

BLUE LACE AGATE FROM YSTERPUTS, SOUTHERN NAMIBIA

by Jo Wicht and Duncan Miller

For several decades small mines in southern Namibia have produced an attractive banded agate, mostly marketed as lapidary material. The major source has been a mine on Ysterputs (or sometimes spelled Ysterputz) farm, producing blue lace agate. It was promoted widely by the late George Swanson who owned the mine, so this material with its wavy blue and white lines is relatively familiar. What is less well known is that the blue lace agate from Ysterputs is accompanied by several minerals forming aesthetic, collectable specimens; and that there are other sources of blue chalcedony in the near vicinity. Several anecdotal accounts of the Ysterputs Blue Lace Agate mine have been published (e.g. Hudson 2002; Cross 2005), but until now there has been no detailed description of the occurrence or the mineralogical composition of the agate, and the associated late-stage minerals have not been described, nor illustrated, in publication.



Figure 1. Approach to the Blue Lace Agate Mine at the foot of the dolerite hills at Ysterputs.

The Ysterputs Blue Lace Agate Mine and surrounding geology

The Blue Lace Agate Mine is situated on the farm Ysterputs 254 in the Karas Region of southern Namibia. It is about 80 km north of the border with South Africa, at Noordoewer on the Orange River. The area is hyper-arid desert, with sparse succulent and seasonal grass vegetation, very low and sporadic rainfall, and extremes of temperature, ranging from 45°C in summer to below freezing at night in winter. The mine lies about 10 km west of the B1 national road, and 1 km from the edge of Blinkpan to the east, at the base of a range of prominent black hills (fig. 1).

These hills consist of the eroded remnants of the Tandjiesberg sill. This very extensive Jurassic dolerite sill, some 100 m thick, intruded older Karoo-age sediments (Werner 2006; Miller 2008). The mine is a linear excavation, more or less parallel to the present edge of the dolerite. The blue lace agate and its associated minerals occur in a nearly vertical brecciated shear zone in the dolerite.

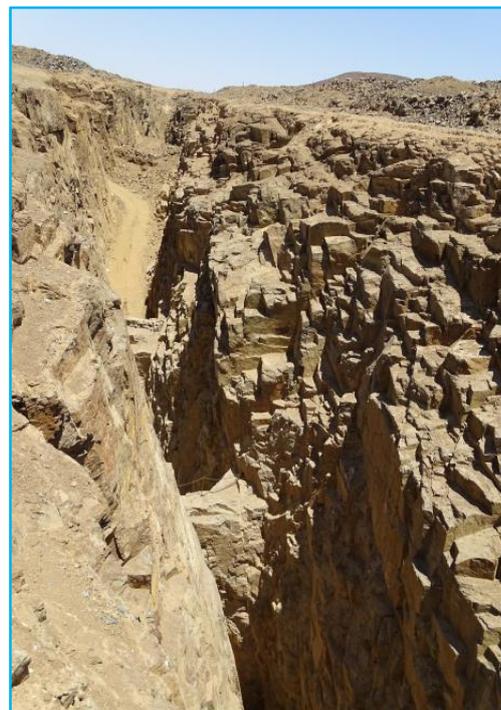
Locally, the Early Permian Karoo deposits are part of the Karasburg Basin, an outlier of the main Karoo basin, and once part of a vast inland sea (Pickford 1995). The local succession consists of the glacial Dwyka Group (Stollhoven et al. 2008), overlain by the fine-grained post-glacial inland sea deposits of the Ecca Group (Swart 2008). Three formations of the Ecca Group occur at Ysterputs: the Prince Albert Formation; the Whitehill Formation; and the Aussenkjer Formation (Palfi 2014). The Whitehill Formation is a widespread and persistent marker horizon, consisting mainly of dark carbonaceous shale that weathers white on exposure (Miller 2008). The development of a gypsum coating on the exposed surface makes it a readily mappable unit, easily visible on aerial photographs.

