al. 2004): (1) a lower crater section of crystalline-clast breccia (including suevite) and brecciated gneiss, (2) an upper crater section of sediment-clast breccia, and (3) post-impact sediments. Most of the drill cores are from the lower crater section of crystalline clast breccia and brecciated gneiss. Samples of these drill cores contain abundant shocked quartz, shocked feldspar, and cataclastic fabrics (Horton et al. 2004, 2005b). This paper is a result of our search for additional shock-induced minerals in rocks of the central uplift.

Preliminary X-ray diffraction (XRD) of drill-core samples from the Cape Charles test hole in the central uplift of the Chesapeake Bay impact structure revealed that the TiO₂ phases anatase and rutile are common accessory minerals in the crystalline-clast breccia and brecciated gneiss. The common presence of TiO₂ phases prompted us to search our Cape Charles samples for the TiO₂ II polymorph discovered by El Goresy et al. (2000, 2001a, 2001c) in clasts of shocked garnet gneiss from suevitic breccia in the Ries crater. The XRD and Raman data for Ries crater TiO₂ II correlated well with those for the synthetic α-PbO₂ structured polymorph of TiO₂ (Linde and DeCarli 1969; Gerward and Olsen 1997).

SAMPLES AND METHODS

Drill cores from depths of 744 to 823 m consist of suevitic crystalline-clast breccia and brecciated cataclastic gneiss. Samples ST2490.2, and ST2511.2 are brecciated gneisses obtained from depths of 2490.2 ft. (747.06 m), and 2511.2 ft. (753.36 m), respectively. To concentrate and identify any shock-induced mineral phases that might be present, including coesite and stishovite, mineral concentrates were produced by acid decomposition of selected whole rock splits. Coesite and