DEVITRIFIED RHYOLITIC VITROPHYRE BOMBS AND OTHER VOLCANIC PHENOMENA FROM THE LATE TRIASSIC MILLIGANS ROAD FORMATION WAUCHOPE, NEW SOUTH WALES

Brian M. England and Chris Morton
Amateur Geological Society of the Hunter Valley Inc.
www.agshv.com

ABSTRACT

Enigmatic spherical to oblate rhyolitic balls up to 16cm diameter found in the Old Bago quarry complex near Wauchope in the Mid North Coast hinterland of New South Wales have variously been described as accretionary lapilli, fossil hail stones, lithophysae, and megapherulites. However detailed studies have shown these features to be composed of a porphyritic volcanic glass or vitrophyre showing a range of devitrification textures. The balls occur towards the base of one of the thick (up to 9 metres) ash fall tuff beds in the Milligans Road Formation, a sequence of ash fall rhyolitic tuffs, coaly beds, and dense mudstones deposited in an overbank fluvial environment in the Late Triassic. Their textural relationships to the host tuff bed indicate they did not form *in situ* but came from a geochemically related external source. Specimens examined *in situ* and retrieved from the quarry show convincing evidence of the viscous vitrophyre balls being ejected under high pressure at high speed from narrow conduits connecting with the main lava conduit and passing up through the mudstone and ash fall beds from below. A very similar occurrence was observed during the 2008-9 Chaitén Volcano eruption in Chile where rhyolitic obsidian bombs to 50cm were ejected from shallow fissures during transitional effusive-explosive activity at speeds of up to 100 metres/second. This provides a near-perfect analogy to the Wauchope occurrence. It is proposed that these features be called "Devitrified rhyolitic vitrophyre bombs". The geology of the quarry and the occurrence of true accretionary lapilli are also discussed.

Key Words: rhyolite balls, vitrophyre, volcanic bombs, Bago quarry, geology, accretionary lapilli, megaspherulites, fossil hail stones, devitrification, ash fall tuffs, Late Triassic, Chilean analogy.

INTRODUCTION

This study was initiated after a scheduled AGSHV field excursion to the Lorne Basin in September 2024 revealed interesting structures in the southern face of the Coastal Quarry Products quarry complex on Milligans Road on the site of the Old Bago quarry that has been in operation since 1897 to the south of Wauchope in the North Coast hinterland of New South Wales (*Figure 1*). These structures were not visible during a previous visit by Dr. Lin Sutherland and one of the authors (BME) in November 2016 when the quarry operated under the name Volcanic Resources. On the day of the AGSHV group visit the quarry was closed and only the eastern part of the complex outside the security gate was accessible.

The quarry was contacted a few days after the excursion to enquire if a visit by a small group from the Society could be arranged during working hours. During the ensuing discussion the quarry manager, Mark Roche, mentioned a curious occurrence of "bowling balls" that were falling from the quarry face after blasting and subsequently sent copies of email communications between himself and Dr. Ian Graham (UNSW) who had recently visited the quarry and had initially described these oddities as "accretionary lapilli" of unusually large size.

Over three subsequent visits by the authors in September and October 2024 the Roche family offered every assistance in locating and