At Ysterputs the dolerite sill intrudes the Whitehill Formation. The sedimentary rocks and the sill are gently folded with dips of less than 30°. Intrusion of the dolerite into the Whitehill Formation produced regional low-grade metamorphism, with estimated temperatures of 250–300°C (Smithard, Bordy, and Reid 2015); although temperatures were high enough at the base of the dolerite sill to cause partial melting of the Whitehill shales at the contact (Werner 2006). This heat drove a hydrothermal system penetrating fractures in the dolerite sill and carrying saline brine and volatiles distilled from the underlying Karoo sediments.

The geology of the hydrothermal system at Ysterputs is not unique. There are deposits on adjoining farms containing chalcedony and prehnite (von Bezing, Bode, and Jahn 2007) and there are several geologically similar occurrences in adjacent South Africa. About 80 km southwest of the town of Kenhardt optical quality Iceland spar was mined from Karoo dolerites intruding the Prince Albert Formation (du Toit 1998) and near Calvinia, a bit further south, hydrothermal breccia plugs in weathered dolerite intruding similar Karoo sediments contained a wide variety of minerals in addition to the optical quality calcite. “It appears that the elements forming these minerals were mobilized from the country rocks (Whitehill and Tierberg Formations) by the intrusion of the thick dolerite sills” (de Beer et al. 2002, p. 68). There may well be other similar occurrences and only those that were exploited commercially appear in the geological literature.



Left. Figure 2. Pivoting hoist on the surface of Ysterputs mine in 2015.



Right. Figure 3. View to the south showing the vehicle access track into the Ysterputs mine in 2015.

At the time of a visit in 2015 to the Blue Lace Agate Mine, access to the main working trench was by chain ladder or by abseiling down the walls. The ropes were attached to chains pegged into the dolerite at the surface. The blue lace agate was jack hammered or chiselled out of the rock, put in bags, and came to the surface in large metal buckets via a crane positioned along the edge of the pit (fig. 2). There was a road in at the one end of the pit but it was blocked some way in to about 20 m height by the supporting walls (fig. 3). The large scoop drove in here to remove the waste rock from a blast, presumably put in the buckets and just dumped over the retaining rock wall, so that the scoop could take it to dumps farther away from the edge of the pit. Blasting was about twice a month. Once at the surface the blue lace agate was cleaned of excess matrix, but mostly the fine cobbling was done at Swanson’s Yard in the South African town of Springbok, some 180 km to the south. Once there were about 50 tons available at the mine, a truck was sent from Springbok to collect it.

The main excavation at Ysterputs is a narrow trench, about 50 m deep and nearly 1 km long, trending NNE/SSW. The primary vein dips 70–85° to the northwest (Hudson 2002; Palfi 2014). It is a seam of coarsely crystallized green carbonate, assumed to be calcite, and blue lace agate of variable width, mostly 2–3 cm wide but expanding in places to up to 50 cm, in “almost vertical, well developed joints in the dolerite” (Schneider 2004, p. 194). The carbonate has been assumed to be calcite because of its solubility in hydrochloric acid. But it has a specific gravity of 2.9, determined by hydrostatic weighing of an 87 g sample, which is near the top of the published range for calcite (Deer, Howie, and Zussman 1966). With further analysis it may prove to be ferruginous dolomite.

There is a clear sequence of mineral deposition, with several layers of the calcite coating weathered dolerite surfaces, followed by a layer of blue lace agate up to 3 cm thick. Where the fissure is narrow the bands may meet in the centre and result in an agate layer 6 cm thick (fig. 4). This represents the maximum thickness of the blue lace agate itself. Where the fissure is wider, fragments of weathered dolerite are also coated first with the coarsely crystallized carbonate and then a layer of banded chalcedony, sometimes producing bulbous masses between the planar layers adhering to the walls of the fissure (fig. 5). The final layer of agate that grew into free space usually is

covered with numerous trigonal points (see fig. 5), and any remaining open spaces are filled with a gritty brown clay, locally called *gom* (meaning 'glue'). This washes off easily with a household pressure washer.



