Iridium anomalies and shocked quartz in a Late Archean spherule layer from the Pilbara Craton: New evidence for a major asteroid impact at 2.63 Ga: Comment and Reply

COMMENT

Andrew Glikson*
Department of Earth and Marine Sciences, Australian National University, Canberra, ACT 0200, Australia

Simonson (1992), Simonson and Hassler (1997), and Simonson et al. (2000) discovered extraterrestrial impact ejecta in the Hamersley and Fortescue Groups, Pilbara Craton, Western Australia, and noted the absence of shocked quartz grains (Simonson et al., 1998). Rasmussen and Koeberl (2004) identify a quartz grain with planar deformation features (PDFs) in the ~2.63 Ga Jeerinah Impact Layer—the oldest shocked quartz grain recorded to date. These authors extend the known distribution of the Jeerinah Impact Layer to two new drill holes (WRL-1, DDI-186) and refer to the possible correlation between the Jeerinah Impact Layer (central Hamersley Basin) and impact spherules in the Carawine Dolomite (east Hamersley Basin)—~200 km east-northeast from the easternmost known occurrence of the Jeerinah Impact Layer. I question (1) the stratigraphic correlations between the Jeerinah Impact Layer and Carawine Dolomite, and (2) the authors’ suggestion that the Jeerinah Impact Layer impact occurred on continental crust.

Rasmussen and Koeberl (2004, p. 1031) state: “Based on petrographic similarities and stratigraphic position, the Jeerinah spherule layer was recently correlated with the Carawine horizon in the Oakover River area of the Pilbara Craton (Fig. 1) (Simonson et al., 2000):” However, whereas the Jeerinah Impact Layer occurs at the top of the Jeerinah Formation (shale, mafic volcanics, 2.68–2.63 Ga), the Carawine Dolomite is located within carbonate-dominated basin facies of this formation. Due to the absence in the east Hamersley Basin of the marker Marra Mamba Iron Formation (2597 ± 5 Ma; Trendall et al., 1998), a Jeerinah Impact Layer–Carawine Dolomite correlation is far from certain. I list here several factors which support a correlation between the Carawine Dolomite and the 2560 ± 7 Ma spherule marker bed of the Wittenoom Formation (Glikson, 2004):

1. Microkrystite spherules of the Carawine Dolomite are located stratigraphically above, as well as injected as microbreccia veins into, a 10–30 m-thick stratigraphically consistent chert fragment–bearing carbonate megabreccia (Simonson, 1992; Simonson and Hassler, 1997). This Carawine Dolomite unit straddles a ~100-km-long strike between Ripon Hills and the Woodie-Woodie area, east Hamersley Basin, and is interpreted in terms of sea floor excavation by a mega-tsunami immediately preceding the fallout of microkrystite spherules (Glikson, 2004).

2. The above relations contrast with the Jeerinah Impact Layer–type section at Hesta (see Figure 1 in Rasmussen and Koeberl, 2004) where the Jeerinah Impact Layer is located above interlayered ferruginous shale and chert above the Jeerinah Formation. The spherules underlie a debris flow breccia, suggesting arrival of the tsunami postdated fallout of spherules. These differences, which reflect differential timing of ejecta fallout and tsunami arrival, complicate stratigraphic correlations.

3. Pb-Pb isotopic studies (Woodhead et al., 1998) suggest a broad age overlap between the Carawine Dolomite (2548 ±26/−29 Ma) and the Wittenoom Formation (2541 ±18/−15 Ma), consistent with the U-Pb age of felsic tuff within the latter (2561 ± 6; Trendall et al., 1998). Both of these units contain microtektites as well as microkrystites. Despite the large errors of the Pb-Pb ages, the Jeerinah Impact Layer may thus be older than the Carawine Dolomite by at least 55 m.y.

Rasmussen and Koeberl (2004, p. 1031) state: “The presence of shocked quartz in the Jeerinah spherule bed indicates that the impact site contained quartz, favoring a continental target rather than an oceanic site.” This interpretation appears to assume that early Precambrian oceanic regimes were lacking in quartz-bearing felsic volcanics and derived sediments, as contrasted with the common occurrence of dacite and rhyolite and felsic tuff intercalations in mafic-ultramafic sequences of Archean greenstone belts—variedly interpreted in terms of tectonic crustal relicts or island arc assemblages. Thus, the presence of a minor shocked quartz component is not evidence for continental impact, nor does it preclude impact in simatic or mixed sial-sima crustal environments.

Clues to the composition of the impacted crust may be furnished from the overall chemistry of least-altered portions of the ejecta. The extensive replacement of spherules by quench K-feldspar, possibly representing absorption of K from seawater during settling of the spherules due to high K_{sea/spherule}, partition coefficients (Glikson and Allen, 2004), and subsequent burial metamorphism, complicate identification of primary geochemical features. On the other hand, the preservation of platinum-group-element anomalies (McDonald and Simonson, 2002; Rasmussen and Koeberl, 2004) in the Jeerinah Impact Layer and of nickel nanoungets in the 2.47–2.50 Ga DGS4 impact unit (Glikson and Allen, 2004) suggest local retention of primary chemical and mineralogical features.

