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Comment

Comment on "A high-precision $^{40}Ar/^{39}Ar$ age for the Nördlinger Ries impact crater, Germany, and implications for the accurate dating of terrestrial impact events" by Schmieder et al. (Geochimica et Cosmochimica Acta 220 (2018) 146–157)

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Abstract

Schmieder et al. (2018) suggest an impact age for the Ries crater in Southern Germany that is at odds with paleomagnetic systematics and thus geologically impossible, even within its external 2-sigma error. Paleomagnetic systematics allow for only two alternative impact ages that are both tightly constrained by orbital tuning. The relative differences to the Schmieder et al. (2018) age amount to 60 and 200 ka, respectively. Such time intervals are, however, highly significant with respect to the timing of climatic and environmental signals recorded in the Middle Miocene molasses sediments.

The accuracy of high-precision geochronological data may occasionally be tested if complementary geological information is available. The 15 Ma old Ries meteorite impact crater at Nördlingen, South Germany, provides such an opportunity. Here a wealth of isotopic age determinations can be evaluated against a geological framework based on orbital tuning and paleomagnetic data (see Fig. 1).

Schmieder et al. (2018) provide new high-precision $^{40}A/^{39}Ar$ age data on various moldavite glasses. Moldavites are tektites generated during the Ries meteorite impact and transported several hundreds of kilometers to the east as far as Moravia, Lower Austria, Bohemia, Lusatia and SW-Poland. The authors dated moldavite samples using a new generation high-precision multi-collector noble gas mass spectrometer and derived an impact age of 14.808 ± 0.038 Ma (total 2σ error), which overlaps by more than 93% with the normal chron C5Bn.1 (14.870–14.775 Ma). Considering paleomagnetic evidence for a reversed magnetic field (Pohl, 1977, 1978) the authors then conclude that the impact

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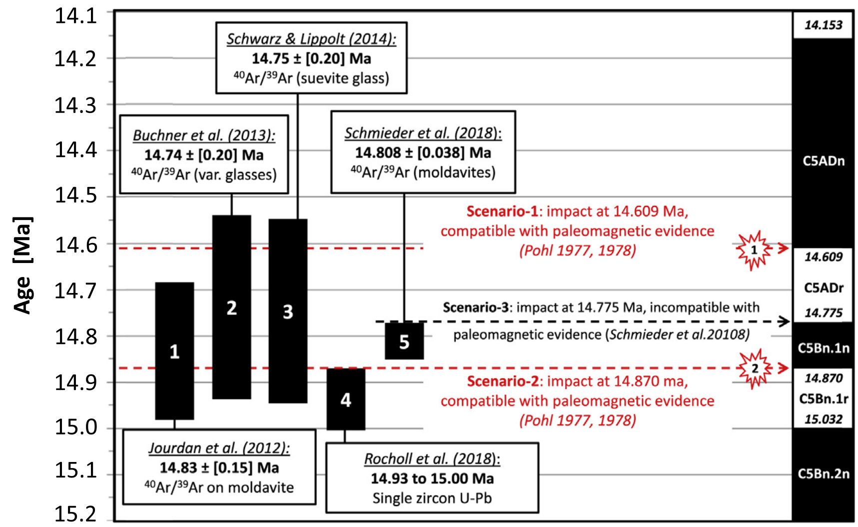

Fig. 1. Recently published formation ages for the Ries impact crater at Nördlingen, South Germany. The paleomagnetic record (Pohl, 1977, 1978) designates the impact to a chron boundary characterized by a switch from a reversed to normal magnetic field polarity. The two possible impact dates (Scenarios-1 and 2) which are compatible with paleomagnetic evidence are indicated by red arrows and stars. In contrast, the Schmieder et al. (2018) impact age (Scenario-3) violates the paleomagnetic evidence. Geomagnetic polarity chrons after ANTS2012 (Hilgen et al., 2012). Normal chrons are shown in black, reversed chrons in white.

occurred at around 14.775 Ma, i.e. contemporary to the switch from normal chron C5Bn.1 to reversed chron C5ADr. This most recent and highly precise age value may be expected to serve as a reference for forthcoming paleontological, paleoclimatic, paleo-environmental and stratigraphic studies, which involve the "Brockhorizont", a layer of carbonatic Ries ejecta, as a stratigraphic marker. This is highly unfortunate because the 14.775 Ma age value is clearly not concordant with paleomagnetic and paleontological systematics and thus will lead to erroneous geological implications.

