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AUSTRALITES FROM THE MURRAY—DARLING CONFLUENCE REGION, AUSTRALIA

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Abstract

Sixteen naturally etched and subsequently moderately abraded australites from the region between the confluence of the Murray-Darling rivers and the South Australian border have been lodged in the collection of the National Museum of Victoria at irregular intervals over the past 72 years. Since only three others are recorded from this area, a distribution of only one per 1,250 km^2 is indicated. Found on the surface of fluviatile, lacustrine and aeolian sediments, these australites are regarded as having fallen there rather than being river-transported from elsewhere. The largest specimen, a round core weighing 56·67 g is 28 times as heavy as the smallest specimen, a dumbbell weighing 2·01 g. The low dynamics of the river system preclude fluviatile transport, but it is possible that Aboriginals carried them.

Introduction

The australites were found over 23,600 km^2 of the plains of the Murray-Darling river system. Thirteen of the specimens are from New South Wales and three from Victoria. The region includes the discovery site of the first australite brought to scientific notice (Fig. 1)—an oval flanged australite button picked up by Major Thomas L. Mitchell in N.S.W. in 1835 on the alluvial plain between the Murray and Darling Rivers. It was described by Charles R. Darwin (1844) as half of a volcanic bomb.

A noteworthy feature of this assemblage is that elongated forms dominate round forms in the proportion of 4:1. Apart from the 16 specimens referred to herein, two from Travellers Lake, 96 km N. of Wentworth, N.S.W., presented by Mr. Gil Black on 16 Oct. 1939, have passed out of the Museum collection, and one is known from Avoca Station, 22 km NE. of Wentworth (Baker 1959, p. 26). The nearest other recorded australites are:

1. A few worn specimens from Oakvale Station in S. Australia, nearly 160 km NW. of Wentworth, and 112 km S. of No. 13, Table 1.
2. A fractured, round, flanged button from Pink Lakes in NW. Victoria (Baker 1959, p. 25), 109 km S. of Wentworth, and 57 km SW. of No. 3 in Table 1.

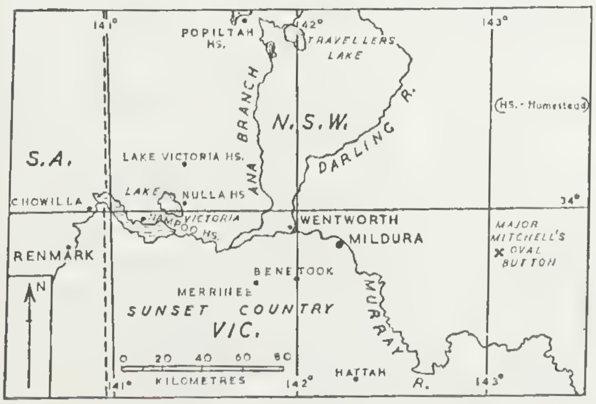


Fig. 1 — Sketch map showing localities.

Field Distribution and History of Discoveries

Australites from an area approximately 120 km from E. to W. and 197 km from N. to S. are listed from 12 general localities (Fig. 1) in Table 1. They were discovered at irregular intervals since 1900. Even though this region has become better known over the past 72 years, there has been no marked increase in the number of specimens brought to the National Museum. It is concluded that the number of specimens received is fairly representative of their spread. The first australite brought to scientific notice was found by Major (later Sir) Thomas Livingstone Mitchell who became surveyor general for N.S.W. in 1828. He led an expedition in 1835 to survey the Darling R., but