The common presence of chlorite in the Jeerinah Impact Layer microkrystite spherules and locally elevated ferromagnesian element abundances hint at mafic components in the source. Further geochemical studies of the Jeerinah Impact Layer are required to elucidate its origin. A study of orientation of the PDFs in the shocked quartz fragment (Rasmussen and Koeberl, 2004) may yield further clues to the shock pressures involved in the ~2.63 Ga impact.

REFERENCES CITED


We welcome a discussion of the Jeerinah Impact Layer and its likely stratigraphic correlation. Glikson accepts the interpretation of the Jeerinah Impact Layer as a distal ejecta layer as first proposed by Simonson et al. (2000), but questions our correlation of the Jeerinah Impact Layer with the Carawine layer, as well as our suggestion that the layer contains debris from a continental impact.

Glikson argues for a correlation between the Wittenoom (rather than Jeerinah) and Carawine spherule beds based on two lines of evidence, the first of which is the different location of spherules relative to interpreted impact-related tsunami deposits in the Jeerinah Impact Layer and the Carawine layer. Specifically, spherules in the Jeerinah Impact Layer from the Hesta Site (see Figure 1 in Rasmussen and Koeberl, 2004) underlie a debris flow breccia, whereas in the Ripon Hills area, spherules occur above a thick dolomixtite unit (Simonson, 1992), suggesting differences in the timing of ejecta fallout and tsunami-induced debris flow in the two layers.

Secondly, Glikson cites Pb/Pb carbonate isochron dates by Woodhead et al. (1998) as further supportive evidence of a correlation between the Wittenoom layer (2541 ± 18/−15 Ma) and the Carawine layer (2548 ±26/−29 Ma). While the Pb/Pb date for the Wittenoom layer is consistent with a SHRIMP U-Pb zircon date (2561 ± 8 Ma) for an underlying tuff in the Wittenoom Formation (Trendall et al., 1998), there is no supportive age data for the Carawine layer. Simonson et al. (2002) recently proposed a correlation between the Jeerinah Impact Layer and the Carawine layer based on palaeogeographic considerations, the presence of “larger, more irregular particles of impact-generated, flow-banded melt” in the Jeerinah Impact Layer (at the Hesta site) and the Carawine layer (at Ripon Hills and the Tarra Tarra turnoff site), and similar ⁵⁶Cr/⁵⁴Cr compositions (Shukolyukov et al., 2002) in the Jeerinah Impact Layer and the Carawine layers, pointing to an ordinary chondrite as the impactor for both layers.

This correlation was recently confirmed by SHRIMP zircon geochronology of a tuff bed ~30 m below the spherule-bearing dolomixtite unit in the Ripon Hills area. The tuff yielded a U-Pb date (Rasmussen et al., 2005) that is indistinguishable from a SHRIMP U-Pb zircon date (2629 ± 5 Ma) from a tuff in the uppermost Jeerinah Formation in the Hamersley Province (Trendall et al., 2004). This result suggests that the Jeerinah Impact Layer and the Carawine spherule bed formed during a single impact ~2.63 Ga. This result has implications for the veracity of Pb/Pb carbonate dating and raises questions about the relationship between the spherule layers and debris flows used as evidence for a Wittenoom-Carawine correlation.

Glikson also questions our suggestion that “The presence of shocked quartz in the Jeerinah spherule bed indicates that the impact site contained quartz, favoring a continental target rather than an oceanic site” (Rasmussen and Koeberl, 2004, p. 1031). Glikson (2005, p. 125) states that “the absence of shocked quartz grains in recorded early Precambrian ejecta and the largely ferromagnesian compositions of the microkrytite spherules…are consistent with impacts into mafic to ultramafic crust.” Now that we document shocked quartz in one of the layers, Glikson argues that the presence of shocked quartz is still consistent with his conclusions. We note that the only demonstrable target component in the Jeerinah Impact Layer is the shocked quartz. All other minerals (including chlorite) could be diagenetic, metamorphic, or detrital (and unrelated to the impactor or target rock). Therefore, we maintain that the presence of shocked quartz favors a continental, over an oceanic, impact site.

Finally, Glikson’s comment that “A study of orientation of the planar deformation features in the shocked quartz fragment (Rasmussen and Koeberl, 2004) may yield further clues to the shock pressures involved in the ~2.63 Ga impact,” is an impractical suggestion. Rasmussen and Koeberl (2004) already noted that the orientations of the planar deformation features in the quartz grain were measured by universal stage, but it is obvious that such measurements are only meaningful if a statistically significant number of grains are present, which is clearly not the case here.

REFERENCES CITED


*E-mails: brasmuss@segs.uwa.edu.au; christian.koeberl@univie.ac.at.