Invited comments on Kirkham's 'Glauconitic spherules from the Triassic of the Bristol Area, SW England: probable microtektite pseudomorphs'

Proceedings, Vol. 114, 2003, pp. 11–21

Comment

Billy P. Glass

Kirkham describes some 'glauconitic' spherules found in the Bristol area of SW England. He lists several possible origins for the spherules, including volcanic, but concludes that they are probably of impact origin. He does not, however, discuss why the other possible origins do not explain the observations. Although the spherules do exhibit features similar to some Cretaceous–Tertiary (K–T) boundary spherules, the lack of teardrop and dumbbell shapes is a problem. The strongest argument for an impact origin is the recovery of 'rare shocked-quartz grains' associated with the Wickwar spherules. Unfortunately, only one photomicrograph of a quartz grain exhibiting planar features was included and no description of the planar features (such as spacing, thickness, crystallographic orientations) is given. No other evidence of shocked mineral grains is reported and there has apparently been no search for an iridium anomaly, except by EDX analysis of the spherules (which, as Kirkham points out, is not capable of detecting Ir at the ppm level). On the other hand, tektites and microtektites are not known to contain Ir concentrations above crustal levels (Koeberl, 1994).

Kirkham interprets the 'glauconitic' spherules as being diagenetically altered microtektites. Cenozoic tektites show little, if any, evidence of alteration. Some microtektites appear to show evidence of hydration (Glass *et al.*, 1997). However, the extensive alteration exhibited by the Wickwar spherules, assuming that they were originally glass, is more comparable to that exhibited by the K/T boundary spherules which were silica-poor compared with most Cenozoic tektites and microtektites. Many authors do not consider the K/T boundary spherules to be diagenetically altered microtektites, but rather just simply impact spherules (e.g. Koeberl & Sigurdsson, 1992). If the Wickwar spherules are diagenetically altered impact spherules, then they probably originally had a low silica content. One of the criteria for recognizing microtektites is that they must occur in a strewn field covering a large portion of the Earth's surface at some distance from the source crater (Koeberl, 1994). Since the Wickwar spherules have only been reported at one site, we do not yet know if they occur within a more extensive strewn field. Until more is known about the geographical distribution of these spherules, it would be more appropriate to simply refer to them as impact spherules, assuming that they actually have an impact origin.

The Wickwar spherule layer is not well dated. In spite of this, Kirkham speculates about the possibility that they might relate to one of the Permian or Triassic mass extinctions. Assuming that the Wickwar spherules are impact spherules, it is not possible at this time to say much about the size of the impact that produced them, since the spherule layer has only been described from one site where it is obvious that the spherules have been reworked. They could be from a small impact of only regional extent or from a major impact of more global significance. Until the spherule layer is found at more geographically dispersed sites and their age more precisely determined, it seems fruitless to speculate about possible associations with known mass-extinction events.

If Kirkham is correct and the Wickwar spherules are of impact origin, and if they are from a major impact event, and if the impact was coincident with a mass extinction, then this is a very important discovery.

Comment

Christian Koeberl

Kirkham (2003) describes spherules of possibly glauconitic composition from a Late Tertiary deposit in SW England, which he interprets as possible altered microtektites. He also reports on rare shocked-quartz grains associated with these spherules, and concludes that the deposit is impact-related. In the present contribution, I am critically discussing the data presented by Kirkham, in relation to other relevant publications, and present suggestions for further work.

As has been discussed in abundance (e.g. Montanari & Koeberl, 2000; Koeberl, 2001), the recognition of impact craters on the Earth is difficult, because active geological and atmospheric processes on our planet can obscure or erase the impact record in geologically short times. Impact craters are recognized from the study of actual rocks (e.g. Koeberl, 2002)—remote sensing can only provide supporting information. Petrographic studies of rocks at impact craters can lead to the discovery of impact-characteristic shock metamorphic effects, and geochemical studies may yield information on the presence of meteoritic components in these rocks. Apart from studying meteorite impact craters *per se*, important information can also be gained from the study of impact ejecta. Such ejecta are found within the normal stratigraphic record, where they can provide excellent time markers, and allow one to relate an impact event directly to possible biological effects (cf. Montanari & Koeberl, 2000; Koeberl & Martinez-Ruiz, 2003). Impact ejecta are commonly divided into two groups—proximal ejecta (those that are deposited closer than five crater radii from the crater rim), and distal ejecta. In some cases, impact events have been identified solely from the discovery and study of regionally extensive or globally distributed impact ejecta. A well-known case in point is the Cretaceous–Tertiary (K–T) boundary, where the discovery of an extraterrestrial signature, together with the presence of shocked minerals, led not only to the identification of an impact event as the cause of the end-Cretaceous mass extinction, but also to the discovery of a large buried impact structure about 200 km in diameter, the Chicxulub structure.