Type	Locality	Remarks	Source	Reg. No.
1. Round Core	E. of Nampoo Station 80 km. W. of Wentworth, N.S.W.	Found near old house	Loan Mr. J. Taylor 7 Feb. 1972.	
2. Oval Core	Benetook, 27 km S.W. of Mildura, V.	Earlier and later phases of spallation	Coll. Mr. R. Wilkinson, July 1950	M16879
3. Round Core	16 km NNW. of Hattah Railway Station, V.	On red loam surface of rabbit warren	Donated Mr. R. B. Eggleton 1968	E4873
4. Dumbbell	Popiltah Station 104 km NNW. of Wentworth, N.S.W.	Flow lines trend parallel with long axis	Donated Mr. M. R. Cudmore, 10 Jan. 1900	M5176
5. Boat Core	Near Wentworth, N.S.W.	Asymmetrical in elevation, one end 3 mm deeper. Pronounced rim	Acquired 3 Mar. 1967	E4210
6. Boat Core	NE. side of Lake Victoria, N.S.W.	Map ref. Ana Branch 428607	Donated Mrs. H. Hansen, 9 Apr. 1968	E4306
7. Oval Core	1 km E. of old hotel, Nulla Stn., N.S.W.	In loose sand 2·5 cm depth on dune. Three remnants of exfoliated shell	Coll. Mr. K. N. G. Simpson 15 Apr. 1971	E4834
8. Fractured Oval Core	Lake Victoria Stn. 64 km NW. of Wentworth, N.S.W.	Most of anterior surface lost by fracturing	Donated Mr. Armstrong, 17 Apr. 1917	E4874
9. Oval Core	Travellers Lake, 96 km N. of Wentworth, N.S.W.	Asymmetrical in plan from uneven spallation	Donated Mr. G. Black, 16 Oct. 1939	M11911
10. Dumbbell	Travellers Lake, 96 km N. of Wentworth, N.S.W.	Marked rim separates anterior/posterior surfaces	Donated Mr. G. Black, 16 Oct. 1939	M11913
11. Oval Core	Travellers Lake, 96 km N. of Wentworth, N.S.W.	Posterior surface virtually flat	Donated Mr. G. Black, 16 Oct. 1939	M11908
12. Incomplete Flanged Button	1·6 km S. of Nulla/Talgarry Stn. boundary E. side Lake Victoria, N.S.W.	Between kitchen middens, top of dune	Donated Mr. M. Barbetti 29 Dec. 1971	E4875
13. Half Dumbbell with flange remnants.	144 km N. of Wentworth, N.S.W.	Fractured across middle of waist	Donated Mr. M. R. Cudmore, 4 Nov. 1905	M11380
14. Button core	Lake Victoria Stn. 64 km NW. of Wentworth, N.S.W.	Two minute stumps of worn down flange	Donated Mr. Armstrong, 17 Apr. 1917	M11397
15. Teardrop	Travellers Lake, 96 km N. of Wentworth, N.S.W.	Flow lines trend parallel with long axis	Donated Mr. G. Black, 16 Oct. 1939	M11912
16. Dumbbell	Merrinee, 48 km SW. of Mildura, V.	Rim sharply marked separating posterior/anterior surfaces. Flow lines trend parallel with long axis.	Donated Mr. N. Favaloro, 23 Mar. 1948	E335

was forced to turn back in the face of hostile natives without reaching its junction with the Murray R. (Mitchell 1838). During this expedition he found a strange object which greatly aroused his curiosity at the approximate locality shown on Fig. 1. On return to Sydney, Mitchell presented this specimen to Charles Robert Darwin (1809-1882) who had filled the post of naturalist on Captain Robert Fitzroy's second voyage (1831-1836) of exploration in H.M.S. Beagle, which was in Australian waters 1835-1836. Darwin evidently received the specimen from Mitchell towards the end of 1835 or early in 1836. It was described as an obsidian-like object that represented half a burst volcanic bomb, which had changed its direction after bursting (Darwin 1844).

This specimen was unique until Rev. W. B. Clarke (1855) described specimens of "obsidian bombs" from the cradle of a gold-washer on the Turon R., N.S.W., and from the Uralla (= Rocky) R. in the New England district of that State.

The button-shaped australite found by Mitchell was referred to by Walcott (1898) under "obsidianites", as having been found on a great sandy plain between the rivers Darling and Murray, several hundred miles from any known volcanic origin. Walcott quoted Darwin: "The specimen seems to have been embedded in some reddish tuffaceous matter, and may have been transported either by the aborigines or by natural means". "The external saucer consists of compact obsidian, of a bottle-green colour, and is filled with finely cellular black lava, much less transparent and glassy than the obsidian". Fenner (1935, p. 136) remarked that Darwin suggested (with some doubt) a volcanic origin, since his mind at the time was largely engrossed by problems of volcanic phenomena encountered during the historic voyages of H.M.S. Beagle.

It is now 137 years since the first tektite was found in Australia, in which time only 19 specimens have been brought to scientific notice from the extensive area embraced by this paper. This is in sharp contrast with the total of 45,000-50,000 specimens known from the Australian strewnfield of some 3,200,000 km².

The concentration density for the Murray-Darling confluence region is only 1 per 1,250 km². This contrasts with the Port Campbell area on the S. coast of W. Victoria, where the density is 1 per 0.007 km², or about 136 per km².

Referring to the specimen described by Darwin, Clarke (1855) suggested it would seem to have drifted a very long distance. From the known habits of the Aboriginals, he thought it more likely to have been dropped by one of them, who probably found it in the trap hills of the Lachlan, to the NE. Clarke was evidently influenced by Darwin's conclusions that the material attached to the surface of the specimen was tuffaceous and that the object was obsidian-like. Fenner (1935, p. 136) classified the specimen as "an oval, with beautiful marked flange, pits, and flow ridges." Compared with the more recently recovered, well-preserved complete buttons from the Port Campbell area (Baker 1961, 1962, 1963a, 1967a, 1968a), the button from the Murray-Darling confluence is much more weathered and much duller in lustre.

