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# NATURAL BLACK GLASS RESEMBLING AUSTRALITE FRAGMENTS

*By George Baker, M.Sc.*

Searches for australites in south-western Victoria, have revealed a number of fragments of materials superficially resembling australite fragments. They were found on some of the less vegetated areas that lie scattered along 50 miles of a narrow coastal strip between Moonlight Head and Childers Cove.

Most of these fragments are readily determinable as non-tektitic, but several are natural black glass fragments (Plates I and II) that have been rather puzzling and required laboratory tests to provide the ultimate proof of their true nature.

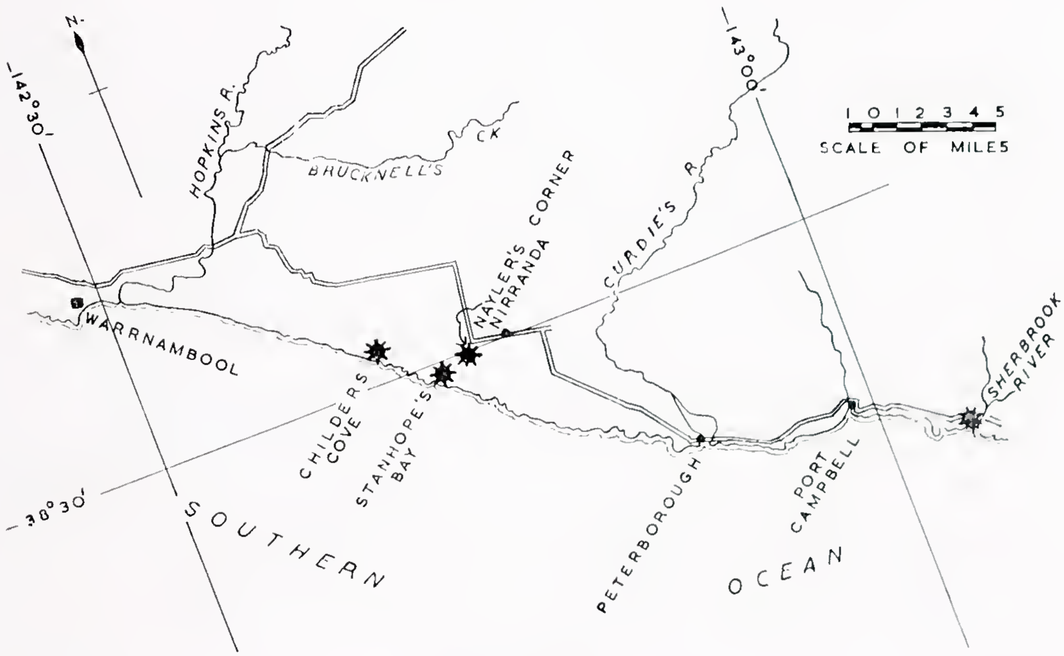


FIGURE 1.

Sketch map of the south-west Victorian coastline from Warrnambool to the Sherbrook River, showing sites (*) of natural black glass fragments.

Fragments of this black glass were located in 1934 on the west bank, near the mouth of the Sherbrook River in the Parish of Waarre, 3½ miles south-east of Port Campbell township (Parish of Paaratte), County of Heytesbury. Additional fragments were located in 1953 by Mr. R. T. M. Pescott, by Mr. E. D. Gill and by the author in the Childers Cove district, 23 miles west of the Sherbrook River site. Black glass localities in the Childers Cove district are (i) near Childers Cove itself, (ii) at Stanhope's Bay 2½ miles south-east of Childers Cove, and (iii) on the road-side, ¾ mile south of Nayler's Corner. These localities, shown in text fig. 1, are all in the Shire of Warrnambool, County of Heytesbury.

The fragments of black glass collected from these localities, are lodged in the National Museum Collection, Melbourne (reg. nos. E1115 to E1151), and twelve other fragments are registered in the Melbourne University Geological Collection (reg. nos. 2958 to 2969).

Chemical analysis has revealed that the black glass is of basic to intermediate composition. It occurs as irregular small fragments on the surface of a wind-swept and rain-washed old soil horizon of geologically recent age, that has been bared of the youngest soil layer and of vegetation on a number of small patches along and near the coastline. On the surface of such exposed areas, the black glass fragments have been found associated with occasional pellets of buckshot gravel, aboriginal flints, aboriginal midden shells and australites at each of the three principal sites of discovery, namely at the mouth of the Sherbrook River, at Childers Cove and at Stanhope's Bay.

The relative rarity of the black glass fragments and their peculiar external sculpture (Plates I and II), are noteworthy features. Fifty-three fragments have so far been collected. Their glassy character, black colour and the resemblance of certain of their external surface sculpture features to some of those shown by several types of the glassy, but acidic, tektites from various parts of the world, raised the question of the possibility that these peculiar black glass fragments might indicate the presence of tektites more basic than usual.

The main object of this paper is to show that in its more essential characteristics such as chemical composition, specific gravity and refractive index, the black glass is most likely non-tektitic, and seems to be of terrestrial origin, inasmuch as it is more specifically allied to the glassy tachylyte which is associated with terrestrial basic volcanic activity. Moreover, the fragments never reveal any remnants that would point to derivation from such symmetrical shapes as those possessed by the Australian tektites. The densely black colour, vitreous nature and resemblance of certain sculpture elements, thus combine to provide an entirely fortuitous set of circumstances causing these black glass fragments to resemble australite fragments. The chemical composition fairly closely approaches that of some tachylytes, while the specific gravity and refractive index values can be closely matched with the most glassy portions of some of the known Victorian tachylytes; in fact, these properties are identical with those of one example of tachylyte. A similar surface pattern to that on the black glass fragments, however, has not yet been observed on fresh or weathered specimens of black tachylyte examined from Victoria, although comparable surface features do occur on some specimens of green and blue tachylytic material lodged in the National Museum, Melbourne.

