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Ballen silica, a post-impact marker – an overview

Abstract: The paper presents an overview of the literature data and the author's original data on ballen silica structures occurring in impactites. These structures have been discovered in more than 30 astroblemes, in various types of rocks metamorphosed by impact. Ballen structures show variations in their macromorphology as well as at the micro level in relation to single clasts or their clusters. The micro-level variations are related to the extinction of polarised light of ballen clast units, their stage of development, recrystallisation and other characteristics. Ballen structures appear as fine-grained, coarse-grained or domain mosaics. The latter may have a concentric or side-by-side pattern. Researchers link ballen structures with the transformations of silica polymorphs, crystalline ones such as cristobalite and quartz and amorphous ones such as diaplectic quartz glass or lechatelierite. Another hypothesis is that ballen structures are formed as a result of the embedding of cooled quartz clasts in an overheated rock melt. Considering the complexity of the post-impact processes, any scientific interpretation of the formation of ballen silica clasts is valid. Deposition of phyllosilicate minerals in the areas of contact between clast units is important for the mechanical stability of the clast. Post-impact dynamics can result in the release of clasts as well as their individual units and their addition to the created suevite breccias containing spherules. Thus, ballen structures can be considered as indicators of changes occurring shortly after a meteorite impact.

Keywords: ballen clasts, macrostructure, mosaicism, extinction, juvenile units, PDFs, spherules, nomenclature

First descriptions

In the literature of impact geology, the term 'ballen', describing a vine infructescence-like structure, refers to the transformation of silica polymorphs at high pressures and temperatures. Thus, the term 'ballen quartz', which can be commonly found in the literature, has a narrower meaning, while the term 'ballen silica' has a broader meaning. Surprisingly, the first ballen structures were discovered by Holst as early as 1890 in the Mien astrobleme in Sweden, which were then interpreted as a product of volcanic activity. Nearly 80 years later, McIntyre observed these structures in the Clearwater impact structure (according to Ferrière et al. 2009a). Von Engelhardt (1972) also made pioneering research on suevite glasses and ballen structures in the Ries astrobleme in Germany, and associated ballen structures with quartz-cristobalite transformations. Further studies on

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impact melt rocks from the Lappajärvi structure in Finland showed that ballen structures form and transform in the impact pressure range of 35–55 GPa (Bischoff and Stöffler 1984). There were certain ambiguities in the descriptions of ballen structures. For example, Grieve et al. (1987) reported ballen silica-like microspherulitic textures showing perlitic fracturing in microcrystalline melt rock from the Boltysh crater in Ukraine, which were interpreted as ballen structures by Ferrière et al. 2009a. In the 1990s, ballen structures were observed, among others, in impactites from Wanapitei, Canada (Dressler et al. 1997) and Deep Bay, Canada (Smith et al. 1999). The knowledge of ballen structures increased significantly in the 21st century. Among many astroblemes, ballen structures have been observed in impactites from the following: Centinela del Mar, Argentina (Harris et al. 2005), El'gygytgyn, Russia (Gurov et al. 2005), Bosumtwi, Ghana (Boamah and Koeberl 2006), Dhala, India (Pati et al. 2008), Dobra River, Croatia (Frančišković-Bilinski et al. 2015) and Zalužany, Czech Republic (Vrána et al. 2019). Ballen silica has been found in impactites from over 35 impact structures (Ferrière et al. 2009a, 2010). Schmieder et al. (2009) reported the presence of ballen silica in impactites from 38 structures. Some unique characteristics of ballen silica were studied using modern mineralogical analytic techniques such as – cathodoluminescence, scanning electron microscopy, Raman spectroscopy, and electron backscattered diffraction (EBSD) (Okumura et al. 2009; Ferrière et al. 2009a, 2010; Trepmann et al. 2020; Zamiatina et al. 2022).

Original supplementary data

For the present review, microscopic screening of ballen structures was performed on thin sections of impactites obtained from Lappajärvi (impact melt rock), Mien (suevite breccia) and Rochechouart (monomict lithic breccia) and on fine-grained fraction microscopic preparations of impactites from Montoume (particulate impact melt rock), Popigai (suevite, i.e. high-temperature tagamite), Ries (suevite), Kara (suevite, polymict breccia, tagamite-melt rock), Puchezh-Katunki (metamorphosed gneiss, coptocataclasite, coptoblastolite), Ilynets (suevite, metamorphosed granite, polymict breccia), Janisjarvi (quartz paramorphoses, tagamite, suevite) and Ternovka (polymict breccia). The nomenclature used for Rochechouart and Montoume impactites was based on the paper by Sapers et al. (2014). Ballen clasts as well as their fragments or single ballen units were separated from rocks by crushing them to fine-grained fraction microscopic preparations (Figs 2C–F; 3C, D, F, G; 4A–F).