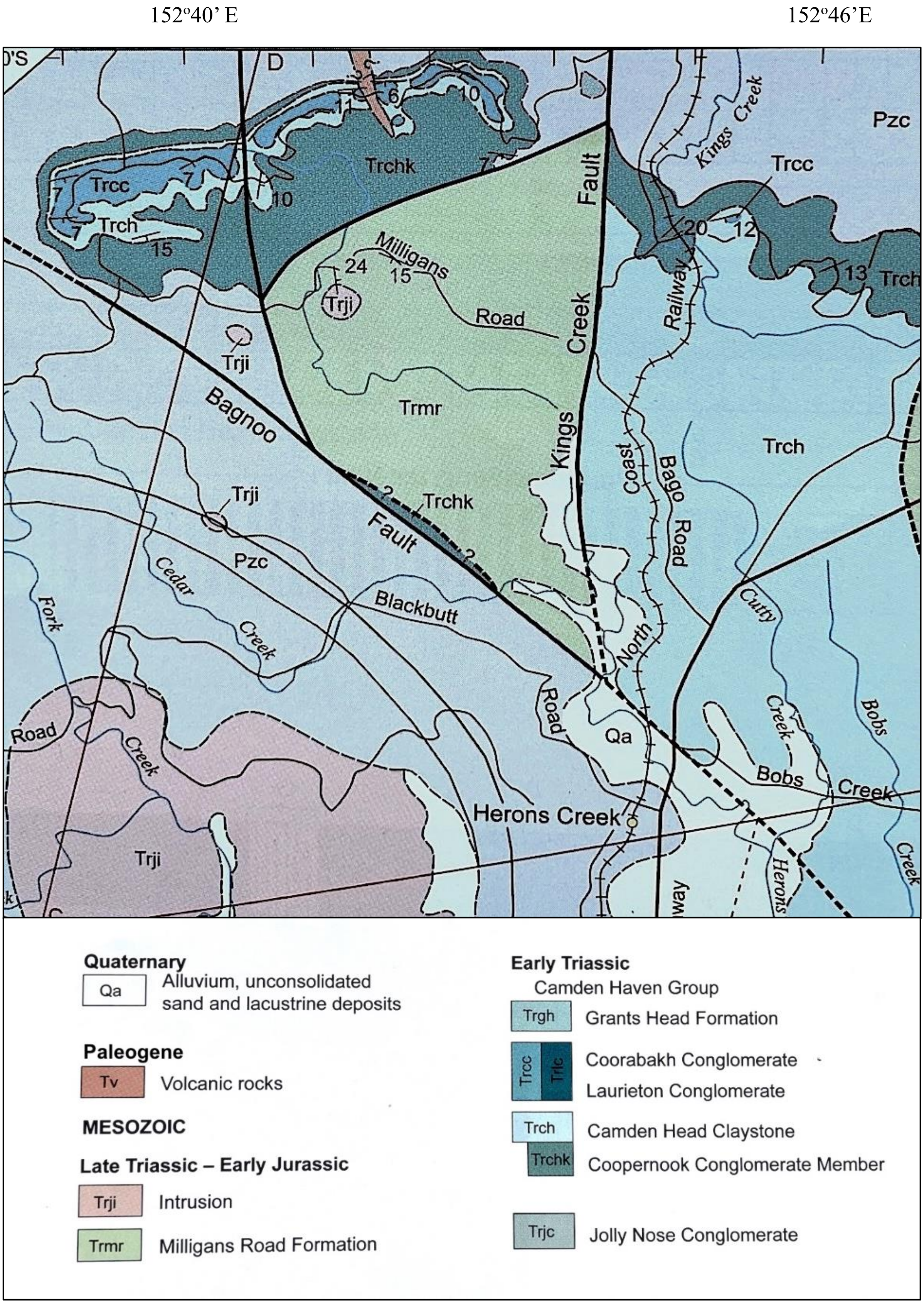

Figure 1. Geological map showing the location of the study area (No 24) (from Pratt, 2010).

collecting material for research and preservation, including several large matrix specimens (*Photo 1*).

This paper is based on what was seen in the quarry face and on the examination of over 100 specimens collected during these visits.

Photo 1. Large matrix specimen on the quarry floor 1m-^{H} x 75cm-^{W}.

GEOLOGY

The Coastal Quarry Products quarry complex exposes the upper part of the Milligans Road Formation, a sequence of poor quality laminated "coal", dense carbonaceous mudstone and rhyolitic ash fall tuff beds up to 9 metres thick, overlying the Early Triassic Camden Haven Group (Pratt, 2010). Away from the "coaly" beds, exposed in the eastern part of the quarry complex (*Photo 2*), the mudstone beds are very dense and dark grey to reddish-purple in colour and occur interbedded with the ash fall tuffs. The tuffs have been fission-track dated at 220Ma, placing this sequence in the Late Triassic. The mudstones represent deposition in back swamps in an overbank fluvial environment (Pratt, 2010). Disturbance within some of these mudstone beds suggests surface disruption by periodic flood events. (*Photo 3*). No identifiable plant remains have yet been recognised in the mudstones or coaly shales, with only tiny carbonised fragments seen in this study. However, small (less than 1cm) nodules in the dense mudstone may represent algal colonies (*Photo 4*).

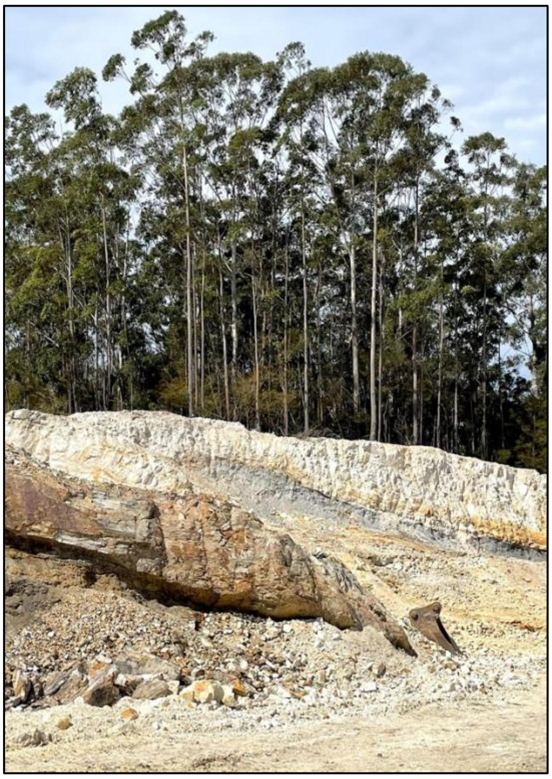

Photo 2. Outcropping shales (at left and centre) with rhyolitic ash fall bed (white) in background.

The texture of the rhyolitic ash fall tuffs varies from porphyritic, with evenly disseminated K-feldspar (sanidine) phenocrysts to a maximum of 6mm diameter and only occasional quartz in a grey aphanitic matrix of very fine ash (*Photo 5*), to a dense cream-coloured rock completely devoid of phenocrysts (*Photo 6*). In all samples examined in this study, the sanidine phenocrysts have been partially to completely altered to clay (kaolinite). Where the original outline of the phenocrysts is visible, all have been significantly rounded by abrasion, as would be expected in an ash fall deposit.

Pratt (2010) records the presence of extremely fragile accretionary lapilli up to 20mm diameter in the basal 300mm of the 9m thick ash fall bed

Photo 3. Inter-laminated mudstone and ash-fall tuff bands severely disrupted by catastrophic water inflow. Brian M. England specimen (R896A). Size: 16cm.

