Icarus 264 (2016) 352–368

Contents lists available at ScienceDirect

Icarus

journal homepage: www.journals.elsevier.com/icarus

Mid-infrared spectroscopy of impactites from the Nördlinger Ries impact crater

Andreas Morlok [a,*], Aleksandra Stojic [a], Isabelle Dittmar [b], Harald Hiesinger [a], Manuel Tiedeken [a], Martin Sohn [b], Iris Weber [a], Joern Helbert [c]

[a] Institut für Planetologie, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany
[b] Hochschule Emden/Leer, Constantiaplatz 4, 26723 Emden, Germany
[c] Institute for Planetary Research, DLR, Rutherfordstrasse 2, 12489 Berlin, Germany

ARTICLE INFO

Article history:
Received 17 April 2015
Revised 25 September 2015
Accepted 2 October 2015
Available online 20 October 2015

Keywords:
Spectroscopy
Impact processes
Infrared observations
Instrumentation

ABSTRACT

This study is part of an effort to build a mid-infrared database (7–14 μm) of spectra for MERTIS (Mercury Radiometer and Thermal Infrared Spectrometer), an instrument onboard of the ESA/JAXA BepiColombo space probe to be launched to Mercury in 2017.

Mercury was exposed to abundant impacts throughout its history. This study of terrestrial impactites can provide estimates of the effects of shock metamorphism on the mid-infrared spectral properties of planetary materials.

In this study, we focus on the Nördlinger Ries crater in Southern Germany, a well preserved and easily accessible impact crater with abundant suevite impactites. Suevite and melt glass bulk samples from Otting and Aumühle, as well as red suevite from Polsingen were characterized and their reflectance spectra in mid-infrared range obtained. In addition, in-situ mid-infrared spectra were made from glasses and matrix areas in thin sections. The results show similar, but distinguishable spectra for both bulk suevite and melt glass samples, as well as in-situ measurements.

Impact melt glass from Aumühle and Otting have spectra dominated by a Reststrahlen band at 9.3–9.6 μm. Bulk melt rock from Polsingen and bulk suevite and fine-grained matrix have their strongest band between 9.4 and 9.6 μm. There are also features between 8.5 and 9 μm, and 12.5–12.8 μm associated with crystalline phases. There is evidence of weathering products in the fine-grained matrix, such as smectites. Mercury endured many impacts with impactors of all sizes over its history. So spectral characteristics observed for impactites formed only in a single impact like in the Ries impact event can be expected to be very common on planetary bodies exposed to many more impacts in their past. We conclude that in mid-infrared remote sensing data the surface of Mercury can be expected to be dominated by features of amorphous materials.

1. Introduction

The aim of this study is to provide mid-infrared reflectance spectra with special emphasis on the region from 7 μm to 14 μm for a range of impactites for the application in planetary remote sensing. We generate these spectra for a database for the ESA/JAXA BepiColombo mission to Mercury (Benkhoff et al., 2010). Onboard is a mid-infrared spectrometer (MERTIS-Mercury Radiometer and Thermal Infrared Spectrometer). This unique device allows mapping spectral features in the 7–14 μm range, with a spatial resolution of ~500 m (Helbert and Maturilli, 2009; Benkhoff et al., 2010; Hiesinger et al., 2010).

Infrared spectroscopy provides a means to characterize the mineralogy of rocks via remote sensing, in contrast to Gamma-Ray, Neutron and X-ray spectrometers, which determine elemental compositions (Pieters and Englert, 1993). Thus, IR spectroscopy provides a central analytical tool to determine the mineralogy of remote planetary surfaces. In order to correctly interpret the remote sensing data, laboratory spectra of natural, synthetic rocks and minerals have to be collected to compare them to the spectra that will be obtained from MERTIS, once BepiColombo enters the Hermean orbit (Maturilli et al., 2008; Hiesinger et al., 2010).

* Corresponding author.
E-mail addresses: morlokan@uni-muenster.de (A. Morlok), a.stojic@uni-muenster.de (A. Stojic), Isabelle.Dittmar@hs-emden-leer.de (I. Dittmar), hiesinger@uni-muenster.de (H. Hiesinger), manuel.tiedeken@uni-muenster.de (M. Tiedeken), martin.sohn@hs-emden-leer.de (M. Sohn), sonderm@uni-muenster.de (I. Weber), joern.helbert@dlr.de (J. Helbert).

http://dx.doi.org/10.1016/j.icarus.2015.10.003
0019-1035/

Comparable earlier instruments were the Thermal Emission Spectrometer (TES) on the Mars Global Surveyor (Christensen et al., 2005) and the Thermal Emission Imaging System (THEMIS) on the Mars Odyssey orbiter (Christensen et al., 2004). The lunar surface was mapped in the mid-infrared with the DIVINER Lunar Radiometer Instrument on the Lunar Reconnaissance Orbiter (Paige et al., 2010). The OSIRIS-REx Thermal Emission Spectrometer (OTES) will map Asteroid Bennu (1999 RQ36) (Hamilton and Christensen, 2014), and the Thermal Infrared Imager (TIR) onboard Hayabusa 2 will map Asteroid 1999JU3 (Okada et al., 2015).