In 1968, the author examined the original, which is lodged with specimens of obsidian in the petrological collection of the Geological Survey Museum, S. Kensington, London, with six other australites. It has been significantly corroded by soil etchants, its lustre has been much dulled by some degree of mechanical abrasion (evidently attrition by wind-blown sands), and a number of small facets around the outer edge have been caused by small-scale chipping.

The material attached to the specimen, said by Darwin (1844) to be tuffaceous, is still present. It is jammed into and partially cemented in the gap region (cf. Baker 1959) at the boundary of the flange and core (Baker 1968b). In the opinion of the author, this material is more consistent with a silty to clayey soil.

It varies in colour from greyish to grey-brown and red-brown, and is comparable with the materials constituting the soils of the river plain whence the specimen was recovered, like (for example) the loam on which the core from Hattah, (No. 3, Table 1) was found.

TABLE 2

Data on Australites from the Murray - Darling Confluence Region

	Shape Type	Wt. (g)	S.G.	Diam. or Length	Width mm	Depth mm	Depth Equatorial Zone (mm)	Max. size Etch Pits (mm)
1[a]	Round core	56.67	2.406	D40.5	-	26.9	15.7	2
2	Oval core	52.24	2.416	L42.8	37.2	26.2	-	4
3[ab]	Round core	46.29	2.410	D38	-	25.1	9.5	1.5 x 0.75
4	Dumbbell	32.52	2.407	L73.9	20.8) 20.5) gibbosities 16.9 waist	16) 15.8) gibbosities 13 waist	-	1.8 x 0.75
5[b]	Boat core	26.35	2.422	L48.4	22.6	14 - 17	6.5 - 9	3 x 1.5
6[a]	Boat core	19.50	2.403	L50.5	18.2	15.1	To 9.5	1.5 x 1
7	Oval core	8.73[d]	2.432	L23.7	20	13.7	6.5 - 8.5	1
8	Fractured oval core	7.04	2.401	L25.2	20.6	12	-	1
9	Oval core	5.93	2.419	L21.5	18.7	11.9	-	1 x 0.75
10[f]	Dumbbell	5.25	2.421	L36.9	12.5) 11.1) gibbosities 10.4 waist	9.3) 8.2) gibbosities 7.8 waist	-	0.75
11	Oval core	4.37	2.417	L18	16.3	11.9	8	1.25 x 0.75
12[c]	Incomplete flanged button	4.06[d]	2.384	D21.4	-	9.6	-	0.5
13[c]	Half dumbbell with flange remnants	3.88[e]	2.417	L25.2	16 gibbosity 8.8 waist	9.7 gibbosity 3.7 waist	-	1 x 0.75
14[f]	Button core	3.27	2.390	D19	-	9.5	-	0.5
15	Teardrop	3.14	2.429	L27.1	11.5 gibbosity 5.5 tail	10.5 gibbosity 3 tail	To 6.5 on gibbosity	1
16	Dumbbell	2.01	2.400	L30.3	9.7 gibbosity 7.4 waist	5.9 gibbosity 4 waist	-	1.25 x 0.75

a. Posterior flow swirls 40 x 39 (No. 1), 30 (No. 3), 13 x 6, 36 x 14.5 (No. 6) mm.
b. Etch grooves. To 8 long, 1 wide, 1 deep (No. 3); to 12.5 long, 1.5 wide, 0.75 deep (No. 5) mm.
c. Flange widths 2.5 (No. 12) and 1.5 (No. 13) mm.
d. Total weights including pieces separated off during ultrasonic cleaning. S.G. determined on main pieces weighing 8.42 g (No. 7) and 3.99 g (No. 12).
e. Approximately 7.8 - 8.0 g before fracturing.
f. Anterior surface flow ridges. No. 10 worn down to faintly recognizable structures. No. 12 concentric, becoming wavy by interference towards perimeter. No. 13 worn down, concentric on gibbosity, transverse on waist. No. 14 faint possibly anticlockwise spiral.

Weights and S.G. values determined by Mineralogy Department, National Museum of Victoria.

Weights, Specific Gravity, Dimensions

Only seven shape types are represented from 20 recognized among australites generally (cf. Baker 1959). A noteworthy feature of the assemblage from the Murray-Darling confluence is that elongated exceed round forms in the ratio 4:1.

From Table 2 it is noted that the weight range is 2·01-56·67 g, a round core from Nampoo Station being 28 times heavier than a dumbbell from Merrinee. The total weight of tektite glass is 281·25 g, and the arithmetic average approximately 17·5 g.