Photo 4. Dense mudstone with what may be fossil algal colonies. Brian M. England specimen (R898B). Size: 10cm.

exposed in the older eastern section of the quarry complex (outside the entry gate). This face was re-examined in this study and abundant lapilli composed of very fine kaolinized ash were found scattered in a 30cm thick lens of kaolinite beneath the base of a thick tuff bed (*Photo 7*). Immediately below lies the thick sequence of the thinly bedded "coaly" sediments mentioned above, showing an apparent moderate dip to the south and conformably underlying the tuff bed, which may be the initial ash fall tuff in the stratigraphic sequence at this locality.

Photo 5. Porphyritic rhyolitic ash fall tuff from the lowest tuff bed exposed in the southern face of the quarry complex. Brian M. England specimen (R589). Size: 10cm.

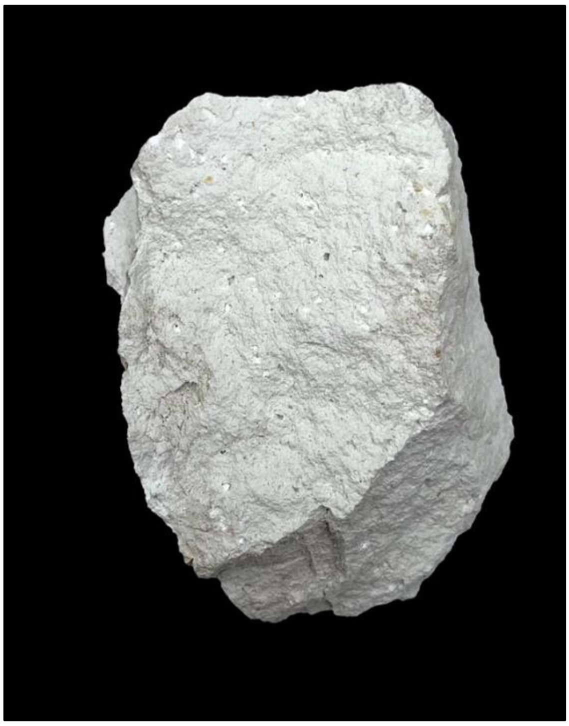

Photo 6. Ash fall tuff almost devoid of sanidine phenocrysts from the bed directly above "coaly" sediments in the eastern part of the quarry complex. Brian M. England specimen (R899). Size: 10cm.

The accretionary lapilli show a variety of irregular rounded shapes (*Photo 8*), including flattened rods, dumplings, and spindle-like forms similar to those seen in basaltic volcanic bombs. They show characteristic features of lapilli including collapsed surface bubbles and accretionary zoning and their horizontal orientation in the clay bed indicates an airfall origin during a Plinian eruption, most likely forming in steam-rich ash columns (Cas, et.al., 1987), perhaps around condensing water droplets.

Photo 7. Vertical section through the lapilli-bearing kaolinite lens between the ash fall tuff bed (above) and "coaly" shale beds (below) in the eastern part of the quarry complex. Largest lapilli is 12cm long.

Above the kaolinite lens, the tuff bed contains scattered spherical nodules of around 20cm in diameter, resting very close to the base of the tuff. These are similar to but not as clearly defined as the nodules recently found near the base of the upper tuff bed in the southern working face of the main quarry, which are the main subject of this study.

None of the rhyolitic tuff beds show evidence of flow banding but some minor linear internal stratification is evident, especially towards their base. This is perhaps due to pulse-type eruptions (Cas, et.al., 1987). Slight fluctuations in discharge rate from the vent will cause particles of a different size and terminal velocity to be released from a different height, producing faint layering in an ash fall bed.

Parts of the ash fall beds are sufficiently porous to have allowed the development of spectacular ferruginous rhythmic colour banding (formerly known as Liesegang banding) due to the seasonal deposition of iron oxides (mainly goethite) from percolating groundwater migrating in from joints during weathering *(Photo 9*).

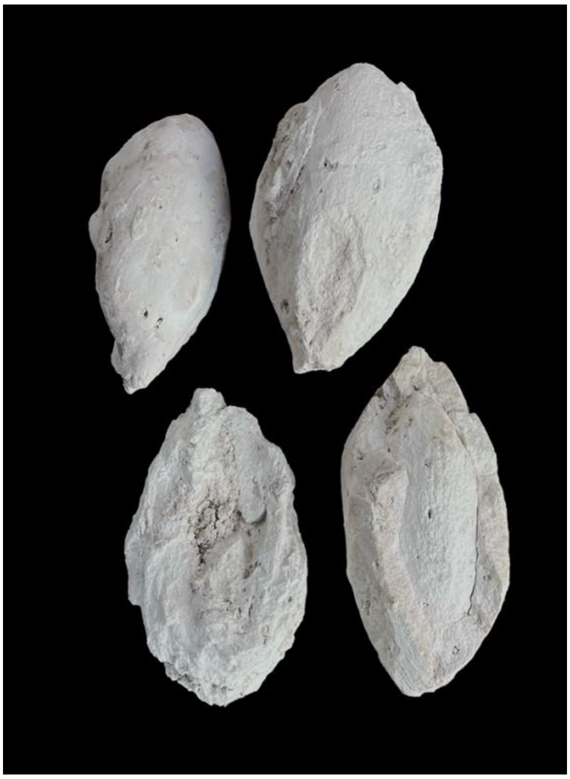

Photo 8. Lapilli collected from the kaolinite lens shown in photo 7. Brian M. England specimens (R900). Size: largest is 6cm.