*Description.*

The black glass is brittle, non-magnetic, harder than orthoclase (H = 6) and just scratched by quartz (H = 7). It does not fuse under the blowpipe, and tends to spall readily under prolonged heating. Freshly fractured surfaces are vitreous and have strongly marked conchoidal fracture (Plate II, figures 14–18), sometimes with a pronounced secondary ripple fracture (Plate II, figure 15) on the curved surfaces, as in broken

TABLE I.

| Black Glass Fragments. | Sherbrook River. | Childers Cove. | Stanhope's Bay. | ¾ Mile South of Nayler's Corner. | Australites. |
|---|---|---|---|---|---|
| Number of specimens .. | 20 | 6 | 26 | 1 | Several thousand |
| Range of weight in grams | 0·49 to 4·05 | 1·06 to 2·96 | 0·26 to 9·80 | .. | 0·06 to 218·0 |
| Average weight in grams .. | 1·92 | 1·87 | 2·0 | 0·21 | 1 to 2 |
| Range in specific gravity .. | 2·67 to 2·81 | 2·80 to 2·83 | 2·66 to 2·83 | .. | 2·31 to 2·51 |
| Average specific gravity .. | 2·78 | 2·81 | 2·80 | 2·79 | 2·41 |
| Refractive Index .. | 1·575 | 1·575 | 1·575 | 1·575 | 1·488 to 1·520 |
| Total weight in grams .. | 38·40 | 11·22 | 51·40 | 0·21 | Several thousand |

australites. Weathered surfaces are duller and the partially worn secondary ripple fracture marks on some such surfaces (Plate II, figure 16), then bear some resemblance to certain flow patterns on weathered tektites.

Table I shows the number of black glass fragments discovered at each locality, together with their weights, specific gravities and refractive indices. Most of the weight and specific gravity values (sp. gr. determined at 20° C.), were determined on an air-damped balance, by Mr. G. C. Carlos. The values for australites generally, are appended to the list for comparison.

For a total weight from all localities of approximately 101 grams, the average weight of the 53 black glass fragments is 1·91 grams, and the calculated average specific gravity 2·79. The mode in the frequency polygon (text fig. 2) is 2·80.

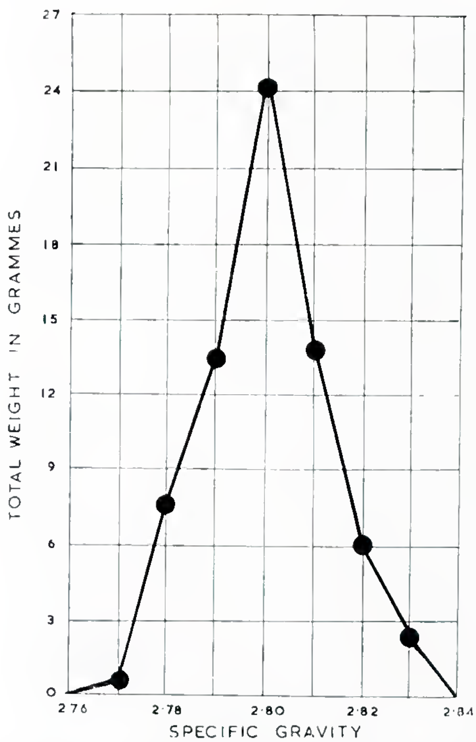


FIGURE 2.

Frequency polygon showing weight—specific gravity relationships in black glass fragments.

In comparison with the above values, the specific gravity of the most glassy piece of tachylyte located during a search of part of the caldera rim of Tower Hill, 7 miles north-west of Warrnambool, has been determined as 2·79, a value comparable with the general run of specific gravity values of the black glass fragments. Away from included crystals, the refractive index (1·575) of the darker parts of this piece of Tower Hill tachylytic glass, is identical with that of the black glass fragments. There are, however, marked differences in the chemical compositions of the two (cf. Table II), because the analysis of the Tower Hill specimen is of a rock composed of part glass and part crystals, the analysis of the black glass fragments is of a glass virtually free of crystals. A specific gravity value for tachylyte from Meredith, Victoria has been determined as 2·83 by Hall (see Dunn, 1914, p. 324), and another for tachylyte from a basalt quarry near Geelong, Victoria, was recorded as 2·74 by Skeats (1915, p. 336).

In contrast to australites, it can be seen from Table I and the black glass fragments have considerably higher specific gravity and refractive index values.

The colour of fresh fracture surfaces of the black glass is an even, dense black over the greater part of all specimens. The only exceptions are certain ring-like structures of glass that are embedded in the black glass (Plate I, figs. 7 and 8) and are greyish in colour.

Apart from colour similarity and vitreous character, the sculpture features that impart to the black glass fragments their superficial resemblance to fragments of certain tektites are (*a*) aggregated bubble pits (Plate I, figs. 1 to 6), and (*b*) ring-like structures (Plate I, figs. 3, 7, and 8), which on weathering, sometimes resemble the " höfchen " and " tischchen " structures found on some specimens of tektites. The characteristic external and internal flow-line patterns of tektites, however, are not present in the black glass. The distribution, diameter and depth of the bubble pits on some pieces of the black glass, are closely similar to those of bubble pits on the fractured and weathered surfaces of certain specimens among several of the different varieties of the tektites, in particular surfaces that are not as crowded as normally with bubble pits.