The range in specific gravity values is from

2·384 for an incomplete button (Talgarry Station) to 2·432 for an oval core (Nulla Station). The average S. G. is 2·411. No value is sufficiently low to suspect a significant content of internal cavities.

The longest specimen is a dumbbell from Popiltah Station measuring about 74 mm, and the shortest a core from Travellers Lake, measuring 18 mm. The widest specimen is a core from Benetook measuring just over 37 mm, and the narrowest a dumbbell from Merrinee, the widest portions of which are the bulbous ends of up to 9·7 mm. The greatest diameter (40·5 mm) is that of a core from Nampoo Station which also reveals the greatest depth value (nearly 30 mm).

For the unbroken dumbbell-shaped forms (Nos. 4, 10, 16), width and depth measurements are given for both gibbosities (swollen ends). These are significantly greater than width and depth measurements for the constricted waist regions. Minor differences in widths and depths of each pair of gibbosities for a given specimen, are largely a reflection of the effects of erosion (e.g. No. 4). Differences of over 1 mm (e.g. No. 10) more likely point to original small size differences in a pair of gibbosities. The same values for both width and depth for a pair of gibbosities (e.g. No. 16) indicate a high degree of primary dumbbell symmetry and comparable amounts of aerodynamic ablation during the secondary phase of tektite sculpture whilst travelling through the earth's atmosphere at hypersonic speeds (Baker 1958).

The length given in Table 2 for specimen No. 13, is only approximately half that of the unbroken form, since fracturing has occurred virtually across the narrowest part of the waist region.

A feature of the only teardrop-shaped specimen (No. 15) is that width and depth values are not of any great difference for the gibbose portion while the width of the attenuated tail portion is significantly greater than its depth.

There is a distinct rarity of forms with attached flanges or their remnants (Nos. 12, 13), and a complete absence of detached flange fragments. This is a reflection of the significant amounts of erosion to which the smaller specimens have been subjected. Larger forms such as Nos. 1-6, by virtue of their greater size, evidently did not generate circumferential flanges. These specimens have also been subjected to considerable amounts of terrestrial erosion.

Where more clearly defined, measurements could be made of the depths of the flaked equatorial zones on some of the forms, and these are shown in the eighth column in Table 2. The depth of the zone, where present, is measured parallel with the trend of the polar axis (i.e. parallel with AB in Fig. 2) and it extends from the rim at the edge of the posterior surface (Pl. 28, fig. C) towards the front polar regions. The range in zone depth developed on the boat core from near Wentworth (No. 5) from 6·5 mm to 9 mm is due to asymmetry in side elevation (one end is 3 mm deeper than the other). The primary form was evidently also asymmetrical.

Table 2 lists the maximum diameter of etch pits produced by natural solution etching during burial in moist soil. The range is 0·5-4 mm. Few are smaller than 0·5 mm, and all are relatively shallow. They occur on posterior and anterior surfaces and on some flaked equatorial zones, but are never especially common. Some were originally small "chatter marks" of lunate to circular shape, now slightly overdeepened by etching (e.g. No. 2). Sometimes they are a little more common on posterior than other surfaces (e.g. No. 5).

Flow swirls occur on only three of the 16 speciments (Nos. 1, 3, 6). The most interesting is on No. 1, where one large flow swirl showing more or less concentric schlieren occupies nearly the whole of the posterior surface. Only a limited, narrow region of the posterior surface is pitted, and this lies outside the limits of the smoother flow-lined central region of the posterior surface.

Sculpture Features

Most specimens reveal occasional etch pits and flow lines that have been made evident by natural solution etching during an earlier period in their history of terrestrial erosion.

This process commenced after the australites landed and evidently became embedded in moist soils. At a later stage, during periods of soil deflation, they were abraded by wind-borne sand to varying degrees. In this manner, many etch patterns were significantly modified and others obliterated, resulting in a generally worn and dulled character. There is no particular evidence to show that any were eroded in river beds, and no river-worn pebbles were associated with them.

An outstanding etch pattern is revealed by a core from near Hattah in NW. Victoria (Pl. 28). The specimen was cleaned by ultrasonic techniques prior to examination, hence the nature of the soil matrix was not observed. However, it occurred on the red loam surface of a rabbit warren. The etch pattern consists fundamentally of an intricate series of sharply marked etch grooves that have been developed on the posterior surface only.

The grooves are up to 8 mm long and nearly 1 mm deep and 1 mm wide. They are V-shaped in cross section and thus contrast markedly with the general etch grooves on australites, most of which are U-shaped in cross section and straight to sinuous in plan (Baker 1967b, figs. 2-5). As observed in plan (Pl. 28, fig. D), the grooves have acute-angled, bifurcating and trifurcating lateral terminations, except where interference occurs in the polar region. The grooves on other australites most frequently possess rounded terminations (Baker 1967b, figs. 2-5) and occur on anterior surfaces or equatorial zones, seldom on posterior surfaces.