Left. Figure 4. Blue lace agate filling a fissure from both sides with walls coated by greenish calcite. The maximum width of the banded agate is 6 cm. Jo Wicht specimen (JW100)

Right. Figure 5. A characteristic example of as-mined blue lace agate from a broad seam, showing the marginal 3 cm thick layers on each calcite-coated wall of the fissure, with a globular central portion, covered with trigonal points and brown clay. The globular central portion actually consists of fragments of dolerite, coated by calcite and a 3 cm thick layer of banded agate. The remaining cavity was filled with brown clay. The piece is 25 cm wide and 25 cm high. Jo Wicht specimen (JW C21)

This clay-rich material filling cavities has been described as nontronite (von Bezing, Bode, and Jahn 2007, p. 391) but without analytical confirmation. An X-ray diffraction analysis of two samples at the University of the Free State showed that it contained a smectite clay mineral. Nontronite, nominally $\text{Na}_{0.3}\text{Fe}_2((\text{Si},\text{Al})_4\text{O}_{10})(\text{OH})_2 \cdot n\text{H}_2\text{O}$, with variable substitution of calcium and magnesium, is the iron-rich member of the smectite mineral group (Deer, Howie, and Zussman 1966). Smectite is a common alteration product of basic rocks under alkaline conditions with availability of sodium, calcium and magnesium (Deer, Howie, and Zussman 1966). This material clearly is weathered dolerite with a smectite clay fraction, but nontronite still could not be confirmed by these analyses. Occasional vugs within the agate contain various additional minerals, including individual crystals of calcite, quartz, dolomite, gypsum, ankerite and siderite, also identified by geochemical analysis at the University of the Free State.

A single location at the Ysterputs Blue Lace Agate Mine is the source of rather enigmatic cubic chalcedony pseudomorphs (Fig. 6; also see <https://www.mindat.org/loc-159631.html>, accessed April 2020) after some unknown mineral, thought possibly to be fluorite (Zzyzx 2011). These pseudomorphs are the subject of ongoing mineralogical investigation.



Left. Figure 6. Cubic pseudomorphs of chalcedony after an unknown mineral, from a single occurrence in the Blue Lace Agate Mine. Width of the field of view is 3 cm. Jo Wicht specimen (JW086)

Right. Figure 7. A typical vein of 'Ellensbury', about 1 cm thick, in dolerite at the northwest Ysterputs workings.

About 150 m northwest of the main seam are several smaller parallel veins running for a distance of about 500 m (fig. 7). These were the location of the original chalcedony find and worked intermittently (Cross 2005), but the material is thin and less banded, occurring in very narrow seams in more weathered dolerite than at the main seam. This was marketed under the name 'Ellensbury', mimicking the name 'Ellensburg' in the USA, an area that produces a visually similar material (Hoskin 2005). Being so narrow it did not sell as well as the agate from the main seam, despite having an intense blue colour (fig. 8). This deposit and others on the adjacent farms Middlepos, Tunis and Grootplaats appear to be simply "stringers" of chalcedony filling minor fissures in the dolerite. They all lack the initial marginal calcite layers and repetitive banding that characterise the main fissure. The lack of brecciation and calcite in these minor veins suggests that these fractures in the dolerite opened after the main shearing and the phase of calcite deposition.



Figure 8. A particularly aesthetic specimen of 'Ellensbury', showing the intense blue colour of the thin agate band surrounded by a shell of decomposed dolerite. The specimen is 150 mm long. Jo Wicht specimen (JW084)

Some 750 m to the south of the main mining trench blue chalcedony is found on the surface among numerous weathered dolerite boulders (fig. 9). In places shallow diggings have been made and so-called "crazy lace" removed, but there is no clear vein visible on the surface so this material was not mined. George Swanson did not commercialise this stone, primarily because there are numerous vugs in it, and buyers of his blue lace agate wanted a constant supply of material without holes. Nevertheless, some of it makes an attractive lapidary material (fig. 10).



Left. Figure 9. "Crazy lace" outcrop in the dolerite boulder field south of the Ysterputs mine. Width of field of view is 150mm. Right. Figure 10. Polished transverse section of "Crazy Lace" vein, 13 cm thick, from the dolerite boulder field south of Ysterputs Blue Lace Agate Mine. Jo Wicht specimen (JW097)

Blue lace agate and associated minerals

Where both walls of the main fissure at the Blue Lace Agate mine are present in a specimen, there is symmetry in the colour and thickness of the individual quartz/chalcedony layers either side of a central plane, sometimes occupied by a terminal central vug or largely filled with massive chalcedony (fig. 11). A similar mirror-image structure has been reported for vein-filling banded chalcedony in so-called Creede Sowbelly agate (Raines 2005). Visual comparison of several sections of blue lace agate revealed a rough correlation in width, colour, and numbers of bands of quartz/chalcedony. We counted the alternating quartz/chalcedony bands, like tree growth rings, on four polished orthogonal sections and found they ranged from 47–49 bands, implying a number of distinct episodes of deposition. However, not all the banding is so regular. Many specimens have much thinner layers of blue

lace agate and some specimens have spectacularly contorted banding around irregular voids, probably formerly filled with decomposed dolerite fragments (fig. 12).