The combined " höfchen " (" little haloes ") and " tischchen " (" little tables ") structures (Plate II, figs. 13, 16, and 19), are similar in shape and arrangement to allied structures that have been variously referred to in tektite literature as " lunar craters ", " navels " and " ring marks." Such structures have been described more particularly from billitonites (see text fig. 3), moldavites and rizalites, and are rather rare on australites.

The " höfchen " are ring-like in plan (text fig. 3B) and are essentially circular grooves of U-shaped cross section surrounding an elevated central portion or small island called

" tischchen " (cf. text fig. 3A). On the black glass fragments from south-western Victoria, the " höfchen " structure is frequently occupied by brownish-grey coloured glass, and the grooves only become evident after the weathering out of this material. Where unweathered, the brownish-grey glass exposed

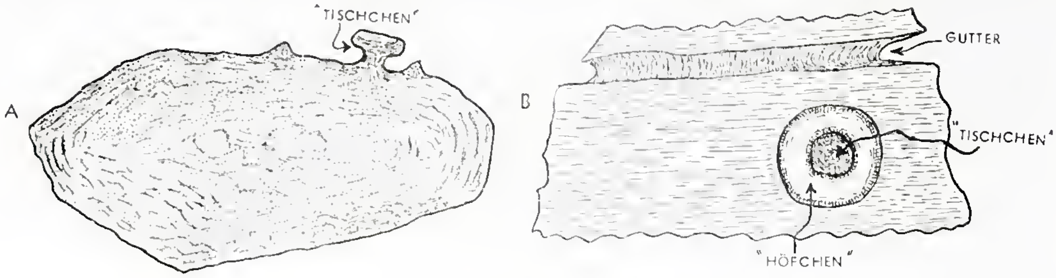


FIGURE 3.

Figure 3—Diagrammatic representation of " höfchen " and " tischchen " structures on billitonites.
A—side aspect of " tischchen " on an irregularly-shaped billitonite.
B—enlarged portion of billitonite showing plan aspect of " navel " (= circular groove or " höfchen "), surrounding an island of glass (= " tischchen ").
Magnification = x4.

on the surfaces of the flatter fragments, lies on much the same plane as the adjacent densely coloured black glass, and the structures resemble rings (Plate I, figs. 7 and 8), being thus similar to the appearance in thin section, as depicted in text fig. 4.

The " höfchen " and " tischchen " structures only become evident and accentuated as the brownish-grey glass is removed by weathering from the ring-like structures, thus leaving a circular, sometimes an elliptical groove having a surround of black glass on its outside, and an island of black glass within its inside curvature (see Plate II, fig. 19).

Fracture planes lying in three directions approximately at right angles to one another, reveal that the " ring marks " represent cross sections through what are virtually spherical to spheroidal shells of brownish-grey glass containing central cores of intensely black glass. These structures are in turn embedded in black glass identical with that of the cores enclosed by the shells of grey glass.

Such structures are of interest, inasmuch as a distinctly marked second type of glass has not been recorded from the " höfchen " structures of tektites. The grey glass shells in the black glass fragments weather more rapidly than the black glass. Chemical changes involve oxidation to a reddish- and brownish-coloured clay-like substance, sometimes quite hard, but frequently relatively soft and hence readily removed by etching and by mechanical processes, leaving the circular and elliptical grooves. Occasionally, in thinner fragments of the black glass, the whole shell of grey glass may thus be removed, the central core of more stable black glass falls away, leaving a hole (Plate II, fig. 17). The external dimensions of the shells of grey glass vary from 0·05 mm. for those that are spherical, to 9 x 14 mm. for those that are spheroidal. The range in thickness of the walls of the shells of grey glass is from 0.010 to 0.750 mm.


FIGURE 4.

Figure 4—Sketch of black glass as it appears in thin section. Rings of grey-coloured glass are embedded in densely coloured black glass. Small spherules of black glass are embedded within the " ring " glass, near the outer walls of the shells. Specimen from the Sherbrook River, near Port Campbell.

The surfaces of the "tischchen" are usually smooth in smaller examples (Plate II, fig. 19), bubble-pitted or irregularly roughened in larger examples (Plate I, fig. 5).

Most of the " ring marks " observed on the flatter fracture surfaces (cf. Plate I, fig. 7), are commonly isolated from one another. Less frequently they have coalesced into figure-8 shapes, and very rarely they are arranged in short chain-like structures composed of three or four links. A few of the smallest of the " ring marks " do not form complete shells of grey glass, the partially enclosed core of black glass being in contact with the surrounding black glass at two or three points, thus revealing disconnected crescent-shaped areas of grey glass as observed in sectional aspect.

The black glass fragments take an excellent polish, and examination of polished surfaces under the reflection microscope, reveals no opaque minerals. Etching in acids and thin section studies reveal no internal flow-line patterns.

It is impracticable to grind the black glass sufficiently thin to observe translucency with ordinary methods of illumination, since there is a tendency for the development of numerous fine, hair-like fracture lines separating the glass into small polygonal areas which break away only too readily with further grinding. The use of a concentrated beam of artificial white light, however, reveals reddish-brown colours in the thinnest parts of the densely coloured glass, while the greyish-brown shell glass takes on a yellowish- to brownish-grey colour and in parts shows strain polarization effects. These characteristics are markedly different from tektites, all varieties of which are evenly translucent in both thin sections and in thicker plates even under ordinary conditions of illumination, showing greenish- to brownish-yellow colours. Finely ground particles of the intensely black glass fragments, mounted in refractive index liquids and examined in daylight with the high power condenser of the petrological microscope inserted, show a smoky brownish- to reddish-grey colour on their thinnest edges. The glass on the whole, however, is remarkably opaque under normal conditions.