Occurrence in impactites

Ballen structures were mainly observed in melt rocks (Lappajärvi – Bischoff and Stöffler 1984; Boltysh – Grieve et al. 1987; Popigai – Whitehead et al. 2002a), impact melt breccia (Centinela del Mar – Harris et al. 2005; El'gygytgyn – Gurov et al. 2005; Dhala – Pati et al. 2008), suevite (Deep Bay – Smith et al. 1999;

Bosumtwi – Boamah and Koeberl 2006; Chesapeake Bay – Jackson et al. 2016), metamorphosed target rocks (Sedan nuclear crater – Short 1970; Wanapitei – Dressler et al. 1997; Nördlinger Ries – Buchner et al. 2010; Puchezh-Katunki – Kosina 2019; Bach/Regensburg – Ernstson 2020). Some examples are shown in Fig. 1. The different types of impactites in which ballen structures have been observed so far include impact melt rock, suevite, melt breccia, shocked granite, and target-rock clasts in breccias (Ferrière et al. 2009a, 2010). In the Dhala structure, Pati et al. (2019) observed ballen clasts mainly in impact melt breccia, while they were rare in suevite. According to earlier syntheses and original data on many impact structures, ballen silica structures were less frequent in suevites than in impact melt rocks and were sporadic in metamorphosed rocks (Ferrière et al. 2009a, 2010).

General morphology of ballen clasts

Ballen silica clasts are of different shapes. For instance, clasts can be clearly demarcated in the form of a pear or a drop of water (Dobra River – Frančišković-Bilinski et al. 2015; Dhala – Pati et al. 2008, 2019; Ries – Trepmann et al. 2020; Popigai – Kettrup et al. 2003; Chicxulub – Ferrière et al. 2009a), and also shown in Fig. 2C–F. They may also appear in the form of a lens (Dellen – Okumura et al. 2009; Wanapitei – Dressler et al. 1997) or ellipses (Ries – Ferrière et al. 2009a; Yallalie – Cox et al. 2019). Irregular forms that can be attributed to complex geometric figures have also been commonly observed (e.g., Mien – Okumura et al. 2009; Zalužany – Vrána et al. 2019; El'gygytgyn – Gurov et al. 2005). On the other hand, clusters of clasts or large clasts separated by veins, as shown in Fig. 3E, are rare (e.g., Popigai – Whitehead et al. 2002a; Lappajärvi – Bischoff and Stöffler 1984; Ries – Trepmann et al. 2020). It is unclear whether the sharp (cut?) edges of some clasts in Bosumtwi (Boamah and Koeberl 2006), Wanapitei (Ferrière et al. 2010) and Zalužany (Vrána et al. 2019) indicate their earlier brecciation. The above data prove a wide variability of shapes of ballen silica clasts in the impactites of a given astrobleme. The size of ballen clasts also varies widely (Ferrière et al. 2010; Fig. 2). For example, the length of ballen clasts observed in thin sections from Lappajärvi ranges from 60 to 1857 μm (Figs 1C and 3B). The texture of ballen structures found in thin sections was often interpreted as resembling fish scales (Whitehead et al. 2002a; Osinski 2004; Harris et al. 2005; Pati et al. 2019). However, ballen units are not flat structures like fish scales, but they are spherical solids similar to berry, a fruit of the grapevine. These units are included in a set similar to berries forming the infructescence of the common grape. This structural description was proven accurate by Ferrière et al. (2009a, 2010). In Polish papers, the term 'panicle quartz' (in Polish 'kwarc groniasty'; Kosina 2017, 2019) is mainly used. Ballen units in a clast can be easily identified if phyllosilicate minerals are developed in the microscopic spaces between them (Ferrière et al. 2009a). When rock fragments are crushed for the preparation of fine-grained fraction microscopic slides, ballen clasts can be