The problem is illustrated in Fig. 1, which covers the time frame of suggested impact ages (e.g., Storzer et al., 1995, Buchner et al., 2013) and encompasses five different magnetic polarity chrons. The chron boundaries are astronomically tuned with extraordinarily high precision and accuracy (ATNTS2012, Hilgen et al., 2012), i.e. with uncertainties ranging between 3 and 10 ka (Hüsing et al., 2010; Hilgen et al., 2012). Note that astronomical tuning is not an isotope-based dating technique such as U-Pb or $^{40}Ar/^{39}Ar$. Instead it is based on the highly precise orbital clockwork as expressed by the Milankovic cycles, and these can be calculated for the past 60–80 Ma with an enormous degree of confidence.

The diagram also depicts the 2-sigma ranges of the five most recent age estimates published by Jourdan et al. (2012; recalculated from Di Vicenzo and Skála, 2009), Buchner et al. (2013), Schwarz and Lippold (2014), Rocholl et al. (2018) and Schmieder et al. (2018). All data, except those by Rocholl et al. (2018) are based on the $^{40}Ar/^{39}Ar$ analysis of tektites and/or impact melts. In contrast, Rocholl et al. (2018) report U-Pb ages obtained on single zircons sampled from tuff layers over- and underlying the Ries ejecta ("Brockhorizont").

The paleomagnetic data of Pohl (1977, 1978) indicate that the impact took place during a reversed chron time interval. Chrons of normal magnetization are therefore inconsistent. For the time window under discussion, either the reversed chrons C5Bn.1r (15.032–14.870 Ma) or C5ADr (14.775–14.609 Ma) are relevant. Additionally, Pohl (1977, 1978) concluded that the impact occurred concurrently with a switch from a reversed to a normal chron, i.e. at or close to a chron boundary. This is best evidenced in the 1200 m drill-core *Nördlingen 1973*. Here, the polarity of the high-temperature suevite fallback breccia is reversed, while the lowest series of pelitic sediments in the crater lake, which formed immediately after impact (Stöffler et al., 2013), is normally magnetized. This observation led Pohl (1978) to suggest that the impact may have even triggered the geomagnetic switch. The two magnetostratigraphic constraints allow for two alternative impact ages at around 14.870 Ma (C5Bn.1r-C5Bn.1n boundary) and 14.609 Ma (C5ADr-C5ADn boundary), respectively, both dated with high accuracy by means of orbital tuning. The two possible impact ages are indicated by the red stars and arrows in the diagram.

The diagram also reveals that the 2-sigma range of Schmieder et al. (2018) overlaps nearly completely with the normal and thus "forbidden" chron C5Bn.1n. A slight overlap of about 5 ka with reversed chron C5ADr exists, if "all 2-sigma uncertainties" (p. 153, Fig. 5) are considered, but not for the internal 2-sigma uncertainty. In order to meet the prerequisite of a reversed chron, Schmieder et al. (2018) allocate the impact to *14.775 Ma*. However, it is evident from the diagram that this date marks the *beginning* of reversed chron C5ADr but not its *end* as required from the paleomagnetic record. The age value of Schmieder et al. (2018) thus violates the paleomagnetic constraints and is

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therefore geologically impossible. Accordingly, the authors' statement of a "*within error limits accurate*" impact age (page 151) is not accurate. Note that the age differences relative to the two possible impact ages amounts to 60 and 200 ka, respectively. These time laps are both significant with respect to climatic and environmental changes recorded in the Middle Miocene molasses sediments.

We conclude that the Ries impact age value suggested by Schmieder et al. (2018) is geologically impossible, even within its external 2-sigma error. In especial, it is not compatible with paleomagnetic evidence, which allows only for two possible impact ages at 14.870 Ma and 14.609 Ma. The two most recent high-precision data sets by Schmieder et al. (2018) and Rocholl et al. (2018) clearly support the older age.

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