In thin sections, the lighter coloured glass of the "ring marks," and the intensely black glass within and around these structures, are generally quite free of crystals, thus indicating a homogeneous glass, since flow lines are also absent. The refractive index of the shell glass is 1·550, that of the black glass is 1·575. The only signs of the onset of crystallization, are extremely rare and very poorly marked. They can be observed under powerful artificial illumination in thin section of one only of the black glass fragments, where the largest of the cores of black glass within a shell structure, contains feathery skeletal crystals that weakly affect polarized light, but are indeterminate. The effect of their presence in this core, is to impart a crude radiating structure (Plate II, fig. 9) as observed in the hand specimen prior to sectioning.

A feature of the grey glass forming the shells of the spherical and spheroidal structures, is the presence of included small spherules of the intensely black glass that are invariably confined to positions close to the outer walls of the grey glass shells, as depicted in text figure 4.

*Comparison with known Victorian tachylytes.*

The usual types of tachylyte encountered in Victoria, are not nearly as vitreous as the black glass fragments discussed herein, and they generally show a microcrystalline to glassy structure under the microscope.

Examination of a collection of unusual and rare types of variously coloured tachylytes lodged in the National Museum Rock Collection, Melbourne, reveals that some of the specimens possess certain features similar to those displayed by the black glass fragments, thus further substantiating the tachylytic nature of these fragments. Bubble pits on iridescent tachylyte from the Mt. Shadwell quarry, near Mortlake, and on greenish-brown tachylyte from Mount Warrenheip, near Ballarat, are similar in size, shape and distribution to those on the black glass fragments from south-western Victoria.

A specimen of tachylyte from Sunday Creek, near Tallarook (reg. no. 1581 in the National Museum Rock Collection), contains black, brownish-green, bluish-green and blue coloured areas of tachylyte all " welded " together in the one hand specimen. The areas of black glass occur as spherulitic patches with a finely radiating structure, while portions of the brownish-green, bluish-green and blue areas contain small spherules of the black glass. Some of these small spherules are enveloped in grey glass, as in parts of the black glass fragments under discussion, and where weathered, similar " höfchen " and " tischchen " structures have been produced. The blue and bluish-green colours in this specimen, are evidently due to a small content of nickel and cobalt, or possibly to manganese and titanium (cf. analysis of the bluish tachylytic glass from Meredith, Victoria in Table II, column 3).

Other specimens of tachylyte in the National Museum Collection, obtained from the Corporation Quarries at Clifton Hill, from Broadford, Mirboo North, the Barwon River near Geelong, Meredith, the Werribee River, Mount Elephant and Mount Warrenheip, are all markedly vitreous, but most specimens differ from the black glass fragments in showing either occasional nests of crystals, or else occasional micro-crystals distributed throughout the glass. These specimens vary in colour from black, through brown, brownish-green, greenish- and brownish-yellow, but none of them have identity with the black glass fragments described herein. Very rare fragments of a greenish-grey coloured tachylyte resembling similarly coloured specimens in the National Museum Collection, have been found on the same rain-washed, wind-swept patch of ground near Stanhope's Bay where some of the black glass fragments were collected.

*Confusion of the black glass fragments with tektite fragments.*

Glassy specimens showing green, blue and reddish-brown colours similar to the colours of the tachylyte specimens referred to above, have been found in parts of Queensland, and have been referred to (Richards, 1934, and anon., 1937) as tektites. The writer has not seen these specimens, but their description is considered to be more applicable to coloured tachylytes which are known in the colours mentioned, rather than to tektites, accepted varieties of which are not known to have these colours.

Similarly coloured specimens of natural glass described from the Philippine Islands (Beyer, 1940), from Colombia in South America by Stutzer, and from Czechoslovakia by Suess and others, have sometimes been referred to as pseudo-tektites, and may well be tachylytes of similar colours to those mentioned above.

That tachylytic material was confused previously with australites and with obsidian in Victoria, becomes apparent from the following remarks. An early publication (Ulrich, 1875, p. 35) contains a description of obsidian as occurring "at Geelong, Ballarat, and in the crater hills and plains of the Western District; in the latter localities generally in small, button-like pieces and sometimes larger balls, hollow and glazed in the centre. A black, pitchstone-like mineral, probably tachylyte, has been found at Phillip Island." These "small, button-like pieces and larger balls" were later called "obsidianites" and are now universally referred to as australites.

The specimens of glass from Geelong, were described by Selwyn and Ulrich (1866, p. 65) as obsidian occurring in patches and irregular veins of an inch or more in thickness. Later, Dunn (1914) quoted some old analyses of the Geelong "obsidian," claiming that these analyses and others, proved there was acidic volcanic glass in Victoria, similar in composition to that of australites. Skeats (1915), however, showed that the analyses were unreliable, as Walcott (1898, p. 32) had already indicated, and that the so-called "obsidian" from Geelong was actually tachylyte (Skeats, 1915, p. 333) and contained globulites, trichites and scattered phenocrysts of olivine, augite and plagioclase felspar which are unknown in true tektites. It was thus the petrological work of Skeats (1915) that ultimately revealed the true character of black glass specimens which earlier had been confused with tektites. Since then, there has been little chance of confusing such specimens with tektites, as long as it could be shown that they were crystal-bearing by the use of thin sections and the petrological microscope. The black glass fragments under discussion in this paper, however, could still be confused with tektites, for so many of them reveal no vestiges whatsoever of globulites, trichites, microlites, crystallites or micro-phenocrysts of any mineral. Hence thin section studies have to be supplemented by specific gravity and refractive index determinations, and sometimes by resort to chemical analysis, in order to prove conclusively that they are in no way connected with the extra-terrestrial bodies of glass referred to as tektites.