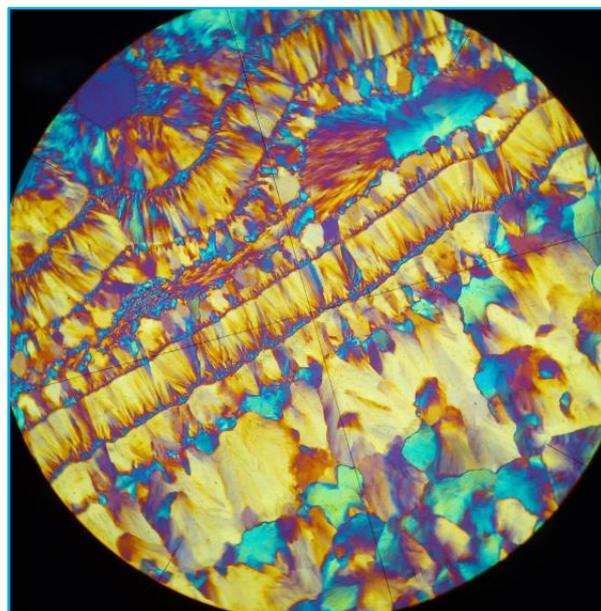
Left. Figure 11. Concentric blue lace agate filling an angular void, with massive chalcedony almost completely filling a central vug. The specimen is 290 mm long. Jo Wicht specimen (JW031)

Right. Figure 12. Spectacularly contorted blue lace agate banding draping around irregular voids, probably formerly filled with decomposed dolomite fragments. Width of specimen is 150 mm. Jo Wicht specimen (JW C25)

Seen in a polished section (fig. 13), chalcedony forms a thin layer within the banded calcite as well as an integral part of the banded agate. The first layer of chalcedony that forms on the final layer of coarse calcite contains numerous small chalcedony spherules, some embedded in the underlying layer of calcite (fig. 13). In a petrographic thin section in a polarizing microscope, the agate banding clearly consists of alternating layers of granular quartz and fibrous chalcedony (fig. 14).



Left. Figure 13. A polished slice through a typical seam of blue lace agate. The lower, yellow, banded calcite has brown ferruginous layers with an intervening thin layer of blue chalcedony. Above that, brown calcite with small, embedded chalcedony spherules leads into the main layers of banded blue lace agate, capped with quartz 'points', and gritty weathered dolerite 'gom'. The width of the blue banded agate is 3 cm. Duncan Miller specimen and photo.



Right. Figure 14. Petrographic thin section of blue lace agate in a polarizing microscope, in crossed polarized light, with a 1 λ (first-order red) wave plate inserted. In this orientation, the yellow colour indicates bundles of chalcedony fibres while most of the blue grains are quartz (diameter of field of view 2 mm). Richard Harrison photo.

The blue colour of chalcedony is reportedly ascribed to Rayleigh scattering — due to cavities, mineral inclusions, or sub-micron-sized spheroids thought to be amorphous silica (Hoskin 2005). Transparent and translucent layers of chalcedony may fluoresce bright green under short-wave ultraviolet light. Under short-wave ultraviolet light some specimens from Ysterputs show green fluorescent layers (figs. 15, and 16) and one specimen from the crazy lace area is draped with a thick layer of chalcedony that fluoresces bright green (fig. 17). Initially we thought this may be hyalite opal, but it cannot be scratched with a steel file, so is too hard for opal. The fluorescence is due to the presence of uranyl ions in small fluid-filled cavities (Michalski, and Foord 2005; Modreski 2005).