The presence of ash fall tuff beds in the Milligans Road Formation suggests an association with the emplacement of Late Triassic to Early Jurassic igneous rocks within the Lorne Basin (Graham, 2006).

Photo 9. Porous ash fall tuff showing ferruginous rhythmic colour banding due to weathering. Specimen on the quarry floor. Size: 28cm.

STRUCTURE

The Milligans Road Formation outcrop lies in fault-bounded blocks in the northeast and southwest parts of the Lorne Basin. The present study area is site 24 in Pratt (2010) in the northeast block.

In early September 2024, the main (southern) working face of the main quarry exposed an excellent section through the local stratigraphy (*Photo 10*) and structural relationships. At the western end of the face, a thrust fault (later destroyed by quarrying) had displaced the local bedding, bringing the thick basal ash fall tuff to a much higher position in the quarry wall. Lateral pressure from this fault has caused pressure buckling of the tuff and interbedded dense mudstone beds on the eastern side, resulting in a small anticlinal fold with an axis dipping to the west.

In the older eastern part of the quarry complex the underlying "coaly" beds apparently dip to the south under the tuff. To the north, these sediments are cut by a normal fault (*Photo 11*).

DESCRIPTION OF THE BALLS

The balls range from 3.5cm to 15cm in diameter and vary from perfect spheres (*Photo 12*) to oblate spheroids (*Photo 13*). Groups of two or three balls fused together are not uncommon (*Photos 14 and 15*) and only rarely show what appear to be compression ridges between them (*Photo 16*). Some show prominent flanges, like button tektites (*Photo 17*) and some have developed incipient spindle-like shapes (*Photo 18*) like basaltic volcanic bombs. All have a fine but rough outer granular surface. Many of the balls have been sheared, with the fragments displaced slightly and recemented by quartz and/or clay (*Photo 19*).

Internally, many of the balls are solid (*Photo 20*) with a fine homogeneous texture comprising phenocrysts of K-feldspar (sanidine) with less common quartz and occasional augite (?) evenly disseminated in a glassy groundmass. This is very different to the texture of the host ash fall tuff bed which comprises sanidine phenocrysts disseminated in a fine ashy matrix with no apparent glass component. The K-feldspar phenocrysts are well rounded, vary from 0.5mm to 5mm in diameter, show no twinning, and only very minimal peripheral alteration to clay (kaolinite), unlike the phenocrysts in the host rhyolitic ash fall matrix which are typically moderately to completely altered. Virtually none of the balls show any evidence for concentric accretionary banding and what at first appear to be nucleation cores may simply be a concentration of impurities and volatiles forced to the centre of the balls as they cooled from the outside inwards (*Photo 21*). One ball shows a highly irregular cavernous core (*Photo 22*) suggestive of a significant localised accumulation of volatiles or a sudden evaporation of contained water.

Many of the balls show discontinuous segmental voids (*Photo 23)* probably formed by shrinkage away from an already hardened rim during cooling. The surfaces of these voids are often coated with drusy colourless to purplish quartz crystals (*Photo 24*). These voids are often filled with later clay and a few contain masses of fine dark grey sediment (*Photo 25*).

Photo 10. The southern quarry face in September 2024 showing the exposed structures and stratigraphy. Chris Morton photo. Fold axis: ━━━ *Thrust fault:* ▪▪▪▪▪▪▪

Photo 11. Fault displacing the sediments below the ash fall tuff in the northern part of the quarry complex.

Similar voids seen in adjacent balls still held within the ash fall tuff appear oriented at random and hence are no indication of the way up within the tuff bed.

A feature common to all the balls found still within the ash fall tuff matrix is the presence of a very uniform one-centimetre-thick rind which remains firmly attached to the matrix when the balls are removed (*Photo 26*).

Microstructurally, the groundmass between the K-feldspar phenocrysts in the balls comprises a dense glass-like phase that shows varying degrees of devitrification, from very fine feathery white crystallites (probably cristobalite) (*Photo 27*), sometimes radially arranged around the K-feldspar phenocrysts (*Photo 28*), to well-developed 3D networks of microspherulites replacing the glass (*Photo 29*) at the outer edge of some spheres. So the precursor to what we see in the Coastal Quarry Products quarry today very likely resembled in texture and composition the glassy vitrophyre found in several igneous dykes in the Kew-Kendall area nearby (*Photo 30)*.

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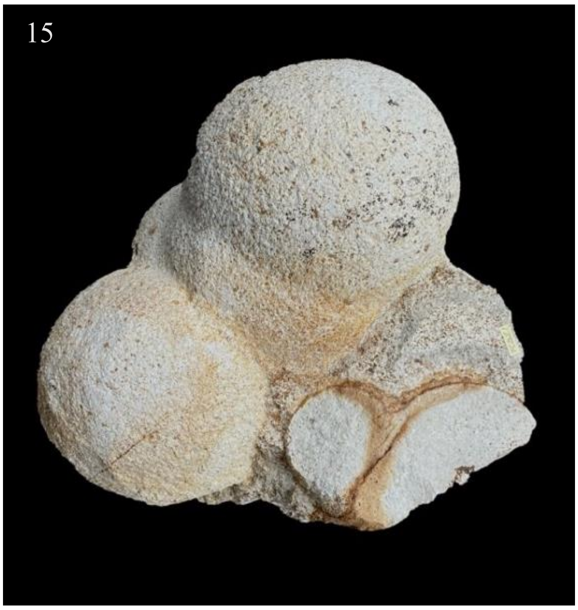