Confusion of these black glass fragments with tektites, moreover, is even more likely to arise by virtue of the fact that they were found upon the same bare patches of ground as undoubted tektites (australites), in an area remote from the usual volcanic associates of tachylyte.

*Chemical Composition of the black glass fragments.*

Several typical specimens of the black glass fragments, totalling 8·2 grams in weight, were selected from the Stanhope's Bay site for the purposes of chemical analysis, and an analysis was also made of the most glassy piece of tachylyte that could be located on Tower Hill caldera, near Warrnambool. These analyses are compared in Table II with tachylytes previously analysed from Meredith, Victoria, and from Inverell, New South Wales, and with an average composition of australites.

The silica content of the tachylyte from a basalt quarry near Geelong, was determined by Walcott (1898, p. 32) as 53·2 per cent. A partial analysis by A. B. Edwards in 1935, of black glass fragments from the mouth of the Sherbrook River, 3½ miles south-east of Port Campbell, reveals close similarity with the black glass fragments from Stanhope's Bay. The $SiO_2$ content of the Sherbrook River example is 52·90 per cent., while $CaO = 6{\cdot}00$ per cent., $MgO = 3{\cdot}39$ per cent., and $TiO_2 = 1{\cdot}27$ per cent.

The chemical composition of the black glass fragments is comparable with that of the Meredith tachylyte and the Inverell tachylyte, but is rather more acidic than the Tower Hill tachylyte, and in no way comparable with the average composition of the much more acidic australites. Moreover, the black glass has a $SiO_2$ content up to 17 per cent. greater, an alumina content seven times greater, and a lime content four times greater than the opaque pseudo-tachylyte (cf. Barnes, 1940, p. 648) found as veins up to over one inch thick in meteorites, while there is much less

MgO, FeO, NiO and CoO. In addition, the specific gravity of meteoritic pseudo-tachylyte is 3·51 to 3·73, which is much higher than the average (2·79) for the black glass fragments discussed in this paper. There is thus little likelihood that the Victorian black glass fragments have come from the thicker veins of pseudo-tachylytic material found in some stony meteorites.

Table II, columns 1 and 2, show that the black glass fragments contain approximately 5 per cent. more $SiO_2$ than the somewhat glassy, but largely microcrystalline tachylyte from the caldera rim

TABLE II.

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|
| $SiO_2$ .. .. | 52·82 | 47·51 | 50·87 | 51·68 | 54·76 | 53·86 | 74·0 |
| $Al_2O_3$ .. .. | 14·93 | 13·69 | 14·33 | 14·77 | 16·49 | 15·41 | 12·8 |
| $Fe_2O_3$ .. .. | 2·08 | 1·87 | 5·37 | 1·26 | 0·80 | 1·50 | 0·5 |
| FeO .. .. | 9·78 | 10·53 | 7·25 | 10·70 | 10·71 | 11·51 | 3·9 |
| MgO .. .. | 3·37 | 7·99 | 4·51 | 4·67 | 3·57 | 3·60 | 1·9 |
| CaO .. .. | 6·80 | 8·56 | 8·22 | 8·37 | 7·89 | 7·18 | 3·0 |
| $Na_2O$ .. .. | 3·54 | 3·12 | 3·39 | 2·61 | 2·67 | 3·04 | 1·0 |
| $K_2O$ .. .. | 2·33 | 3·02 | 1·35 | 2·52 | 2·03 | 1·24 | 1·9 |
| $H_2O$ (+) .. | 1·10 | 0·13 | 0·17 | 0·13 | 0·59 | 1·10 | } 0·3 |
| $H_2O$ (−) .. | Nil | 0·06 | 0·33 | 0·01 | 0·11 | 0·44 | |
| $CO_2$ .. .. | Nil | Nil | .. | Nil | .. | .. | .. |
| $TiO_2$ .. .. | 2·67 | 2·91 | 3·38 | 2·91 | n.d. | 0·36 | 0·5 |
| $P_2O_5$ .. .. | 0·24 | 0·26 | 0·07 | 0·26 | 0·32 | 0·35 | .. |
| MnO .. .. | 0·34 | 0·33 | 0·58 | 0·33 | n.d. | 0·16 | 0·1 |
| NiO + CoO .. | .. | .. | 0·06 | .. | .. | .. | .. |
| $Cl_2$ .. .. | tr. | tr. | str. tr. | 0·12 | .. | .. | .. |
| Total .. | 100·00 | 100·01 | 99·88 | 100·34 | 99·94 | 99·75 | .. |
| Specific Gravity .. | 2·823* | 2·849* | 2·831 | .. | .. | .. | 2·41† |

* Specific gravity determined in the powdered state (−100 B.S.S.) at 20°C.
† Average specific gravity of 1,086 australites.

KEY

1—Black glass fragments (crystal-free) from Stanhope's Bay, 15 miles south-east of Warrnambool, Victoria. (Anal. G. C. Carlos.)

2—Tachylyte (crystal-bearing) from southern rim of caldera, Tower Hill, near Warrnambool, Victoria. (Anal. G. C. Carlos.)

3—Bluish coloured glassy portion of tachylyte, Meredith, Victoria. (Anal. A. G. Hall—see Dunn, E. J. *Rec. Geol. Surv. Vic.*, III., pt. 3, p. 324, 1914.)