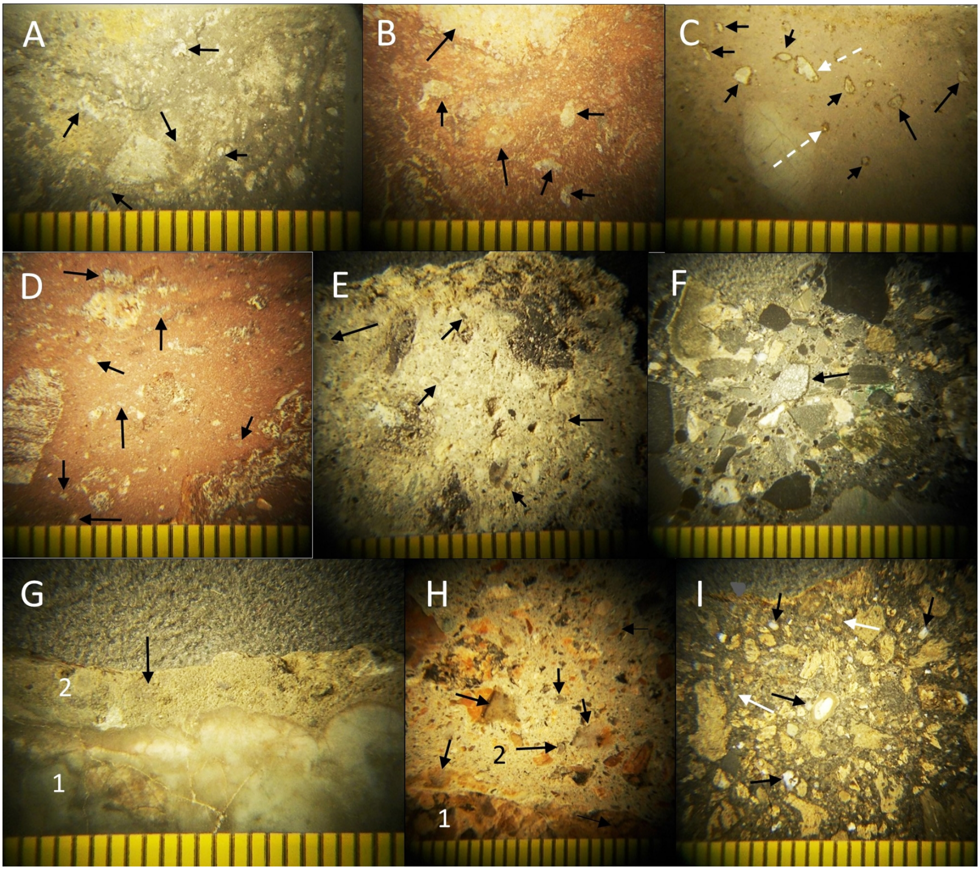

Fig. 1. Fragments of some impactites from which silica clasts were isolated. A – Mien, suevite breccia; B – Rochechouart, monomict lithic breccia; C – Lappajärvi, impact melt rock; D – Montoume, particulate impact melt rock; E – Ries, suevite breccia; F – Kara, polymict breccia; G – Janisjarvi, quartz paramorphosis (1) and fine-grained matrix vein (2); H – Ilynets, metamorphosed granite (1) with a vein of breccia (2); I – Popigai, impact melt rock (HT-tagamite). Black and white arrows indicate sites with more or less visible light or dark clasts of silica; white dashed arrows in C indicate two ballen clasts of extremely different sizes. A–C – thin sections, D-I – cut fragments of impactites. Scale in mm.

separated from the rock (Fig. 2C–F), and ballen units, covered with other minerals, can be obtained from them (Fig. 4A, C, D). Crushing also leads to cracks in ballen units (Fig. 4B, E). The organisation of ballen units may differ in a clast. A literature review indicates two types of dominant spatial patterns, both of which are fairly common – units of similar dimensions evenly cover the entire clast (Fig. 2C), or large units can be found in the centre of the clast and small ones on the periphery. In large central units, often of irregular shapes, juvenile forms of ballen units occur later (Fig. 3H). Ballen units of different sizes are also visible in clasts showing structural domains, in which small and large units occupy separate domains with more or less clear borders (Lake Saint Martin – Schmieder et al. 2014; Bosumtwi – Boamah and Koeberl 2006; Mien – Ferrière et al. 2009a; Lappajärvi; Fig. 2A).