The Triassic–Jurassic (Tr–J) boundary is marked by yet another major mass extinction—one the big five mentioned above. Bice *et al.* (1992) reported on the discovery of shocked-quartz grains from a Tr–J boundary location in northern Italy, although the identification of the planar deformation features has been questioned (e.g. Mossman *et al.*, 1998). A search for shocked-quartz at Tr–J boundary locations in Nova Scotia (Canada) was negative (Mossman *et al.* 1998). The 100-km-diameter Manicouagan impact structure in Quebec has an age that is comparable to that of the Tr–J boundary, but currently available dates indicate that with an age of 214 Ma (Hodych & Dunning, 1992) it slightly predates the Tr–J boundary. Spray *et al.* (1998) discussed new evidence for a multiple-impact event in the late Triassic, probably slightly predating that Tr–J boundary. However, as past experience has shown, it is very difficult to correlate radiometric ages obtained from impact melt rocks with biostratigraphic ages obtained from the sedimentary record, as a correlation between the two records implies the use of the same time scale, which is basically never the case. Thus, the confirmation of an impact signature at other Tr–J boundary locations might be the next step in the investigation of the end-Triassic event.

Recent analysis of tetrapod footprints and skeletal material from over 70 localities in eastern North America shows that large theropod dinosaurs appeared less than 10 thousand years after the Tr–J boundary and less than 30 thousand years after the last Triassic taxa, synchronous with a terrestrial mass extinction (Olsen *et al.*, 2002). These authors found also that this extraordinary turnover is associated with an Ir anomaly (up to 0.28 ppb, average 0.14 ppb) and a fern spore spike, suggesting that a bolide impact was the cause. Eastern North-American dinosaurian diversity reached a stable maximum less than 100 thousand years after the boundary, marking the establishment of dinosaur-dominated communities that prevailed for the next 135 million years. Thus, it could be that impact events also influenced on the biosphere in ways other than just causing mass extinctions. However, the presence of an Ir anomaly alone is not yet confirming evidence of an impact event (although it certainly presents a strong case); the extraterrestrial nature of Ir needs to be established (e.g. with further and more detailed studies of the platinum-group element [PGE] abundances, or isotopic studies).

This is where Kirkham's (2003) study is interesting. The discovery not only of a possible distal impact ejecta layer, but especially of one that might be related to a mass extinction, is of great importance. Unfortunately, the data available so far do not allow any such unambiguous conclusion. The rock units studied by Bice *et al.* (1992), even if the discovery of a layer with shocked quartz in Italy confirmed (work is currently in progress to do this), seem to be related to the *c.* 200 Ma Tr–J boundary; as is the work of Olsen *et al.* (2002). In contrast, the deposit described by Kirkham (2003) clearly predates the Tr–J boundary. On the other hand, Kirkham's deposit might be related to the Norian stage, for which some extinctions are also noted.

Before going any further in this discussion it might be a good idea to critically evaluate the data presented by Kirkham (2003). I have little doubt that the deposit described is unusual in the stratigraphic succession (which obviously made him pay attention already in 1973); also, I agree that the clay spherules are most likely pseudomorphs of impact-derived spherules, similar to those described from the K–T boundary (e.g. Bohor & Glass, 1995). The one picture (Kirkham, 2003, fig. 11) of a shocked-quartz grain does look convincing; thus, the interpretation of this deposit as an impact-derived deposit is almost certainly correct.

