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A new model for rapid global climate changes: explosive venting of greenhouse gases from metamorphic aureoles around sills in volcanic basins, and its relevance for the PETM and the Toarcian global warming

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The Paleocene-Eocene thermal maximum (PETM) and the Toarcian (Early Jurassic) global warming and carbon cycle perturbations have been explained by massive release of carbon to the atmosphere. The source of this carbon is however strongly debated. Both melting of gas hydrates and volcanic degassing have been suggested as sources. However, neither of the hypotheses can fully explain the available proxy data. We present new results from the Karoo Basin in South Africa suggesting that the Toarcian global warming was triggered by carbon release from heated sedimentary rocks around sill intrusions. In addition, we put the new results in the context of our 2004 model for triggering of the PETM (Svensen et al., 2004, *Nature* 429).

The Karoo Basin in South Africa was intruded by voluminous basaltic melts in the Early Jurassic. Black organic-rich shale in the lower parts of the Karoo Basin (the Ecca Group) were intruded by up to 130 m thick sub-horizontal magmatic sills, whereas dominantly saucer-shaped sills were emplaced in the overlying fluvial sedimentary sequences. Emplacement of sill in the shale caused rapid maturation of the organic matter and generation of CH_4 and CO_2. The subsequent pressure build-up led to vent formation and gas release to the atmosphere. We present new geochemical data supporting loss of carbon and other light elements from heated shale. Mass balance calcu-

lations suggest that the volume of the released greenhouse gases was likely sufficient to trigger the Toarcian global warming.

The Vøring and Møre basins offshore Norway were intruded by a sill complex about 55 Ma that resulted in the formation of thousands of hydrothermal vent complexes. There are many similarities between the vent formations in these two different settings, and the contact aureoles from South Africa gives complimentary data relevant to understand the 55 Ma event. This strengthens the applicability of these events for understanding the consequences of anthropogenic carbon emissions.