Figure 15. Green fluorescent banding in blue lace agate under SW UV light. This specimen is the same as in fig. 4. Jo Wicht specimen (JW100)

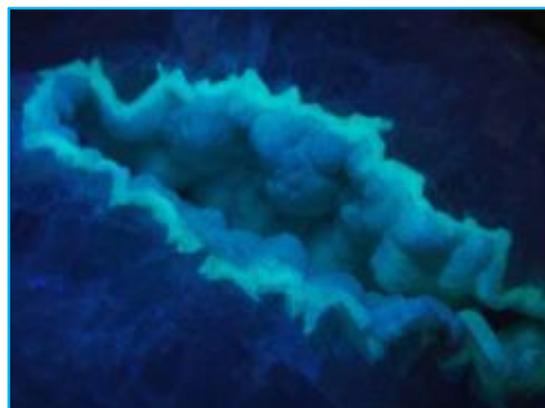


Figure 16. Yellow-green fluorescence under SW UV light of white chalcedony coating a thick layer of columnar quartz crystals lining a vug with a thin rind of blue lace agate. Jo Wicht specimen (JW012)



Figure 17. Green fluorescence of colourless chalcedony coating "crazy lace", under SW UV light. The specimen is 120 mm long. Jo Wicht specimen (JW046)

Discrete, scalenohedral crystals of calcite (CaCO_3) adorn the inner surfaces of some vugs (fig. 18) and the outer surfaces of some of the blue lace agate specimens (fig. 19). These are distinguished visually from ankerite/dolomite/siderite by their habit, and lighter colour. Dolomite, $\text{CaMg}(\text{CO}_3)_2$, also occurs as late-stage, euhedral, rhombohedral crystals in vugs (fig. 20), as blades on the outer surfaces of blue lace agate slabs (fig. 21), and as coatings on other crystals (fig. 22). The magnesium may derive from the marine sediments of the Whitehill Formation or perhaps from weathered ferromagnesian minerals originating in the dolerite. The presence of sulphate and the inferred presence of NaCl could have promoted the formation of dolomite at temperatures as low as 150°C (Deer, Howie, and Zussman 1966, p. 490).



Left. Figure 18. Scalenohedral calcite crystals growing on a drusy layer of presumed dolomite rhombs in a vug in blue lace agate. Width of field of view 35 mm. Jo Wicht specimen (JW C15)

Right. Figure 19. Scalenohedral calcite crystals growing on a layer of blue lace agate over coarsely crystalline calcite. Width of specimen 75 mm. Duncan Miller specimen



Left. Figure 20. Rhombohedral crystals of dolomite with siderite and ankerite coatings, determined by SEM-EDS. These rhombohedral carbonates cannot be distinguished visually. Width of field of view 60 mm. Jo Wicht specimen (JW078)

Right. Figure 21. Blades of dolomite on drusy quartz coating a slab of blue lace agate. The specimen is 70 mm long. Jo Wicht specimen (JW042)



Left. Figure 22. Calcite crystals coated in chalcedony, with fine brown dolomite crystals on the tips. The specimen is 100 wide. Jo Wicht specimen (JW094)

Right. Figure 23. Gypsum crystals perched on a layer of blue lace agate coating underlying green calcite. Specimen is 60 mm high. Jo Wicht specimen (JW082)

Gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, forms as discrete crystals perched on the outer surfaces of chalcedony in former vugs (fig. 23). These are very vulnerable to damage during mining, and few completely undamaged specimens are known to have

survived. The presence of gypsum is significant and probably derived from silica-depleted late-stage hydrothermal fluids circulating through the saline and gypsiferous Whitehill Formation marine sediments intruded by the dolerite sill.

Quartz, SiO_2 , forms an integral part of the blue lace agate and also occurs as discrete crystals. Quartz probably forms the trigonal points on the outer surfaces of many of the blue lace agate specimens (see figs. 5, and 24). These points are the expression of development of only the positive rhombohedral faces, as in “pseudo-cubic quartz” (Marché 2018; Menzies, and Frazier 2012). Other macroscopic quartz forms much finer secondary druses on the exposed surfaces of some blue lace agate slabs (e.g. figs. 19, and 21). Some vugs contain linings of white or blue quartz crystals (figs. 16, and 25) and in one unique example clusters of small, doubly-terminated, Herkimer-like crystals (fig. 26).