It also appears as if the deposit described by Kirkham (2003) is similar to, if not identical with, spherule layers described from the same area by Walkden *et al.* (2002). If this is indeed the case, Kirkham, which is not mentioned by Walkden *et al.* (2002), should probably be credited with the initial discovery of this layer. There are a number of interesting similarities and discrepancies between the papers of Kirkham (2003) and Walkden *et al.* (2002). Kirkham (2003) notes that the exposures where he found the spherules were subsequently destroyed by quarrying operations; no mention is made how much material Kirkham was able to save before this unfortunate development. Walkden *et al.* (2002) seem to have sampled a deposit in the same area, which may or may not still exist—these authors do not give any detailed location information (reportedly to prevent other collectors from 'exhausting' the supply), which I do not consider good practice. Kirkham (2003) notes that stratigraphically the spherule deposit cannot be dated because of an unconformity. The stratigraphic relationships at the locations described by Kirkham seem to be fairly complicated. In contrast, Walkden *et al.* (2002) do not give any stratigraphic information for their finding location; they only show a general stratigraphic column (in the supplementary material to their article). Kirkham notes that the deposit looks like a pocket, about 6 m wide and 1 m thick. In contrast, Walkden *et al.* describe a 0–15 cm layer over an extent of 200 m. If both reports concern the same layer or event, there are some regional differences, probably based on paleotopography.

Petrographic and geochemical information is not particularly abundant in the paper by Kirkham (2003). Only one shocked-quartz grain is shown, and it is noted that they are rare. To confirm if these grains do indeed show evidence of shock metamorphism, a shock-petrographic study of the crystallographic orientations of the planar features in the quartz grains is necessary. Walkden *et al.* (2002) report such a study, and did find orientations that agree with an interpretation of the lamellae as shock-diagnostic planar deformation features. Neither of the two studies has done any geochemical work to try and detect any chemical anomalies that might be characteristic of a meteoritic component (cf. Koeberl, 2002). Kirkham (2003) mentions an attempt to find iridium with energy-dispersive X-ray (EDX) spectrometry, which is unfortunately a totally inadequate method for such an undertaking. Detection limits for EDX are approximately 0.1 wt% (even though often numbers are reported below this limit, they are statistically insignificant and meaningless), whereas typical impact-related deposits have Ir abundances in the ppt (10^{-12} g/g) to ppb (10^{-9} g/g) range (see Montanari & Koeberl, 2000; and Koeberl, 2001, 2002, for reviews). The Ir anomaly found by Olsen *et al.* (2002) is in the range of 0.1 ppb—seven orders of magnitude below the detection limit of the EDX method employed by Kirkham (2003). A detailed geochemical study of this material is an absolute necessity for future work.

The age of this impact deposit is also an interesting issue. Kirkham (2003) notes that Simon Kelley (Open University, UK), tried to date his material (more specifically, the glauconite), but obtained only an age-range from 210 Ma to Paleocene, and suggested that the real age of the spherules is older than 210 Ma. On the other hand, Kelley is a co-author of the paper by Walkden *et al.* (2002), in which these authors report an age of 214 ± 2.5 Ma for intergranular K-feldspar. It would be interesting to know why Kirkham's material did not yield a reliable age.

In conclusion, Kirkham (2003) presents an interesting discovery, which is confirmed by the more or less coeval work by Walkden *et al.* (2002). Future work should include the following: further field work to try and find more locations of this interesting impact deposit; provision of exact locations of these deposits to the scientific community; detailed petrographic and geochemical studies of the deposits (using high-resolution trace element and isotopic techniques with good detection limits); and attempts at better stratigraphic or radiometric ages of the deposits. This would go hand in hand with attempts to obtain better dates for the two large impact structures of similar age (Manicouagan and Rochechouart), both of which are not all that well dated.

Acknowledgements: I appreciate the invitation by R.J. Howarth to contribute this note; support was provided by the Austrian Science Foundation (project Y58-GEO).

Rejoinder

Anthony Kirkham

As acknowledged experts in the study of impact-related phenomena, Billy Glass and Christian Koeberl are thanked for their constructive review and advice following my description of probable impact spherules/ microtektites pseudomorphs (Kirkham, 2003) and I shall endeavour to elucidate some of the points raised by them.

The impact spherules/microtektite pseudomorphs were first described as such in Kirkham (2002) wherein it was stated that a more detailed account (i.e. Kirkham, 2003) was 'being published elsewhere'. In the meantime, Walkden *et al.* (2002) subsequently and independently published on the same subject and reached very similar conclusions to myself. Their work therefore reassuringly assists in addressing some of the points raised by Glass and Koeberl. For brevity, common items raised by Glass and Koeberl are dealt with simultaneously wherever appropriate.