The darker appearance of the grooves in the photographs (Pl. 28, figs. A, C, D) arises from their floors and walls being infinitely fresher in appearance than the surrounding, more eroded posterior surface. The glass of the groove floors and walls has a high degree of vitreous lustre.

Where the grooves are more concentrated towards the central portion of the surface (Pl. 28, fig. A), they link to form a crude interlacing network, but towards the periphery they are independent structures. The floors of some gutters are slightly deeper than others, due to differential etching. The partially radial arrangement of the grooves is not a function of the trends of the internal schlieren, but of the hemispherical nature of the posterior surface (Pl. 28, fig. C).

All the grooves are significantly deeper than earlier-formed (and subsequently partially abraded) micro-etch pits and etched out flow lines (schlieren) which can be readily detected in the enlargement shown in Pl. 28, fig. D. Since these grooves definitely cut across several of the earlier-formed micro-etch pits and distinctly transect the trends of the concentric schlieren (Pl. 28, figs. A, and D), it is evident that they are of much later development. They are, in fact, the last features to have been developed, and are of a nature not commonly present on australites. The only other described specimen with comparable grooves is from W. Australia figured by Simpson (1902, Pl. 38, fig. 1) and showing similar bifurcations and trifurcations.

The two stages of etching reflect climatic change, or transportation by Aboriginals from one climatic zone to another. The earlier developed micro-etch pits and the differential etching of schlieren shown in Pl. 28, fig. D, are regarded as arising from the action of soil etchants with associated soil biota. On the other hand, the etch grooves on the core from Hattah were apparently produced when the posterior surface was exposed at a later period, and could be the result of the solvent action of the hyphal filaments of such organisms as mosses or encrusting lichens. The latter are remarkable for their production of acids (there are over 200 so-called lichen acids).

The only lichen-encrusted australite known (hitherto unrecorded) is a round core from Mt. William in the Grampians, Victoria. The author examined and described this specimen (Baker 1968b), along with other australites in the British Museum (Natural History), London (reg. no. 1926, 394) during tenure of a Nuffield Special Study Grant. Weighing 22 g, this specimen has a specific gravity of 2·395-2·400 (det. Dr. D. R. Chapman), a diameter of 28·7 mm for the spalled core (31·7 mm including the still attached remnant of non-spalled glass), and a depth of 21·2 mm. The label refers to it as being "Lichen-covered". Dried-out lichen could still be observed in 1968; it occupied solution etch grooves and etch pits, especially on the equatorial zone in the vicinity of the still-attached "indicator" remnant, and was firmly attached.

Like the core from Hattah, the round core from Mt. William was generally eroded and in places revealed internal flow line patterns because of light natural etching. The sculpture pattern on the Hattah core (Pl. 28) proves that the etch grooves are of late origin, and not an outcome of high-speed aerodynamic gouging during its atmospheric transit phase.

Fractured Specimens

Four of the australites (Nos. 2, 8, 12-13) have lost significant proportions of their bulk by fracturing. Varying degress of weathering of the fracture surfaces indicate that such fracturing occurred at different stages. On the oval core from Benetook (No. 2) two sets of fracturing at various stages have resulted in the loss of considerable proportions of the tektite glass from one side of the specimen. Age differences for these events are evident from one fracture surface, up to 24 x 14 mm in area, being much dulled through weathering compared with smaller fracture surfaces (up to 17 x 14 mm across) that reveal vitreous lustre and a rippled fracture superposed on the conchoidal to sub-concheoidal fracture surfaces.

The dulled fracture surface is of some antiquity, but not quite as weathered as the surrounding non-fractured surface. The high lustre of the smaller fracture surfaces points to much more recent development. The end of the specimen diametrically opposite the more highly lustrous fracture surface reveals a characteristic, almost saccharoidal appearance of chattered and partially shattered glass generated at a pressure point where it was evidently in contact with a hard surface such as a stone, or possibly an anvil. This fracture seems to have been produced by human agency, and the fact that it has been lightly solution-etched points to the probability of fracturing by an Aboriginal rather than a European.

Prior to fracturing, but subsequent to ablation and spallation of the aerothermal strained zone (Baker 1963b), this specimen is estimated to have been some 20 to 30 g heavier, so that its weight would have been in the region of 80 g. The primary biaxial ellipsoid, prior to initial atmospheric entry, would have weighed in the region of 250 g.