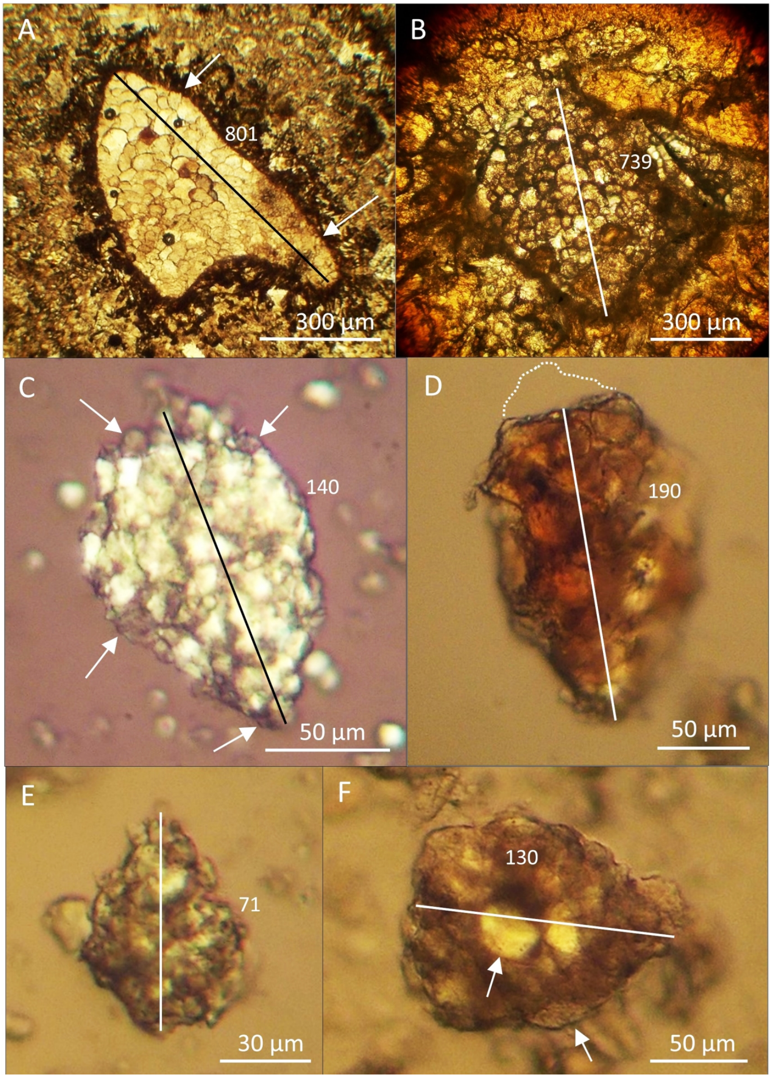

Fig. 2. Ballen clasts of different shapes and dimensions obtained from crushed fragments of impactites. A – Lappajärvi, impact melt rock (white arrows indicate two domains of ballen units differing in size); B – Mien, suevite breccia; C – Kara, suevite (arrows indicate ballen units differing in extinction); D – Popigai, impact melt rock (HT-tagamite), fragment of the clast detached in the upper part (dotted line); E – Kara, polymict breccia; F – Ilynets, fine-grained polymict breccia (arrows indicate ballen units differing in extinction). Lengths of clasts are shown with white and black lines with numbers in μm near them. A, B – thin sections. Nicols are slightly crossed.

Microscopic characteristics of ballen silica

Bischoff and Stöffler (1984) defined effect of impact pressures in the range from >10 to 65 GPa in impactites from the Lappajärvi structure. They reported that ballen structures formed at the highest pressures in the range of ~30 to ~65 GPa. In the pressure range of ~30–45 GPa, the ballen structures were optically homogeneous (type I), while at higher pressures ballen units had different optical orientations (type II), with recrystallisation occurring in them (type III). The direction of changes from type I to type III refers to the transition from diaplectic quartz glass to cristobalite and subsequently to -quartz. Further research (Ferrière et al. 2008, 2009a) suggested the extension of the above classification to five groups identified microscopically with crossed nicols:

I. ballen silica composed of -cristobalite showing homogeneous extinction;
II. ballen silica composed of -quartz with homogeneous extinction;
III. ballen silica with -quartz units with heterogeneous extinction;
IV. ballen silica with -quartz units showing intra-unit recrystallisation;
V. ballen silica with -quartz units with a chert-like pattern of recrystallisation.

The authors indicate that the above classification cannot be used to determine the level of the shock pressure because ballen structures are formed in the post--impact stage, when there is a reduction of pressure and temperature. According to Ferrière et al. (2008, 2009a), two types of changes occur following an impact: 1) solid-to-solid changes leading to the transition of -quartz to diaplectic quartz glass, and at high temperatures, the formation of -cristobalite – -quartz ballen units with transition back to -cristobalite – -quartz ballen units; 2) solid-to--liquid changes leading to the transition of quartz to monomineralic lechatelierite above 1700°C. Whitehead et al. (2002a) also observed -tridymite in addition to -cristobalite in Popigai samples using X-ray diffraction analysis. Trepmann et al. (2020) related the formation of ballen structures to the stage of post-impact decompression and cooling of the amorphous melt and the preservation of the ‘structural memory’ of the quartz crystals subjected to the impact. When this information is retained in the melt, quartz crystals are formed (topotactic crystallisation), whereas in its absence, cristobalite crystallisation occurs.

Ballen silica and PDFs

Ferrière et al. (2009a) emphasised that planar deformation features (PDFs) are rare in ballen structures. In the study of impactites from numerous astroblemes, the authors did not find their coexistence. However, analyses of suevite from the Deep Bay impact structure revealed the frequent co-occurrence of ballen silica and PDFs – the spatial relationship between ballen units and PDFs indicated the existence of PDFs before the formation of ballen clasts (Smith et al. 1999; Chanou et al. 2015). PDFs ran through several ballen units, and were therefore superior to them. The formation of ballen texture began in dark quartz (‘toasted quartz’) with PDFs formed above 35 GPa. Ballen units contained individual -quartz crystals with the same optical orientation (Grieve et al. 1996). In their study of impactites from the Dhala structure analysing the co-occurrence of ballen silica and PDFs, Pati et al. (2008, 2019) found that multidirectional PDFs were limited to single ballen units and did not cross their boundaries. This is contradictory to the data of Smith et al. (1999) and Chanou et al. (2015). PDFs in the Dhala impactites are most likely residual, which explains their limitation to single ballen units.