4—Tachylyte, near slate quarry, allotment 55, Parish of Meredith, Victoria. (Anal. A. G. Hall, *Ann. Rept. Sec. Mines, Vict.*, 1910, p. 64.)

5—Tachylyte, Inverell, New South Wales. (See *Ann. Rept. Dept. Mines, N.S.W.* (1898), p. 187, 1899.)

6—Tachylyte, Inverell, New South Wales. (Anal. W. A. Greig—see *Ann. Rept. Dept. Mines, N.S.W.* (1912), p. 198, 1913.)

7—Average composition of australites from various localities in Australia.

of Tower Hill. The formation of this rather more acidic tachylytic glass, evidently lies in the early separation of rather more basic crystals from the parent (terrestrial) basic magma. These crystals would be floating in a molten groundmass having a generally more acidic composition than either that of the already formed crystals, or that of the magma as a whole. Separation of the crystals, probably by a process of local sinking, followed by rapid cooling of the residuum, produced a black (iron-rich), homogeneous glass showing practically no signs of further crystallization, and containing some 5 per cent. more silica and considerably less MgO than crystal-bearing tachylytic glass such as the Tower Hill example (Table II, column 2). The mode of formation of the small greyish-brown coloured shells of glass (which are a little more acidic again), embedded in black glass, is problematical.

*Remarks and Conclusions.*

On first appearance, the fragments of black glass described herein, are more readily mistaken for fragments of australites than are any other materials found in searches for tektites in several of the australite strewnfields of south-western Victoria. As well as being vitreous and equally as black in thick fragments, the glass sometimes shows bubble-pitting similar to that of some australites, and also shows the "höfchen" and "tischchen" structures so typically developed on certain varieties of the tektites. Photographs of portions of two australites have been included in the accompanying plates (see Plates I and II), in order to give some idea of the close resemblance in the hand specimens of the black glass fragments and tektite fragments.

Detailed examination, involving the preparation of thin sections and polished surfaces, the carrying out of chemical analyses, and the determination of refractive index and specific gravity values, finally proves that the black glass in question does not come into the same category as the acidic tektites with their ubiquitous and unique, complex internal and external flow-line patterns, different chemical composition, and lower specific gravity and lower refractive index values. Features which do show some resemblance to certain features of tektites, are therefore only pseudo-tektitic features.

The black glass fragments evidently come from a rare and special type of tachylyte, formerly gathered by the keen-eyed aborigines from a source as yet unlocated by us, and possibly prized by them for some particular purpose. It is known that the aborigines used tachylyte for implements (*fide* Mr. S. R. Mitchell), but the black glass fragments referred to herein, appear to be merely chips that were not worked for any special purpose, as they show no signs of aboriginal secondary chipping. They might well have been employed for ceremonial or other purposes, however, and so would be collected by the aborigines and carried for some considerable distance from their natural source. The aborigines are known to have utilized " emu-stones," consisting of australites and other black stones resembling them, in one of their emu-hunting methods, and evidently it did not matter to them whether the black stones were australites or fragments of black tachylytic glass, as long as they were densely black and possessed a vitreous character and some degree of rarity. It is also known that these black stones (" emu-stones ") formed a considerable proportion of the gizzard stones of large native birds. Thus it seems highly likely that the fragments of black glass were left by the aborigines, along with chipped flakes from other types of rocks, also grinder stones, &c., on areas close to large kitchen middens and camping grounds which are of frequent occurrence along these parts of the south coast of Western Victoria.

Whether or not these fragments became buried under surface soils at one time or another, their exposure over a considerable period of time, on barren patches of ground that are now much wind-swept and rain-washed, has led to the accentuation of their bubble-pitted structures and the etching out to varying degrees of the less stable greyish-coloured glass in the " ring marks ", thus producing tektite-like sculpture on black vitreous material.

The origin of the bubble pits evidently lies in gas bubbles escaping through glassy basic lava that was rapidly chilled, but the origin of the grey glass shells with enclosed cores of black glass, which on weathering ultimately gave rise to structures resembling the " höfchen " and " tischchen " structures on tektites, is a matter for considerable speculation. The lighter coloured glass of the "ring marks" has a lower index of refraction than the neighbouring black glass, thus reflecting a slightly different chemical composition, the most marked variation in which seems to be a lower iron content and a higher silica content. The refractive index of the greyish-coloured glass ($n = 1 \cdot 550$) being significantly lower than that of the densely black-coloured glass ($n = 1 \cdot 575$), indicates that it is rather more acidic, for it has been shown (Spencer, 1939, p. 425) that refractive index decreases with increased silica content in natural glasses. Having a lower refractive index value than that of the black glass, and hence suspected of being more acidic, the specific gravity of these grey-coloured shells would also be less, since the specific gravity of natural glasses also decreases with increased silica content. The shells of grey glass would thus be somewhat lighter than their cores of enwrapped black glass and their external surround of similar black glass. It would appear, therefore, that the grey glass shells represented bubble walls of lighter glass that had incorporated some of the denser black glass, and was suspended and partially dispersed in heavier black glass. The mode of formation of such shells of slightly different glass, however, at present remains a mystery.

The fragments of black glass have been subjected to minor amounts of natural flaking by sub-aerial agencies, during their period of exposure on an exhumed former soil horizon. This is indicated by the presence of quartz grains jammed into many of the circular and elliptical grooves, and into some of the bubble pits, added to which there has been some cementation of fine sand and clay constituents into similar positions. Differential expansion and contraction during diurnal changes of temperature (changes that would be very marked on the naturally bared patches where the fragments were discovered), would set up strains and stresses tending to weaken parts of the glass, ultimately causing spalling away of small fragments. Several specimens reveal evidence of minor fracturing that can be ascribed to such a series of events.