The Ries crater in southern Germany (Fig. 1) provides well preserved layers of impactites and is one of the best studied impact sites in the world (von Engelhardt et al., 1995). The 14.6 Myr old crater with a diameter of 24 km (Buchner et al., 2010) offers the whole range of impact-associated rocks and minerals (von Engelhardt, 1990). Large impact events play a key role in surface modification processes in effect on most terrestrial planets and their moons (Hörz and Cintala, 1997). Thus, the investigation of terrestrial impact processed rocks and understanding how these processes affect the spectral properties of the resulting impact generated rocks and melt glass is important for the interpretation of infrared data from the surfaces of other planetary bodies. Given the characteristics of surface regolith, we need spectral data from different grain size fractions. This is necessary because grain size variations affect the corresponding spectra immensely by reducing the spectral contrast of features and creating additional features at small grain sizes (e.g., Salisbury and Eastes, 1985; Salisbury and Wald, 1992; Mustard and Hays, 1997; Ruff and Christensen, 2002).

Reflectance and emission studies about spectral features in the mid-infrared in minerals undergoing high shock metamorphism including formation of melt glass were made on experimentally shocked samples, e.g., on anorthosite, pyroxenite, basalt, and feldspar (Johnson et al., 2002, 2003, 2007; Johnson, 2012; Jaret et al., 2015). In these studies, especially feldspar-rich material showed loss and degradation of features, as well as band shifts with increasing structural disorder resulting from increasing shock

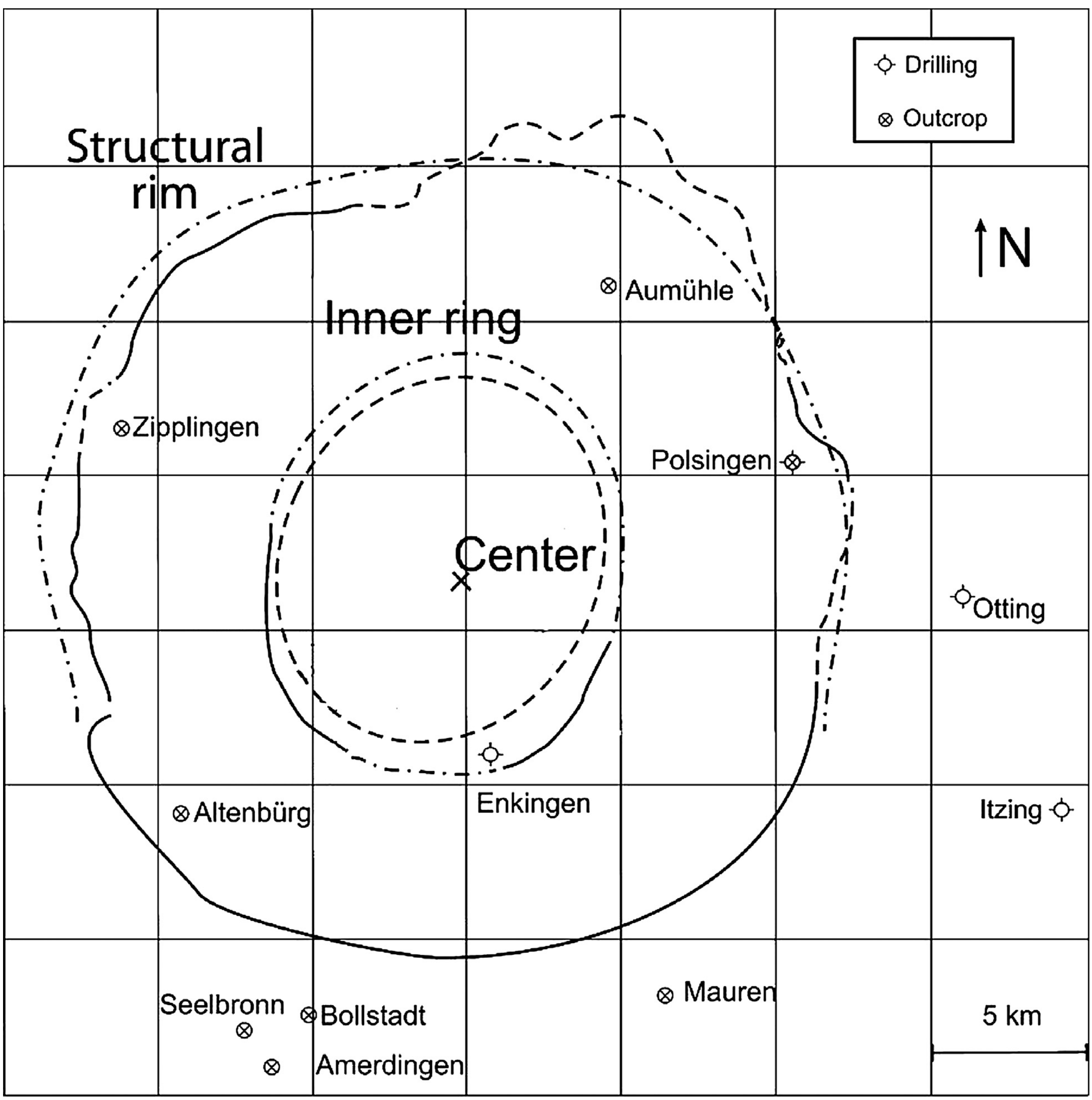

Fig. 1. Map of the Ries area (adapted from Stöffler et al., 2013). Samples for this study were taken in the Otting, Aumühle and Polsingen locations.