According to the classification of Ferrière et al. (2009a), ballen units with PDFs come under type II. Trepmann et al. (2020) also reported the occurrence of PDFs in ballen units from the Ries structure. These authors assumed that the appearance of PDFs in ballen units is determined by the preservation of the structure relics of quartz crystals when the crystals are shocked to the amorphous stage. Ballen structures with PDFs appear when quartz glass is cooled. PDFs do not appear when a ballen structure is created with cristobalite, a polymorph without the structure relics of a quartz crystal. The co-occurrence of ballen and PDFs was frequently noted in impactites formed from a crystalline substrate (granite, gneiss, quartzite) and much less often on a sedimentary substrate changed by impact (Osinski 2007).

Ballen structure mosaicism

Ballen units may form a homogeneous or a highly heterogeneous set within a clast. Fine ballen units of similar size, which may differ in other characteristics, form a fine-grained mosaic pattern (e.g., Rochechouart – Okumura et al. 2009; Zalužany – Vrána et al. 2019; Fig. 2C). In turn, units of various sizes, large and small, which may also differ in other characteristics and are randomly scattered, form a coarse-grained mosaic pattern (Dhala – Pati et al. 2019; Fig. 2B). If there are both smaller and larger groups of units, which differ from each other and are spatially separated, such a pattern can be called domain variation. Ballen structures are characterised by 1) mosaic variability (mosaicism), which refers to the variability within one ballen clast in terms of unit sizes; 2) the presence of toasted or non-toasted quartz; 3) different rates of formation of ballen units, which is equivalent to the coexistence of older and younger ballen units; 4) recrystallisation within ballen units; 5) different crystallographic orientations of ballen units, which is manifested by differences in their extinction of polarised light. Such differentiation can be observed using various methods of analysis. It was mentioned earlier that domains that differ in the size of units can be oriented in the side-by-side pattern (Fig. 2A) or concentrically (e.g., large units in the centre) (Bosumtwi – Boamah and Koeberl 2006). Milky and brown 'toasted' quartz show a similar characteristic, with water-filled inclusions arranged linearly. However, in 'toasted' specimens, these inclusions are smaller and more abundant. They are linked with the lamellae of PDFs, which are then more visible (Whitehead et al. 2002b). Ferrière et al. (2009b) observed a toasted feature in the marginal quartz portions of the silica clast in the Chesapeake Bay crater impact. The co-occurrence of -quartz (toasted) and -cristobalite (non-toasted) in the Popigai structure indicated a domain pattern – two domains of quartz polymorphs (Ferrière et al. 2010). In the Dhala structure, the toasted domain is distributed in the centre of the ballen clast (Pati et al. 2019), i.e. at the opposite position than in the Chesapeake Bay sample. Thus, the position of the toasted domain depends on the location of the non-toasted -cristobalite domain in the clast, either in the centre or on the periphery (Ferrière et al. 2010).

Juvenile ballen units

Juvenile ballen units of -cristobalite were found in suevite from Bosumtwi structure (Ferrière et al. 2009a). Such units were also observed in impactites from Mistastin, Deep Bay (Canada) and Popigai (Russia) (Chanou et al. 2015). The units were smaller and had thinner sphere walls without or with a less amount of phyllosilicate mineral deposit. Such development of ballen units was observed in the large ballen silica clast from Lappajärvi (Fig. 3H). The initial development of arched walls occurs in a bright, central domain composed of large, irregular units. The shape of the initially formed walls indicates that they will be ballen units. The domain is surrounded by small, mature units. The central domain is distinguished from the surrounding by the size of its units and the juvenile state within them. This is structurally different from intraballen recrystallisation (Fig. 4E, F), where fine quartz crystals are formed in mature ballen units. Ferrière et al. (2009a) noted the coexistence of two quartz polymorphs in one ballen clast, -cristobalite and -quartz, i.e. younger and older recrystallisation products. The development of ballen units from the outside towards the inside of the clast was confirmed by the analyses of Chanou et al. (2015). The authors have shown this condition in Fig. 1A in their paper, which is similar to that shown in Fig. 3H in the present paper.