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## Description of Plates

### Plate I. (x3).

Figure 1—(E1119)*, showing bubble pits and bubble craters, one small and one large of the "höfchen" and "tischchen" structures.

Figure 2—(E1131), the largest fragment observed, irregular in shape and showing single and nested bubble pits, craters, occasional small "höfchen" and "tischchen" structures within and outside the craters, and groove containing altered shell glass extending from large "höfchen."

Figure 3—(E1138), showing bubble pits, several small "höfchen" and "tischchen" structures, groove with altered shell glass, and conchoidal fracture.

Figure 4—(E1118), showing larger "tischchen" with papillate and minutely pitted surface, surrounded by "höfchen" containing grey shell glass.

Figure 5—(E1117), side aspect of figure 9 (Plate II), showing large "tischchen" with irregular roughened surface (top of photograph) and ripple fracture marks. Smaller weathered "höfchen" and "tischchen" structure in left centre of photograph.

Figure 6—(E1146), showing vitreous lustre and group of medium size bubble pits ornamented with the wall remnants of smaller bubble pits.

Figure 7—(E1116), flat surface of a fracture fragment, showing broken "höfchen" and "tischchen" structures appearing as elliptical and circular "ring marks."

Figure 8—(E1136), sliced and polished surface, showing elliptical "ring mark" composed of grey shell glass (equivalent to "höfchen" structure), surrounding core of black glass (cf. "tischchen" structure), the whole structure being embedded in black glass.

### Plate II. (Nos. 9-18 magnified three times; No. 19 magnified fifteen times).

Figure 9—(E1117), a different aspect of figure 5 (Plate I) showing crudely radiating arrangement on surface of large "tischchen," due to incipient crystallization.

Figure 10—Portion of australite (E847) with groove and part of flow ridge, included for comparison with figure 11.

Figure 11—(E1145), showing deeply etched groove, few small bubble pits and a ridge formed by the junction of two fracture surfaces.

Figure 12—Portion of australite (E961), showing bubble pits; included for comparative purposes (cf. right-hand side of figure 18).

Figure 13—(E1133), showing occasional "höfchen" and "tischchen" structures, and three pits (in line trending north-east) from which both the shell glass and the core glass of the "höfchen" and "tischchen" structures have been removed.

Figure 14—(E1150), showing conchoidal fracture of densely black glass, and groove with weathered shell glass (on right).

Figure 15—(E1127), showing vitreous lustre on fresh conchoidal fracture surfaces having subsidiary ripple fracture.

* Numbers so given are registered numbers in the Rock Collection of the National Museum of Victoria

Figure 16—(E1125), showing flatter fracture surface with three small, well-developed " höfchen " and " tischchen " structures (cf. figure 19).

Figure 17—(E1151), showing weathered, slightly convex surface of conchoidal fracture fragment from which one " höfchen " and " tischchen " structure has been removed leaving a hole; others have been removed to leave pits.

Figure 18—(E1144), the smallest fragment observed, showing minutely pitted surface (cf. figure 12) and conchoidal fracture surfaces.

Figure 19—(E1125), enlarged portion (x15) of figure 16, showing small " höfchen " and " tischchen " structures.