The alternative possible origins, mentioned briefly in Kirkham (2003), were not discussed for two main reasons: 1) the microtektite origin seemed so convincing. A companion paper by Walkden *et al.* (2002) independently supported such an origin; 2) my considerations of other possible origins evolved over many years and would have been too voluminous to include in Kirkham (2003). One such hypothesis arising from my work on these same spherules was actually referred to by Fairchild (1977).

Within the bounds of the techniques that I used, compaction effects led to ambiguity in confidently identifying any suspected tear drop or dumbbell shapes. However, Walkden *et al.* (2002) recorded both these morphologies amongst the spherules.

It is unclear whether Glass is questioning the presence of shocked quartz, evidence of which many experts usually require to support the occurrence of impact spherules. However, as Koeberl correctly points out, Walkden *et al.* (2002) also discovered and illustrated shocked quartz associated with the spherules. The occurrence illustrated in Kirkham (2003, fig. 11) was not the only one recorded by me.

I do not consider the lack of evidence of an iridium anomaly critical because some other occurrences of impact spherules of different ages discovered elsewhere in the world are not accompanied by such anomalies. As stated by Kirkham (2003) and Koeberl, the EDX technique applied was indeed inappropriate for detecting iridium.

Koeberl seems to have deduced that the spherules described by Kirkham (2002, 2003) and Walkden *et al.* (2002) are identical because they were discovered in the same area. Koeberl is indeed correct in his deduction. In fact, this was confirmed by Walkden during the mid-1990s when Kirkham revealed his samples to Walkden at a fortuitous meeting in Abu Dhabi. It was simultaneously established that they were collected from the same basic locality, although it is less likely that they were discovered at precisely the same exposures due to quarrying operations progressively extracting rock material from working quarry faces. As explained by Kirkham (2003), the spherules actually occurred at more than one exposure within the quarry, although only one exposure was safely accessible for detailed examination, owing to the dangers of inspecting a working quarry face. I discovered the spherules resting directly above the top-Carboniferous unconformity (associated with a conglomerate at the base of the Triassic Mercia Mudstone), whereas Walkden *et al.* apparently found their spherules occurring as a discontinuous(?) horizon within the Mercia Mudstone. Since the Carboniferous limestones dip westwards, the western quarry face is retreating (being excavated) westwards, and the Mercia Mudstone is horizontally bedded and onlapping the Carboniferous eastwards, it is possible that my exposures are at the feather-edge of the spherule deposit which forms a discrete chronostratigraphic horizon within the onlapping Triassic strata. Whether they are sedimentologically recycled, and therefore older than their stratigraphic level would suggest, is still open to question although Walkden *et al.* (2002) do provide evidence to suggest an age only 3 million years older than a date (210 Ma) recorded in Kirkham (2003).

I agree with Koeberl that additional geochemical work would be worthwhile, but the lack of sponsorship and easy access to relevant analytical equipment has so far precluded my pursuing such efforts. Until now, my main aim has been to establish the existence of these impact spherules.

Glass' comments about impact spherules typically occurring as extensive strewn fields echo similar statements in Kirkham (2003), but the recognition of any strewn field must be initiated by the first discovery of impact-spherules related to a single strewn field. The body of evidence strongly supports the conclusion that these spherules are indeed impact-phenomena and so the search should now be focused upon finding correlatable equivalents.

Glass understandably urged caution in equating the inferred Late Triassic meteorite impact with mass extinctions. In Kirkham (2003), I had hoped to convey the possibility of such a relationship, whilst acknowledging that no specific relationship could yet be confirmed. To completely ignore such a possibility simply because the evidence is equivocal hardly assists scientific progress, but Koeberl's comments on this theme will hopefully encourage other geologists to focus their efforts in further testing the hypothesis. I also discussed (Kirkham, 2003) the less-likely possibility that the spherules are perhaps related to the end-Permian 'mother of mass extinctions'. Poreda *et al.* (2003) review evidence that those extinctions are also related to a bolide impact, concluding that the most likely impact-site is the Bedout structure, Canning Basin, NW Australia.

REFERENCES

Bice, D.M., Newton, C.R., McCauley, S., Reiners, P.W. & McRoberts, C.A. 1992. Shocked quartz at the Triassic–Jurassic boundary in Italy. *Science,* **255**, 443–446.