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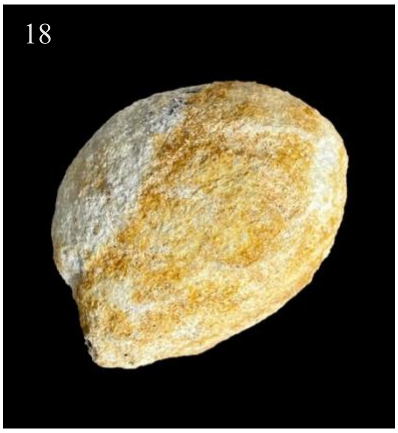
Photo 12. Spherical devitrified rhyolitic vitrophyre balls. Brian M. England specimens (R902). Size: largest sphere is 15cm. Photo 13. Symmetrically distorted devitrified rhyolitic vitrophyre balls. Brian M. England specimens (R903). Size: largest is 12cm. Photo 14. Fusion of two devitrified rhyolitic vitrophyre balls. Brian M. England specimens (R907). Size: Largest is 16cm. Photo 15. Fusion of three devitrified rhyolitic vitrophyre ball in ash fall matrix. Brian M. England specimen (R931). Size: 23cm. Photo 16. Fusion of two devitrified rhyolitic vitrophyre balls showing what appears to be a pressure ridge between them. Brian M. England specimen (R909). Size: 13cm.



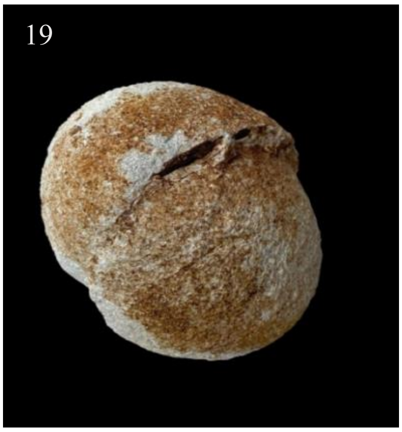


Photo 17. A devitrified rhyolitic vitrophyre ball showing a prominent flange. Brian M. England specimen (R906). Size: 7cm. Photo 18. A devitrified rhyolitic vitrophyre ball showing an incipient spindle shape. Brian M. England specimen (R905). Size: 8cm. Photo 19. Fractured and recemented devitrified rhyolitic vitrophyre ball. Brian M. England specimens (R904). Size: 12cm. Photo 20. Devitrified rhyolitic vitrophyre ball with solid core. Brian M. England specimen (R910). Size: 7.5cm. Photo 21. Devitrified rhyolitic vitrophyre ball with apparent nucleation core. Brian M. England specimen (R911). Size: 11cm. Photo 22. Devitrified rhyolitic vitrophyre ball showing a highly irregular central void. Brian M. England specimen (R913). Size: 9cm.

The rinds which remain attached to the host rock show no such devitrification textures and may simply be rapidly chilled glass. The internal surface of the pits left behind in the host rock show an identical granular texture to the surface of the balls. So, separation of the balls from the enclosing rind may simply be the result of shrinkage during the initial stages of cooling. Alternatively, and much more likely, the rinds may be a later feature developed through induration by fluids containing SiO_4H_4 released into groundwater by the weathering of the K-feldspar phenocrysts in the host rock through the following reactions (Esteoule-Choux, et.al., 1993). These chemical reactions during weathering also releases $Al(OH)_2$, which above a pH of 3.35 combines with the SiO_4H_4 to produce kaolinite, which replaces or precipitates adjacent to the K-feldspar phenocrysts.

$$KAlSi_3O_8 + 2H^+ + 6H_2O > 3SiO_4H_4 + Al(OH)_2^+ + H_2O$$

$$\underset{\text{Quartz}}{SiO_4H_4 > SiO_2 + 2H_2O}$$

$$\underset{\text{Kaolinite}}{2SiO_4H_4 + 2Al(OH)_2^+ > Si_2Al_2O_5(OH)_4 + 3H_2O + 2H^+}$$

But below this pH only quartz is deposited and kaolinite is not produced. Both reactions result in additional water which assists in the transport of the other reaction products, especially the

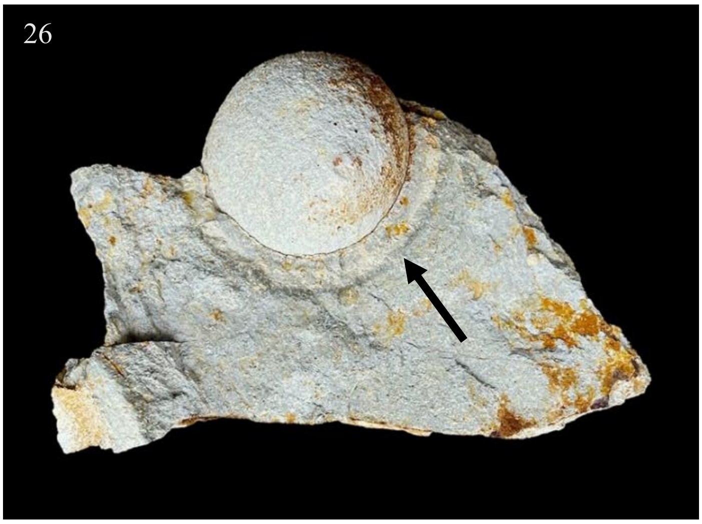


Photo 23. Devitrified rhyolitic vitrophyre ball showing annular void. Brian M. England specimen (R915). Size: 13cm. Photo 24. Devitrified rhyolitic vitrophyre ball broken open to show drusy quartz lined annular void. Brian M. England specimen (R916). Size: 12cm. Photo 25. Devitrified rhyolitic vitrophyre ball broken showing mass of fine sediment in central void. Brian M. England specimen (R917). Size: 15cm. Photo 26. The rind which remains firmly attached to the rock matrix when the vitrophyre balls are removed. Brian M. England specimen (R918). Size: 23cm.