Siderite, FeCO_3 , and ankerite, $\text{Ca}(\text{Mg,Fe})(\text{CO}_3)_2$, have been identified by SEM-EDS analysis as components of several yellowish-brown rhombs on a slab of blue lace agate (fig. 20). The siderite crystals are visually indistinguishable from associated dolomite and the ankerite.



Left. Figure 24. Typical trigonal quartz points on the outer surface of a bulbous specimen of blue lace agate. This is a closer view of part of the surface of the specimen shown in fig. 5. Width of field of view is 60 mm. Jo Wicht specimen (JW C21)

Right. Figure 25. Blue quartz crystals lining a vug in blue lace agate. Width of field of view 60 mm. Jo Wicht specimen (JW095)



Left. Figure 26. Clusters of Herkimer-like quartz crystals in a chalcedony-lined vug, surrounded by coarse green calcite. Width of field of view 100 mm. Jo Wicht specimen (JW098)

Discussion and conclusion

Campos-Venuti (2018, p. 129-31) proposed a mechanism of formation of lace agate that involves an alternation of two distinct saline brines. One is a shallow, cold source associated with a weather-dependent saline lake and the other a hydrothermal system from greater depth, driven by heat from a magma chamber. Despite the suggestive presence of the adjacent Blinkpan, it is unlikely to have played any role in the Ysterputs deposit. The intrusion of the dolerite sill, part of the Karoo Dolerite Suite, took place 183 ± 2 million years ago (Duncan and Marsh 2006). There is currently no hydrothermal activity in the near vicinity of Ysterputs and the modern playa is a geologically recent feature, the result of differential erosion of the softer Karoo sediments at the base of the more resistant dolerite hills.

The regularity of the Ysterputs chalcedony banding, with mirror-image deposition on either side of the main fissure and a more-or-less uniform number of bands, is suggestive. It could be due to hydrothermal fluid pulsing (Heany 1993) or cyclical segregation of chemical components from a gel (Merino 2005) – the two unresolved

competing models of banded chalcedony formation (French, Worden, and Lee 2013; Howard, and Rabinovitch 2017). The Ysterputs blue lace agate has a characteristic alternation of quartz and chalcedony banding that is common to ordinary agate (French, Worden, and Lee 2013), so it is appropriate to call the Ysterputs blue lace “agate”, rather than an “agate-like, banded, chalcedony” (von Bezing, Bode, and Jahn 2007, p. 391).

In most cases the associated late-stage carbonate minerals – ankerite, calcite, dolomite and siderite – that decorate some vugs and blue lace agate slabs cannot be distinguished visually. Exceptions are the light-coloured scalenohedral calcite crystals and the very dark brown siderite rhombohedra. Hence, positive identification of rhombohedral crystals associated with blue lace agate necessarily depends on chemical analysis of the individual specimens.

The Ysterputs Blue Lace Agate Mine is reported to have operated from 1962 (Cross 2005) although the first available production figures are from 1965 (Palfi 2014). Production figures for the period 2003–2012 averaged 140 tons of cobbled material a year (Palfi 2014). Over the five decades of operation the Ysterputs Blue Lace Agate Mine produced many tons of blue lace agate for the lapidary market. In addition to the lapidary material from this hydrothermal deposit, judicious preservation of interesting mineral specimens by the mine manager and other staff has allowed local mineral collectors access to a suite of aesthetic specimens. Further images of Ysterputs mineral specimens can be found on Mindat (<https://www.mindat.org/loc-229681.html> and <https://www.mindat.org/loc-159631.html>); and mineral specimens and lapidary products (e.g. fig. 27 & 28), including carvings, at <http://namibianbluelace.co.za/>. Since January 2017 the mine has been dormant and currently its future is unknown. No private visits or collecting are allowed.



Left. Figure 27. Faceted blue lace agate bead set in silver, with a blue lace agate bead necklace.

Right. Figure 28. Blue lace agate snail with quartz crystal feelers. Both Jo Wicht lapidary

Acknowledgements

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All photos were taken by Jo Wicht, unless otherwise noted.

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Ysterputs “Crazy Lace” area looking north