Bohor, B.F. & Glass, B.P. 1995. Origin and diagenesis of the K/T impact spherules—From Haiti to Wyoming and beyond. *Meteoritics & Planetary Science,* **30**, 182–198.

Fairchild, I. 1977. Phengite spherules from the Dalradian Bonhaven Formation, Islay, Scotland: glauconized microfossils. *Geological Magazine,* **114**, 355–364.

Glass, B.P., Muenow, D.W., Bohor, B.F. & Meeker, G.P. 1997. Fragmentation and hydration of tektites and microtektites. *Meteoritics & Planetary Science,* **32**, 333–341.

Hodych, J.P. & Dunning, G.R. 1992. Did the Manicouagan impact trigger end-of-Triassic mass extinction? *Geology,* **20**, 51–54.

Kirkham, A. 2002. Triassic microtektite pseudomorphs of the Bristol area. *Geoscientist,* **12**, 17–18.

Kirkham, A. 2003. Glauconitic spherules from the Triassic of the Bristol area, S.W. England: probable microtektite pseudomorphs. *Proceedings of the Geologists' Association,* **114**, 11–21.

Koeberl, C. 1994. Tektite origin by hypervelocity asteroidal or cometary impact: Target rocks, source craters, and mechanisms. In (Dressler, B.O., Grieve, R.A.F. & Sharpton, V.L.; eds) *Large meteorite impacts and planetary evolution.* Geological Society of America. Special Paper **293**, 133–152.

Koeberl, C. 2001. The sedimentary record of impact events. In (Peucker-Ehrenbrink, B. & Schmitz, B.; eds) *Accretion of extraterrestrial matter throughout Earth's history.* Kluwer Academic–Plenum Publishers, New York, 333–378.

Koeberl, C. 2003. Mineralogical and geochemical aspects of impact craters. *Mineralogical Magazine,* **66**, 745–768.

Koeberl, C. & Martinez-Ruiz, F.C. (eds) *Impact Markers in the Stratigraphic Record.* Springer Verlag, Heidelberg.

Koeberl, C. & Sigurdsson, H. 1992. Geochemistry of impact glasses from the K/T boundary in Haiti: Relation to smectites, and a new glass type. *Geochimica et Cosmochimica Acta,* **56**, 2113–2129.

Montanari, A. & Koeberl, C. 2000. *Impact Stratigraphy—The Italian Record.* Springer Verlag, Heidelberg.

Mossman, D.J., Grantham, R.G. & Langenhorst, F. 1998. A search for shocked quartz at the Triassic-Jurassic boundary in the Fundy and Newark basins of the Newark Supergroup. *Canadian Journal of Earth Sciences,* **35**, 101–109.

Olsen, P.E., Kent, D.V., Sues, H.-D., Koeberl, C., Huber, H., Montanari, A., Rainforth, E.C., Fowell, S.J., Szajna, M.J. & Hartline, B.W. 2002. Ascent of dinosaurs linked to Ir anomaly at Triassic–Jurassic boundary. *Science,* **296**, 1305–1307.

Poreda, R.J., Basu, A., Becker, L., Nicholson, C. & Campo, A. 2003. Global Evidence for a Permian-Triassic Impact Event. Abstracts 34th Lunar and Planetary Science Conference, March 17–21, 2003, League City, Texas. *Lunar and Planetary Science,* **34,** n.p., www.lpi.usra.edu/meetings/lpsc2003/pdf/1482.pdf..

Spray, J.G., Kelley, S.P. & Rowley, D.B. 1998. Evidence for a late Triassic multiple impact event on Earth. *Nature,* **392**, 171–173.

Walkden, G., Parker, J. & Kelley, S. 2002. A Late Triassic Impact Ejecta Layer in Southwestern Britain., 2002. *Sciencexpress,* www.scienceexpress.org 14 November 2000, 10–1126, science 1076249; and *Science,* **298**, 2185–2188.

Billy P. Glass
Geology Department,
University of Delaware,
Newark,
DE, USA
(email: bglass@udel.edu)

Christian Koebert
Department of Geological Sciences,
University of Vienna,
Althanstrasse 14, A-1090,
Vienna, Austria
(email: christian.koeberl@univie,ac at)

Anthony Kirkham
Ty Newydd,
5 Greys Hollow,
Rickling Green,
Saffron Waldon
Essex CB11 3YB, UK
(email: kirkhama@compuserve.com)