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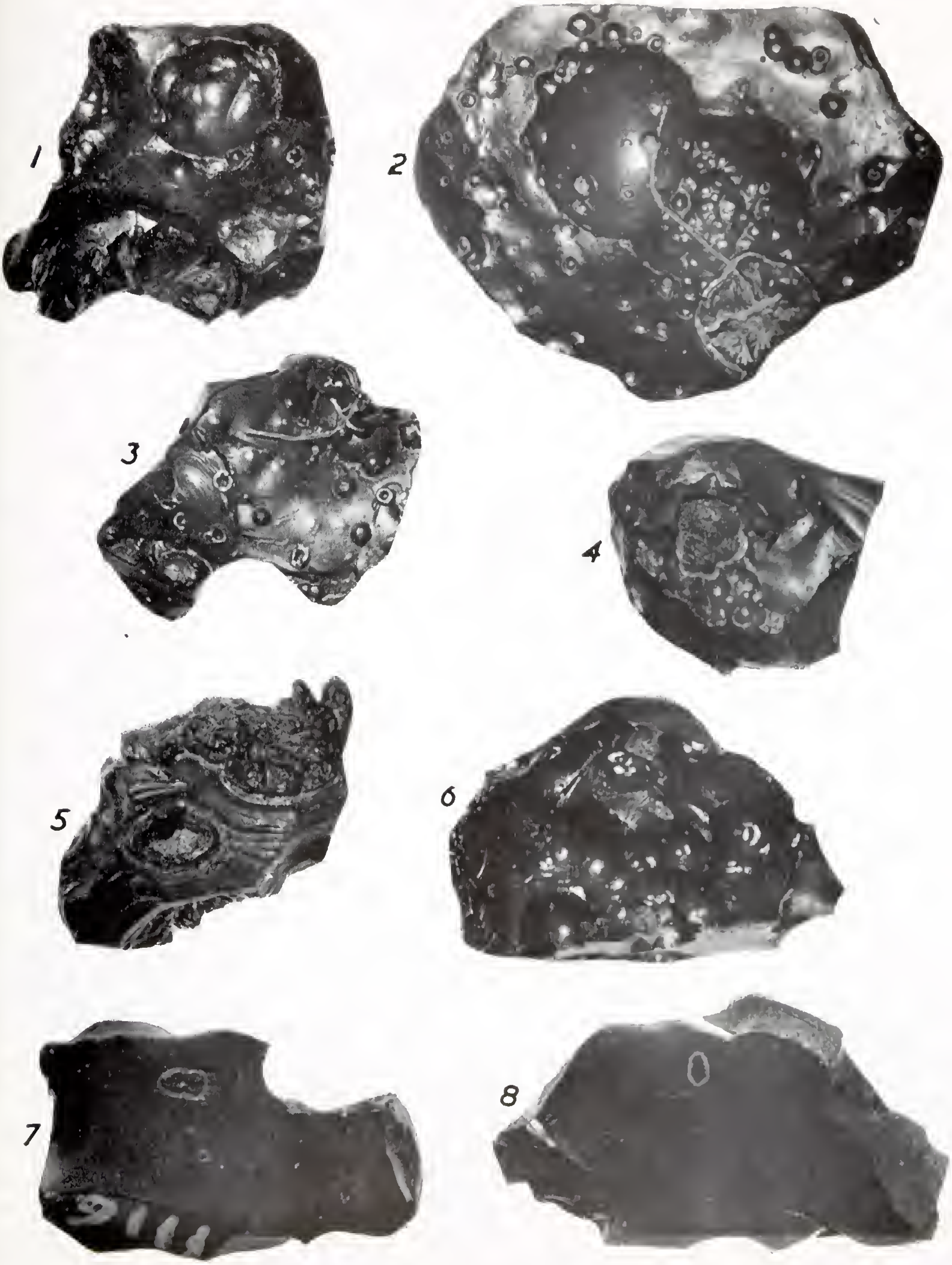
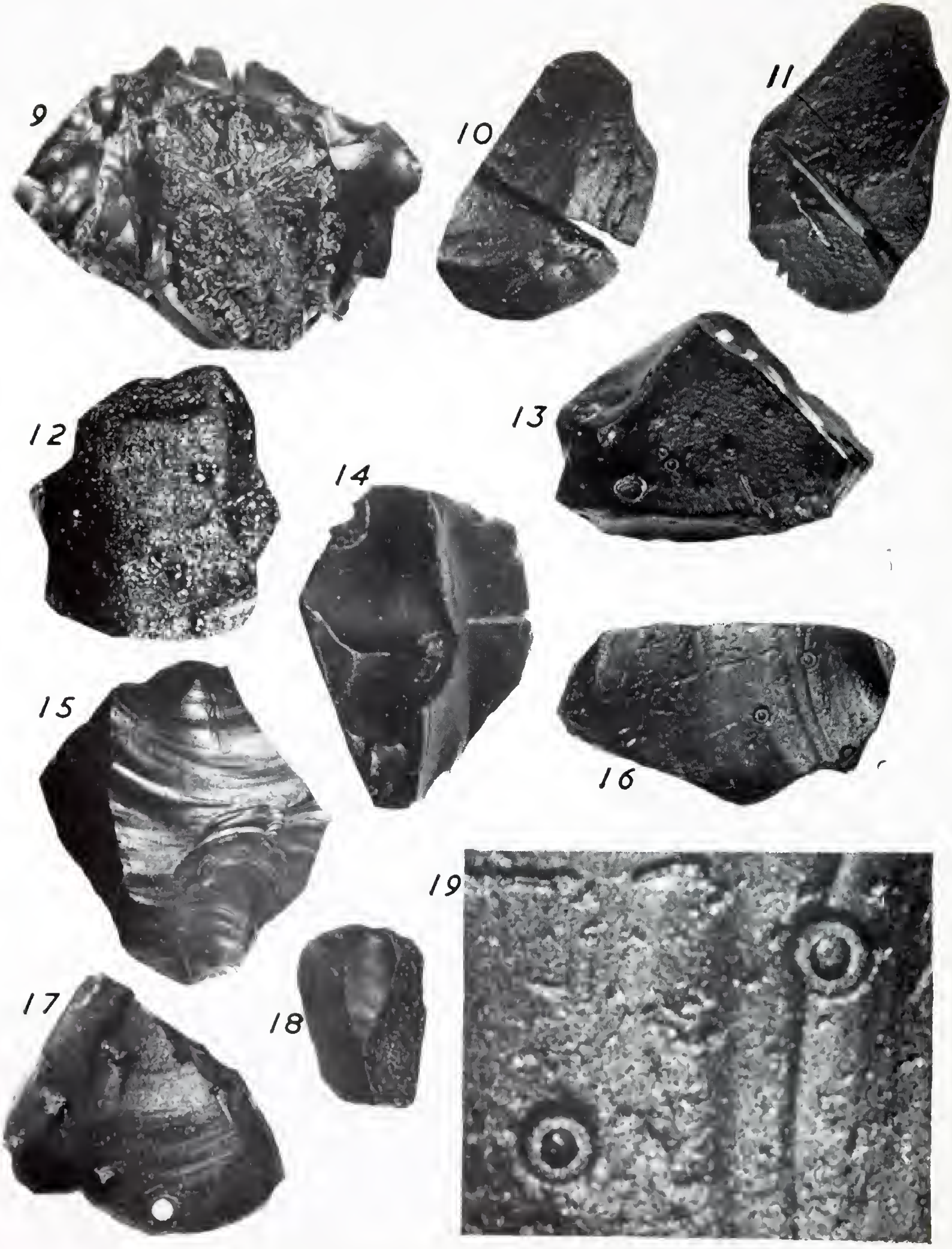



Black Glass Resembling Australite Fragments. (Magnified three times.)




Black Glass Resembling Australite Fragments. (9-18 magnified three times, No. 19 magnified fifteen times.)