The oval core (No. 8) lost the bulk of its anterior surface region through fracturing relatively early in its erosional history. A large conchoidal fracture occurred on the anterior surface, suggesting the possibility of fracturing on impact with the earth's surface on landing. That this may be so, is indicated also by its dull lustre and degree of erosion. If not an effect of impact on landing, then this fracture surface may be a consequence of diurnal temperature changes at a very early stage in the terrestrial history of the specimen. There is insufficient evidence to conclude that it was caused by Aboriginal man.

Of considerably less antiquity is the fracturing of the incomplete flange button (No. 12). This resulted in removal of some of the circumferential flange and a portion of the equatorial regions of the body core. That fracturing occurred relatively recently is indicated by the fairly high degree of vitreous lustre of the fracture surface and by the fact that internal schlieren have only been faintly brought up by light amounts of etching.

Considerable interest attaches to the fracturing of the half-dumbbell with still attached flange remnants (No. 13). Originally a little over 50 mm long (ex-flange), the dumbbell was fractured neatly across the central portion of the waist. The vitreous lustre of the surface has been slightly dulled by weathering, so evidently the fracture is of no great antiquity.

It could have been produced by an Aboriginal, because the broken portion of the constricted waist is bevelled and possibly secondarily retouched by pressure flaking to give a chisel-like edge. The gibbosity of the half-dumbbell is certainly a handy shape for gripping.

Developmental Phases of Etched Core from Hattah

Phases in the diminution of the primary glass

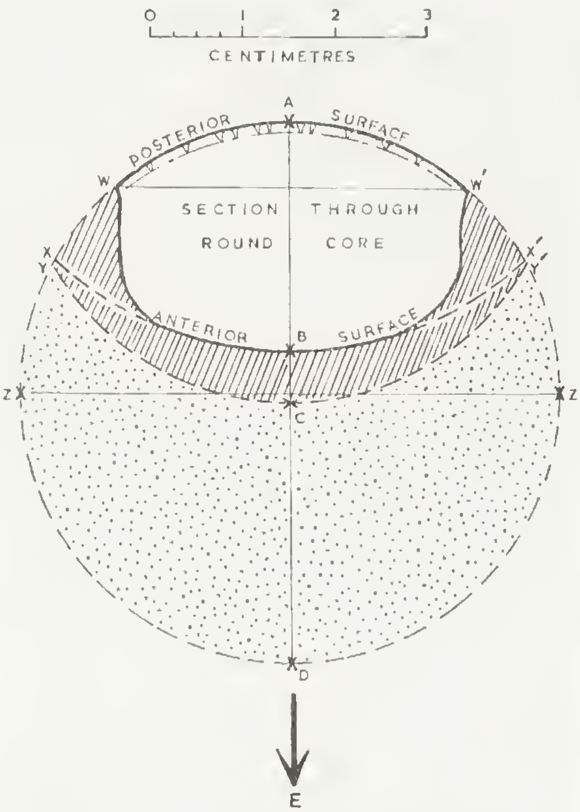


Fig. 2 — Diagram of development of round core from primary sphere of australite glass, based on specimen E4873 from Hattah, Victoria, illustrated in Pl. 28.

sphere from which the remnant round core (E4873) was developed by the secondary process of aerodynamic ablation followed by a tertiary process involving exfoliation and terrestrial weathering, are diagrammatically illustrated in Fig. 2.

The radii of curvature of the posterior and anterior surfaces have been determined graphically from silhouette traces as $R_B = 29{\cdot}3$, and $R_F = 37{\cdot}5$ mm. Inasmuch as R_B represents the curvature of the rear part as aligned in stable aerodynamic equilibrium (Fig. 2), and has not been affected by aerodynamic ablation nor severely modified by subsequent terrestrial weathering, the diameter (ZZ′, Fig. 2) of the original parent sphere from which the round core was developed, was approximately 58·6 mm.

Phases in sphere reduction represented in Fig. 2 are:

1. Removal of over 50% of the tektite glass by aerodynamic ablation (cf. Baker 1958), which resulted in the backward migration of the front pole of the specimen from D to C (Fig. 2) and migration of the equatorial regions from ZZ′ to YY′. This represents a loss of 2·9 to 3 cm depth of glass in the stagnation point region (i.e. front polar region) as a consequence of successive thin-film melting, evaporation, and possibly some fusion stripping; as a consequence, the diameter was reduced by approximately 8 mm.

2. Probably during the final stages of subsonic flight through the atmosphere and certainly after earth landing, spallation of the aerothermal strained zone (cf. Baker 1963b) resulted in the loss of a further 10 to 20% of tektite glass. The front pole migrated an additional 0·5-0·6 cm, from C to B (Fig. 2), and the equatorial regions from YY′ to WW′. This left the anterior surface of the round core with the arc of curvature XBX′, whilst also producing a flaked equatorial zone with a relatively sharply marked rim (Pl. 28, fig. C) separating the posterior from the anterior surface, and also producing a slightly recurved silhouette in side aspect, as shown below WW′ in Fig. 2. There was a further reduction of 13 mm in the diameter.