Mosaic variation of extinction

Heterogeneous extinction resulting from different optical directions of ballen units, which is a feature of type III ballen silica, was reported in impact melt rock from Rochechouart (Ferrière et al. 2009a). Such an optical mosaic is also shown here in Figs 2A, C, F and 3A–D, F–H. The mosaic shown in Fig. 3B is actually a mosaic of domains, i.e. groups of units with different optical orientations. Similar ballen silica with domain extinction mosaic from the Jänisjärvi structure was analysed by Zamiatina et al. (2022), and from the Dhala structure by Pati et al. (2019). In addition, in a small fragment of ballen silica from Dhala, composed of approximately seven units, almost each had a different optical orientation (Pati et al. 2019). Analyses of ballen clasts from gneiss in the Ries impact melt rock revealed not only heterogeneous extinction between ballen units but also micro-mosaic of this feature within units. These micro-mosaic details were additionally analysed using the EBSD method (Trepmann et al. 2020), which proved a very high crystallographic orientation variability in the ballen silica recrystallisation process. A similar orientation variation of recrystallised quartz grains in single ballen units was demonstrated in impactites from the Jänisjärvi astrobleme using the EBSD method (Zamiatina et al. 2022). Other examples are shown in Fig. 4A, C–F.

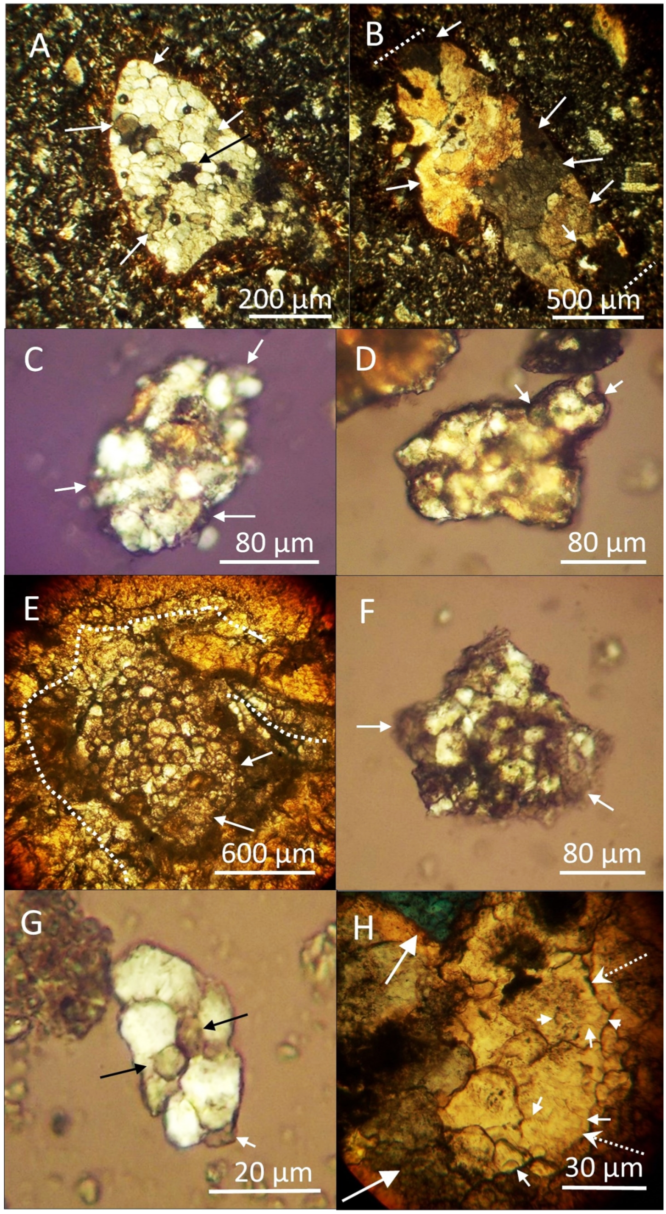

Fig.3. Variation of optical orientation (extinction) in ballen clasts and their fragments. A, B – Lappajärvi, impact melt rock; arrows indicate groups of ballen units with homogeneous extinction in clasts showing heterogeneous extinction (type III). In B, two dotted lines indicate the largest clast with a length of 1857 µm in the thin section. A domain pattern of various optical orientation is also visible. C – Ilynets, a fragment of clast from fine-grained matrix in metamorphosed granite; D – Kara, a fragment from suevite; E – Mien, thin section from suevite breccia; dotted lines indicate adjacent narrow ballen clasts and arrows indicate parts of the clast with more visible chert-like recrystallisation in units (types IV and V); F – Janisjarvi, a fragment from fine-grained matrix in quartz paramorphosis; G – Kara, a fragment from suevite; H – Lappajärvi, impact melt rock, a central domain with large, irregular ballen units (dotted arrows) with initiating curved rims of juvenile units in them (small arrows) and adjacent large domains with different optical orientations (large arrows); C, D, F, G – ballen units with different extinction indicated by arrows (type III). Nicols are highly crossed, not at 90° to get optimal microphotographs.