SiO_4H_4. The drusy quartz deposited in the annular voids in the balls may have also come from these reactions, but may have also crystallised from residual fluids trapped inside the balls (see below).

THE DEVITRIFICATION PROCESS

The growth of spherulites (and hence crystallites) from a rhyolitic glass melt is mainly in response to significant undercooling as the lava cools. Experimental evidence provided by Gardner, et.al. (2012) shows that the silica and feldspar polymorphs forming the crystallites grow in acicular and/or fibrous forms because of this undercooling. Continuous cristobalite growth begins at magmatic temperatures of 790-825°C, passes through the glass transition temperature range of 750-620°C and is further modified in the solid state. The presence of polygonal masses of micro-spherulites in the Wauchope balls (*See Photo 29*), particularly towards their rims, may be due to a lower cooling temperature (<300°C) (Clay, 2012), with the enclosing or overlying ash acting as a thermal blanket, allowing complete devitrification to take place. None of the balls examined show any residual glass. Larger spherulitic structures could not have formed due to the abundance of sanidine nuclei.

Photo 27. Devitrified glass (vitrophyre) comprising feathery white crystallites. Photomicrograph by Chris Morton. Field of view is 0.5mm.

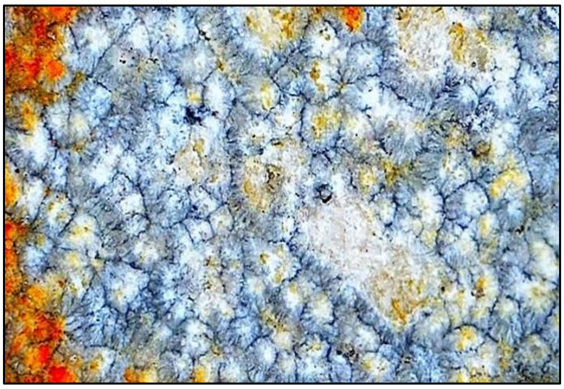


Photo 28. Devitrified glass (vitrophyre) showing crystallites radiating around sanidine crystals. Photomicrograph by Chris Morton. Field of view is 0.5mm.

Photo 29. Devitrified glass (vitrophyre) showing network of microspherulites. Chris Morton photomicrograph. Field of view is 0.5mm.

Photo 30. Specimen from one of the vitrophyre dykes in the Kendall area. Size: 11cm. Brian M. England specimen (R895).

This process introduces compositional gradients in the glass surrounding the developing crystallites of anhydrous mineral as a result of the effusive expulsion of incompatible constituents and diffusion of these away from the areas of progressive crystallite growth (Clay, et.al., 2012). Two of the main expulsed constituents are silica and water. Details of this process are very complex and are a function of melt composition, temperature, pressure and the actual degree of undercooling (Gardner, et.al., 2012). This is significant in the case of the Coastal Quarry Products quarry balls as it more likely explains the development of quartz/chalcedony-lined void linings, which are an obvious late-stage feature rather than inciting the external source of silica from feldspar weathering already discussed. In addition, the minimal weathering of the sanidine phenocrysts inside the balls may not have provided sufficient silica to form the void linings.

Studies on spherulite (and hence crystallite) growth in the Rocche Rosse obsidian flow in the Aeolian Islands (Clay, et.al., 2012) in fact show that water is expelled from the melt, so that excess silica from anhydrous crystallite growth may be carried by this water into voids. The presence of occasional rings of iron oxide (goethite) in the balls is due to change in iron oxidation state as the devitrification process proceeds.

SUGGESTED ORIGINS OF THE PRECURSOR GLASS BALLS

An extensive literature search by the authors unearthed a wide variety of possible origins. However, at first, no precise counterpart was found to the balls found in the Coastal Quarry Products quarry.

Fossil Hail Stones

The Earth to Space Science website suggested that during a thunderstorm, hail stones ploughed through a cloud of fine ash from an erupting volcano in the Cascade Range of Southern Idaho. As the hail stones fell and slowly melted, they became enveloped in ash and by the time they reached the ground had formed the thin-walled ash shells recently found in road cuttings. Regarded as accretionary lapilli, they are unusual in that they are hollow, instead of having formed by accretion around a solid core or condensed water droplet.

Only one of the many balls examined in this study has a central cavity (*See Photo 22*) and this is highly irregular, as if formed by the sudden volatilisation of water, perhaps originally contained in a muddy core. Hence their origin as hail stones is very unlikely.