3. Natural solution etching, and some mechanical erosion by wind-borne abrasive particles, gave rise to further but much less significant losses of glass. In this way, the micro-etch pitted and flow-lined portions of the posterior surface (Pl. 28, fig. A) and the micro-etch pitted anterior surface (Pl. 28, fig. B) were produced. Subsequently, much more recent etching, evidently brought about more directly by plant action than by soil etchants, produced the remarkable pattern of etch grooves shown in Pl. 28, (figs. A, C-D), a sculptural pattern confined entirely to the posterior surface. These etch grooves penetrate about 1 mm below the surface as indicated by the Vs and the broken line (below WAW′) in Fig. 2.

References

BAKER, G., 1958. The role of aerodynamical phenomena in shaping and sculpturing Australian tektites. *Am. J. Sci.* 259: 369-383.

———, 1959. Tektites. *Mem. natn. Mus. Vict.* 23: 5-313.

———, 1961. A complete oval australite *Proc. R. Soc. Vict.* 74: 47-54.

———, 1962. Volumenbeziehungen von wohlerhaltenen Australit-Knöpfcn,—Linsen und—Kernen zu ihren primären Formen. *Chemie Erde* 21 (3/4): 269-320.

———, 1963a. Australite buttons. *GeoTimes* VII (5): 26-27.

———, 1963b. Exfoliation from the anterior surface of a flanged australite button, Port Campbell, Victoria, Australia. *Chemie Erde* 23(2): 152-165.

———, 1967a. Structure of well-preserved australite buttons from Port Campbell, Victoria, Australia. *Meteoritics*. 3(4): 179-217.

———, 1967b. A second large dumbbell-shaped australite, Ongerup, Western Australia, with notes on two other large australites *J. R. Soc. West. Aust.* 50(4): 113-120.

———, 1968a. Six well-preserved australites from the Port Campbell-Princetown region, Western Victoria. *Meteoritics* 4(1): 43-56.

———, 1968b. Australites in the British Museum (Natural History) Meteorite and Tektite Gallery, London. (254 quarto pp., 55 octavo pp., 8 pp. appendix, 1 map, 6 graphs). Xerox copy Brit. Mus. (Nat. Hist.) Library, South Kensington, London; original ms. in Min. Dept., natn. Mus. Vict., Melbourne.

CLARKE, W. B., 1855. On the occurrence of obsidian bombs in the auriferous alluvia of New South Wales. *Q. J. geol. Soc.* 11: 403.

DARWIN, C. R., 1844. *Geological observations on coral reefs, Volcanic Islands*, p. 38. London.

FENNER, C., 1935. Australites, Part II. Numbers, forms, distribution and origin. *Trans. R. Soc. S. Aust.* 59: 125-140.

MITCHELL, T. L., 1838. *Three Expeditions into the Interior of Eastern Australia.*

SIMPSON, E. S., 1902. Obsidianites. Notes from the departmental laboratory. *Bull. geol. Surv. West. Aust.* 6: 79-85.

WALCOTT, R. H., 1898. The occurrence of so-called obsidian bombs in Australia. *Proc. R. Soc. Vict.* 11: 23-53.

Explanation of Plate 28

Round australite core (E4873) from 16 km NNW. of Hattah Railway Station, NW. Victoria, showing natural solution etch pattern.

FIG. A—Posterior surface (x 2·27) showing intricate, sharply delineated natural solution etch grooves of biochemical origin, superposed upon an earlier-developed etch pattern of micro-pits and concentric schlieren, which had become modified and sometimes obliterated by wind-blown sand abrasion during a period of deflation.

FIG. B—Anterior surface (x 2·13) showing little surface sculpture apart from some micro-pits largely modified by subsequent mechanical abrasion.