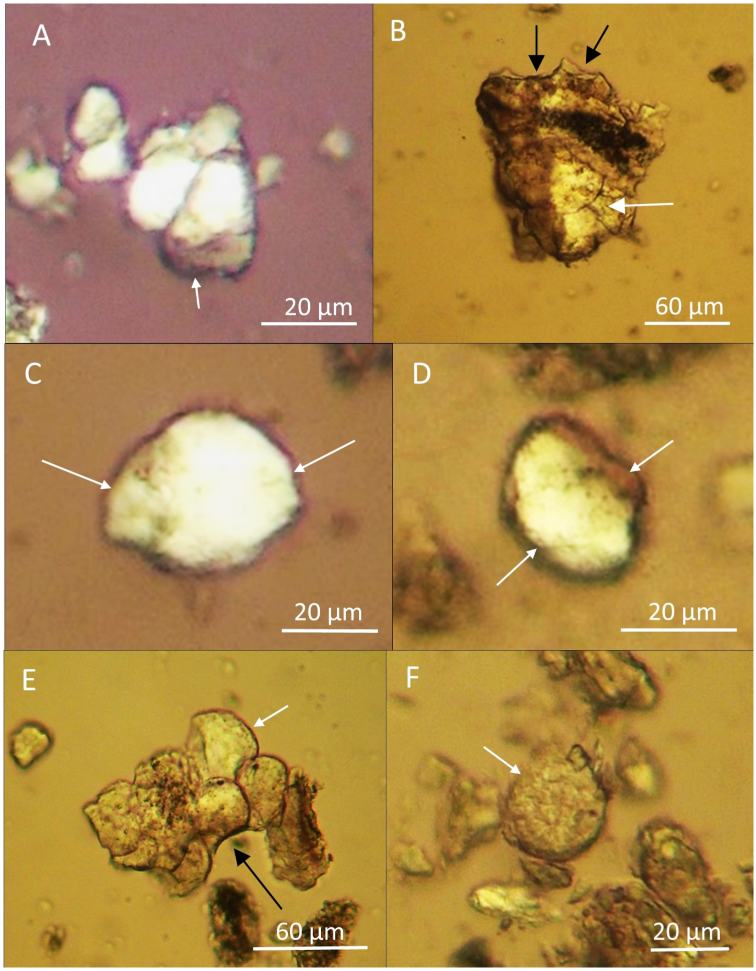

Fig. 4. Variation of optical orientation (extinction) in ballen clast fragments and ballen units. A – Kara, a fragment from suevite; B, C – Montoume, particulate impact melt rock; D – Ilynets, fine-grained polymict breccia; E – Montoume, particulate impact melt rock; F – Ries, suevite. In A, C and D, white arrows indicate parts of units with different extinction (type IV); in B and E, black arrows indicate free edges after detachment of individual units during preparation (crushing of impactite fragments); in B a white arrow indicates ballen units covered partly with a dark layer (?); in E and F full recrystallisation is visible in ballen units (probably type V). Nicols are highly crossed, not at 90° to get optimal microphotographs.

Ballen units and spherules

Can isolated ballen units coexist with glass spherules in suevite breccia? The answer will be 'yes' if ballen silica clasts are brecciated in the post-impact processes. When rock fragments were crushed to fine-grained fraction microscopic preparations, such clasts, their fragments and individual units were isolated (Figs 2D; 3D, F, G and 4A–F). Ballen clasts have been found in many suevite breccias (numerous citations above). For instance, von Engelhardt (1972) found a few homogeneous spherules and ballen clasts in suevite from Ries. Sparse bubbles, quartz grains and lechatelierite were found in spherules up to 2 cm in diameter. The author emphasised that these spherules should be distinguished from similar fragments of ’perlitic glasses’. Ballen structures in suevite Ries underwent cristobalite-to-quartz recrystallisation (von Engelhardt et al. 1995). Sears et al. (1996) observed Ries spherules with mean diameters in the range of 134–277 μm. Some categories of spherules showed partial or full recrystallisation. All ballen units shown in Figs 3G and 4A–F are smaller; however, Ferrière et al. (2009a) showed that the diameter of ballen units ranged from 8 to 214 μm. Thus, both solids, spherules and ballen, are characterised by an overlapping distribution of diameters. In addition, recrystallisation blurs the differences between them. Some examples of ballen clasts shown in the literature (e.g., Bosumtwi – Fig. 6C in Boamah and Koeberl 2006; Wanapitei – Fig. 1A in Ferrière et al. 2010; Zalužany – Fig. 7 in Vrána et al. 2019) reveal that clasts can be brecciated, having angular, sharp edges with cut ballen units. Such a state of ballen clasts would be in line with the theory of ballen silica formation presented by Chanou et al. (2015). These authors state that ballen silica are formed as a result of embedding of cold quartz clasts in an overheated impact melt. It is highly probable that the quartz clasts can be released during impact processes. Next, the clasts in impact melt are rapidly cooled by the addition of successive cold rock clasts. Whole and brecciated quartz clasts can be embedded in this process. Such a process does not require phase transformations of quartz (quartz to cristobalite to diaplectic glass, and return during slow cooling). The initiation of cracks in quartz and ballen clasts in the melt from the outside towards the inside confirms the above theory (Ernstson 2020). In the post-impact stage, before the stabilisation of the suevite deposit, brecciation of ballen clasts and release of single ballen units are very likely to occur. This would be facilitated at the interface of suevite and other impactites during the mixing of their components, as was observed in the Rochechouart (Sapers et al. 2014) or Gardnos (Kalleson et al. 2010; Kosina and Madej 2020) structure. Then, suevite breccia could contain spherules together with free ballen units.