Accretionary Lapilli

This origin was suggested by Ian Graham in his email reply to Mark Roche. Milton Orlando, National University of Columbo (Fisher,1984, page 238) provides the following detailed description of accretionary lapilli. They are common in fine-grained fallout ash deposits where the required moisture is provided by rain that often accompanies pyroclastic eruptions or from water or steam in the eruption column. Voids are often developed in the outer layers and in the core of lapilli from escaping volatiles (steam).

Excellent examples of accretionary lapilli were collected from the eastern side of the quarry complex (see geology section and *photo 8*). These are very typical of the accretionary lapilli described in the literature. In contrast, the precursors of the balls found in the Coastal Quarry Products quarry were found in this study to be dense spherical masses of rhyolitic glass (vitrophyre), not an accumulation of airborne ash particles.

Megaspherulites

Mineralogical and geochemical studies have been carried out on megaspherulites from Argentina, Germany and the United States (Bretkreuz, et.al., 2021). All megaspherulites comprise three concentric zones, centre, inner and outer. This distinct concentric zonation is always present. Early evolution is characterised by either central cavities or dendritic quartz-sanidine domains. The latter comprises bundles of fibres, each radiating from a single point, reflecting relatively high growth rates close to the glass transition to solid temperature. The termination of growth is marked by centimetre-size spherules on the surface. In addition, there are no small spherules in the lava host rock. Megaspherulite formation is dependent on low phenocryst content in the host lava, i.e., limited nucleation points, and they can only develop in dense glassy volcanic rocks such as obsidian, pitchstone or vitrophyre. Growth may last 30 to 40 years.

Although the balls from the Coastal Quarry Products quarry show some areas of microspherulite development, they have no single centre of radiating crystallites, show no distinct zonation, and could not have formed in a porous ash fall tuff bed devoid of dense glass layers. So, in the strictest sense they cannot be classed as megaspherulites! But they do resemble in part lithophysae, bodies formed in lavas at high temperature that develop one or more voids during growth.

DISCUSSION

Although the rhyolitic balls from the Coastal Quarry Products (formerly Volcanic Resources) quarry show some similarities with spherulites and even lithophysae, in the strictest sense they cannot be classed in either category. The main reason being that all our research points to the fact that they did not form within the rhyolitic ash fall bed in which they occur, as the ash fall beds are not glassy, but came from a geochemically related external source.

So how did the original vitrophyre balls form? Several of the collected specimens provide the most likely answer. The observed morphologies suggest the cooling of megadroplets of molten vitrophyre below the glass/solid temperature boundary before or as the lava was ejected at high speed under very high pressure through a narrow opening connected to the main vent, much like the ejection of a fluid from a spray gun. The lava would have been propelled upwards episodically by escaping gas and the balls very likely developed their spherical forms and groupings before being ejected. One of the collected matrix specimens (*Photo 31*) illustrates this process in vertical section, with devitrified glass balls trapped within fissures filled with fine tuffisite. This process also provides an explanation for the stretched and columnar forms of some of the glass bodies which formed constrained by the confined space (*Photo 32 and 33*). Some of the tuffisite veins did not reach the surface, terminating (*photo 34*) and sometimes trapping the vitrophyre balls in the cap rock. Even the rimmed (*See Photo 17)* and spindle (*See Photo 18*) shapes may have developed in these fissures prior to their ejection. Transverse re-healed fractures present in many of the balls (*See Photo 19*) probably formed on impact with the ground surface.

A very similar occurrence was observed during the 2008-9 Chaiten volcanic eruption in Chile (Saubin, et.al., 2016). During this eruption rhyolitic obsidian bombs were ejected from shallow conduits during transitional explosive-effusive activity. These bombs were ejected explosively at high speed (100 metres/second) following deep degassing of the magma below an obsidian dome. The dome and dense conduit plug became deformed by this deeper magma pressure, leading to plug and dome fracture and