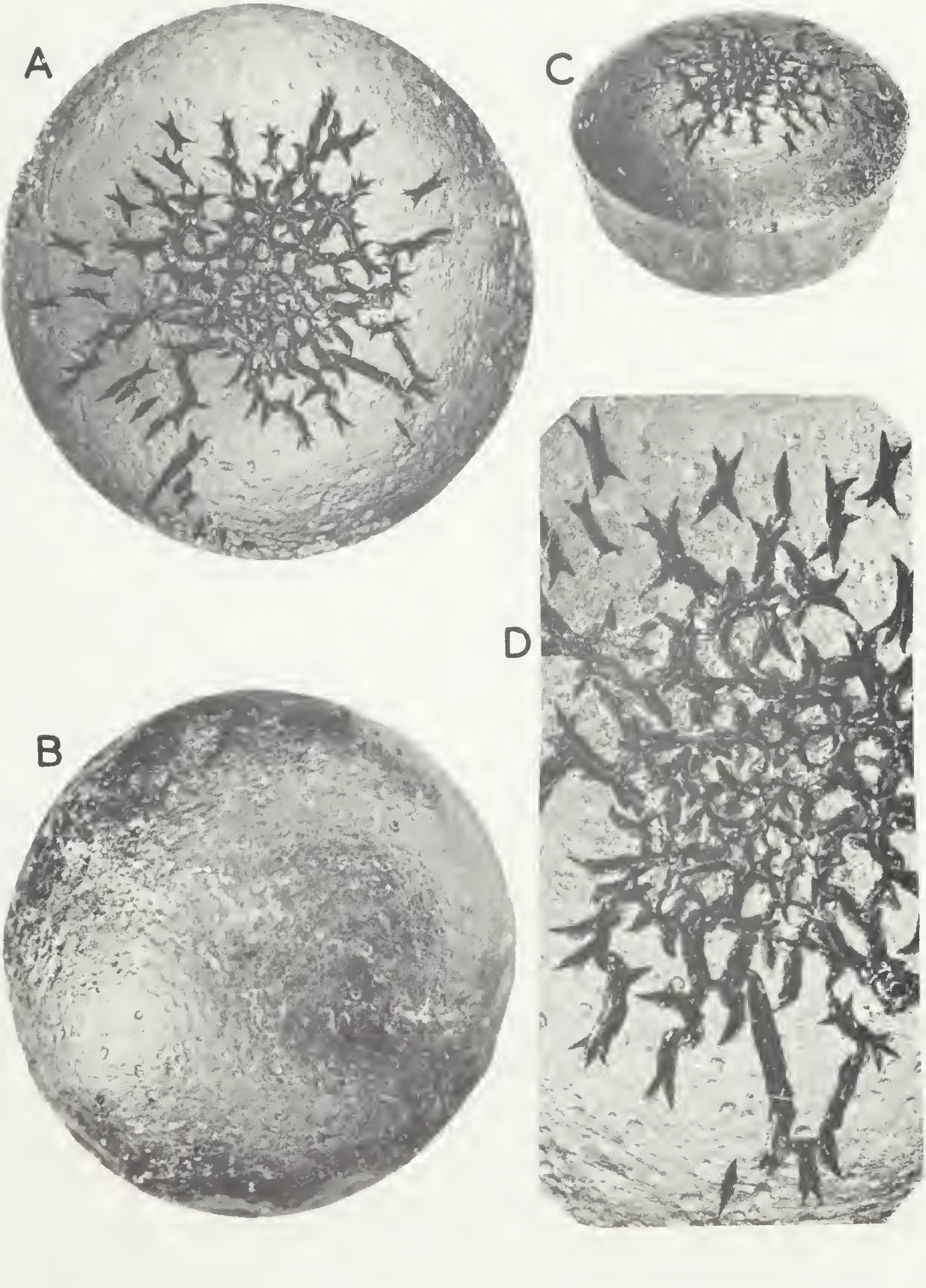
FIG. C—Oblique view (x 1·4) showing fairly sharply delineated rim separating the posterior surface (uppermost) from the flaked equatorial zone.

FIG. D—Enlargement (x 4·5) of the later etch pattern of natural solution grooves on the posterior surface, showing sharp, bifurcating and trifurcating terminations. Darker appearance of grooves due to fresher glass than surrounding posterior surface. Etch grooves transect earlier micro-etch pits and concentric schlieren.

(Photographs R.M.I.T.)

E = direction of movement for sphere in aerodynamic equilibrium moving down the flight path earthwards.
D = front pole of sphere (primary form)
C = front pole of ablated form (secondary form)
B = front pole of remnant core (tertiary form)
A = rear pole common to primary, secondary, and tertiary forms
AD = polar axis of primary sphere (= 58·6 mm)
AC = polar axis of secondary lenticular form (= 30 m)
AB = polar axis of tertiary remnant core (= 25·1 mm)
ZZ′ = diameter of primary sphere (= 58·6 mm)
YY′ = diameter of secondary lenticular form (= 51·5 mm)
WW′ = diameter of tertiary remnant core (= 38 mm)
YCY′ = arc of curvature of anterior surface of secondary ablated form
XBX′ = arc of curvature of anterior surface of tertiary remnant form
WAW′ = arc of curvature of posterior surface of tertiary remnant core

Stippled portion removed by aerodynamic ablation.
Hachured portion removed by exfoliation of aerothermal strained zone.
Broken line below and parallel with posterior surface represents greatest depth of penetration of etch grooves.


A
B
C
D