Ballen silica nomenclature problem

Here comes the last question: Is ballen silica a marker of impact? This was posed by Schmieder and Buchner (2007) and Schmieder et al. (2009) citing the occurrence of -cristobalite ballen structures in volcanic rocks, fulgurites, industrial quartz ceramics and sandstones changed by volcanic basalts. According to these authors, the ‘impact-diagnostic’ feature of ballen silica is not fully understood. Considering this, Ferrière et al. (2009a) emphasised that the impact ballen structures are pure silica (SiO_2), while non-impact ones contain admixtures of other oxides (Al_2O_3, K_2O, NaO). Regardless of whether the formation of ballen structures is associated with slow cooling of the melt and phase transformations of silica (Ferrière et al. 2010), or the embedding of quartz clasts in the overheated melt and their rapid cooling (Chanou et al. 2015), the process occurs after the impact, when pressure and temperature parameters are lowered. Thus, ballen silica structures are undoubtedly a marker of events occurring shortly after an impact.

Streszczenie

Krzemionka groniasta jako marker pouderzeniowy – przegląd

Artykuł jest przeglądem danych literaturowych wraz z suplementem oryginalnych danych autora na temat struktur krzemionki groniastej (ang. *ballen silica*) występujących w impaktytach. Klast takiej krzemionki przypomina owocostan winorośli, grono, stąd nazwa polska. Termin krzemionka groniasta ma znaczenie szersze niż termin kwarc groniasty (ang. *ballen quartz*), często spotykany w literaturze. Struktury te odkryto w ponad 30 astroblemach, w różnych typach skał przekształconych przez impakt meteorytu, najczęściej w stopach skalnych, brekcjach, również w brekcji suewitu, natomiast rzadziej w zmetamorfizowanych skałach podłoża struktury impaktowej. Struktury groniaste wykazują zmienność makromorfologiczną (wielkość, kształt) oraz na poziomie mikro w odniesieniu do pojedynczych klastów lub ich skupień. Zmienność na poziomie mikro ujawnia się w stopniu wygaszania światła spolaryzowanego pomiędzy jednostkami w groniastym klaście, ich etapem rozwoju, rekrystalizacją i innymi cechami. Struktury groniaste krzemionki pojawiają się jako mozaiki drobnoziarniste, gruboziarniste lub domenowe. Te ostatnie mogą mieć wzór koncentryczny lub obokleżny. Badacze łączą struktury groniaste z przemianami polimorfów krzemionki, krystalicznych, takich jak krystobalit i kwarc, oraz amorficznych, takich jak diaplektyczne szkliwo kwarcowe czy lechatelieryt. Inna hipoteza głosi, że struktury groniaste powstają w wyniku zatapiania chłodnych klastów kwarcowych, wcześniej uwolnionych z impaktytów w dynamicznych procesach pouderzeniowych, w przegrzanym stopie, kolejno szybko schładzanym. Biorąc pod uwagę złożoność procesów zachodzących po impakcie, każda naukowa interpretacja powstawania klastów krzemionki groniastej powinna być uważana za cenny element poznania dynamiki procesów pouderzeniowych. Powstawanie minerałów krzemianów warstwowych w obszarach styku jednostek składowych groniastego klastu jest istotne w odniesieniu do jego mechanicznej stabilności. Dynamika pouderzeniowa może skutkować uwalnianiem klastów oraz ich jednostek składowych i dodawaniem ich do tworzonych brekcji suewitu zawierających szkliste sferule. Specyfika współwystępowania planarnych struktur deformacyjnych w kwarcu (PDF) i struktur groniastych dowodzi, że te drugie powstają w fazie pouderzeniowej modyfikacji krateru i impaktytów. Groniaste struktury krzemionki można uznać za wskaźnik zmian zachodzących wkrótce po uderzeniu meteorytu, podczas schładzania stopów skalnych i powstawania brekcji impaktowych.

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