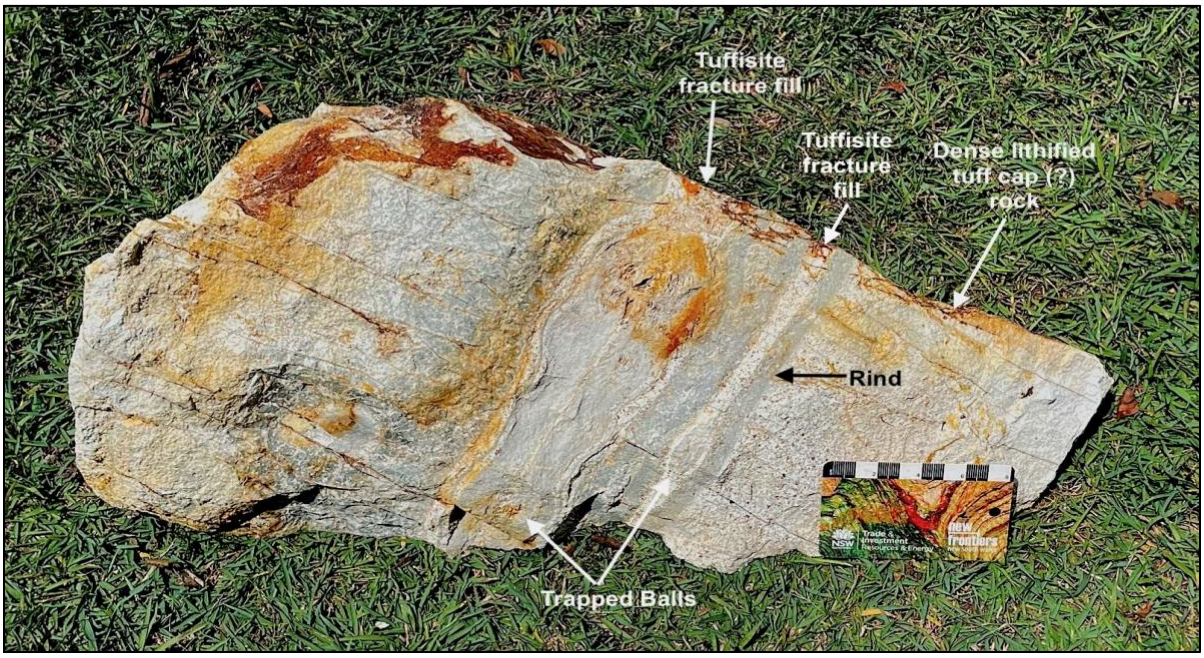


Photo 31. Specimen of lithified rhyolitic tuff cap (?) rock containing devitrified rhyolitic vitrophyre masses which have travelled along fracture-filling tuffisite veins towards the surface. Brian M. England specimen (R920). See scale for size.

formation of tuffisite (debris-filled) vein networks connecting the deeper and shallower conduits, allowing ascent of gas and obsidian bombs along a common vent episodically. The end result was a series of bomb-ejecting explosions. This is apparently typical of rhyolitic activity. This provides an almost perfect model for the formation of the rhyolitic spheres found at the Coastal Quarry Products quarry.

With the molten vitrophyre passing along these tuffisite conduits through the ash fall beds from below this would explain the elongate forms in *Photos 32 and 33* and the presence of mudstone inclusions (*See Photo 25*). Note that in *Photo 31* the tuffisite veins are also rimmed by rinds identical to those around the spheres, so these rinds are indeed formed after the balls became embedded in the tuff.

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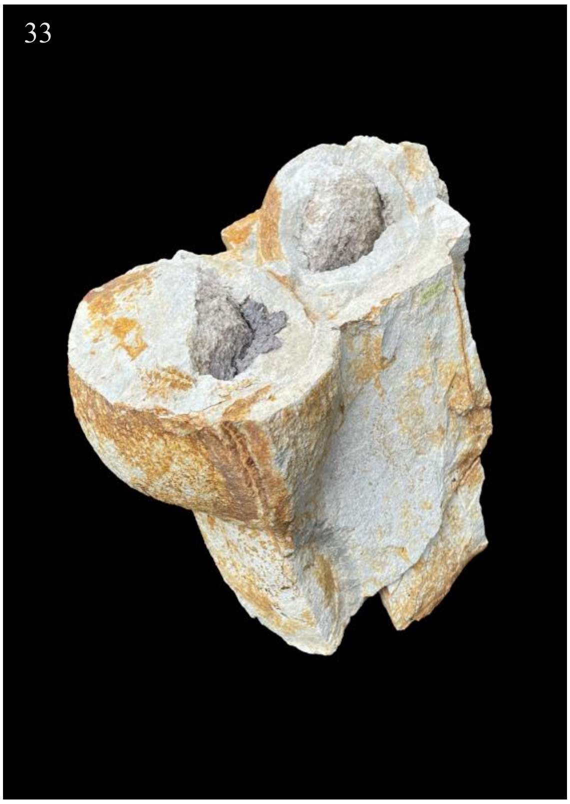

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Photo 32. Columnar devitrified rhyolitic vitrophyre mass. Brian M. England specimen (R919). Size: 27cm.

Photo 33. Matrix specimen showing a columnar devitrified rhyolitic vitrophyre body terminated in a ball at the top. Brian M. England specimen (R922). Size: 21cm tall.

Photo 34. Fracture-filling tuffisite vein which terminates within lithified cap rock. Chris Morton photo. Size: 45.5cm.

CONCLUSIONS

Although the balls from the Coastal Quarry Products quarry at Wauchope might resemble megaspherulites or lithophysae in part, they have a markedly different make-up and origin.

The absence of significant bodies of glass in the host rock and the presence of spectacular devitrification textures within the balls are very strong evidence that the balls did not form *in-situ* but came from an external geochemically related source. In fact, convincing field evidence shows they began as molten vitrophyre lava balls formed within and ejected from pressure-induced fractures in a mass of solidified lava blocking a volcanic vent. This conclusion is backed by reports of a similar modern analogy recorded during the 2008-9 Chaitén Volcano eruption in Chile.

The presence of crystallised quartz and botryoidal chalcedony in voids within the balls has also been explained. While infiltration of silica into from weathering of the sanidine phenocrysts in the host rock is a recognised source of both silica and water, as well as clay (kaolinite) the most likely source in this case was the progressive expulsion of silica (and water) during crystallite growth within the balls, with the excess migrating into shrinkage voids formed during cooling.

The location of the eruptive centre remains unknown, but must be vertically proximal. It probably lies below the current quarry floor beneath the exposed stratigraphy in the southern wall. The source of the magma may be a small intrusion (such as a cupola) or subsidiary conduit associated with a larger eruption centre which produced the ash fall beds. But this is purely speculative and the truth may never be known.

We suggest that these unusual and perhaps unique phenomena from the Coastal Quarry Products quarry at Wauchope be called “Devitrified rhyolitic vitrophyre volcanic bombs”.

Text by Brian M. England, updated 17th March 2025. Formatting by Chris Morton. Photos by Brian England unless noted.

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