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AUSTRALITES FROM NURRABIEL, WESTERN VICTORIA.

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ABSTRACT.

Thirty-nine australites (Australian tektite glass bodies) were discovered in 1961 resting upon an old soil horizon exposed on removal of a thin cover of sand by the process of local deflation, at Nurrabiel, 16½ miles south-south-west of Horsham in the Western District of Victoria. They reveal most of the characteristic shape types represented in collections of australites from other districts in Western Victoria.

Although relatively well-preserved, they are more abraded than specimens naturally released from soils in the Port Campbell district, 128 miles to the south-south-west, but are generally much better preserved than the majority of the more numerous specimens of australites recovered from the marginal lands and more arid regions of South Australia, Central Australia and Western Australia.

Two unusual forms are a thin and slender canoe-shaped australite and an elongated, thin, bowl-like australite, each weighing approximately only 0·1 gms. Features of significance are (i) a clockwise spiral flow ridge on the anterior surface of a teardrop-shaped australite, and (ii) an internal cavity 9 mm. across exposed in one of the gibbosities of a dumbbell-shaped australite as a consequence of natural flaking.

Several of the forms have been fractured and some of these flaked further by natural means, but three fragments reveal evidence of aboriginal manufacture. A complete flange from an australite button, provides evidence of separation as an entire detached entity from the central body portion as a result of natural, terrestrial weathering.

Introduction.

Thirty-nine australites were discovered during an organized search of a large sand blow on the property of Mr. McDonald 1 mile west of Nurrabiel State School. The search was conducted at the end of April, 1961, under guidance in the field by Mr. Eric Barber, President of the Field Naturalists Club of Horsham. The locality lies approximately 16½ miles south-south-west of Horsham in Western Victoria, and 180 miles west-north-west of Melbourne. As a result of two and a half hours searching by seven people, it is believed that all of the australites and fragments exposed at the time, were recovered from the site. Others, however, could be later exposed by further superficial weathering of the surface of the ground. It is notable that the area searched yielded examples from all the usual australite shape types except the lens group.

The australites rested upon the surface of an old soil horizon uncovered by deflation and local wind erosion of a thin cover of drift sand. Once freed of enveloping finer soil components, they were exposed to abrasion by wind-borne quartz sand which has a hardness value slightly greater than that of australite glass. Most of the specimens occurred at the lower (western) end of a gently sloping, wind-swept and rain-washed soil surface approximately 1,600 square yards in area. None was located on the quartz sand accumulations that had drifted across this area.

Associated with the australites on the old soil horizon were numerous aboriginal flakes and occasional implements prepared from flint, chert, greenstone and other rocks. There was very little buckshot gravel, which is often a common associate of australites found *in situ* in various parts of the extensive Australian tektite strewnfield.

Other australites from areas some 33 miles south-west and 30 miles south-south-west of Nurrabiel have been recently described (Baker, 1955B; 1959B).

Degree of Preservation.

The specimens are rather worn compared with many of the well-preserved, excellent specimens recovered from the Port Campbell district (Baker, 1937; 1940A; 1940B; 1944; 1946; 1957; 1959A; 1960A; 1960B; 1961A; 1962), and the Moonlight Head district (Baker, 1950) on the south coast of Western Victoria. This is largely because they have been exposed to abrasion by quartz sand drifting over them. Several, however, are in a rather better state of preservation than others, and reveal structural features in part accentuated by solution-etching during partial or complete burial in soils. They match some of the not so well-preserved Port Campbell australites and are better preserved than most of the Nirranda (Baker, 1956) australites. Such specimens were evidently more recently released from the old soil horizon than the abraded specimens.

On the whole, the specimens are in a much better state of preservation than most of the more common and badly weathered australites that have been found in the sub-arid to arid parts of the Australian tektite strewnfield (cf. Baker, 1961C; 1961D), such as parts of South Australia, Central Australia and Western Australia.

Proportions of Shape Types Represented.

Omitting the naturally produced nondescript fragments (see Table 1) and the flakes prepared by aboriginal craftsmen (cf. Baker, 1957), none of which provide sure evidence of derivation from a particular australite shape group, the collection of Nurrabiel australites is constituted of 57 per cent. of forms that are round in plan aspect and 43 per cent. elongated forms. The proportion of elongated forms is rather high, for in larger collections and throughout the australite strewnfield generally, round forms exceed elongated forms in the ratio of 2·4 : 1.

Including the naturally flaked nondescript specimens, but not those flaked by aborigines, 43 per cent. of the collection consists of fragments resulting from the effects of terrestrial erosion. The remainder consists of better preserved, recognisable forms, none of which is entirely complete (*note*: the complete, detached flange [Table 1, No. 17] is virtually entire in itself, but has broken from an australite button).

Weights, Specific Gravity Values and Dimensions.

Of the 39 australites found at Nurrabiel, only 34 are described in detail herein. Five specimens remained in the possession of a resident in the Horsham district and were not available for detailed investigations. These five included a large oval core, a badly chipped and pitted flanged button, a canoe-shaped form with flange remnants, and two nondescript fragments.

The weights, specific gravity values and dimensions of the other 34 specimens are listed in Tables 1 and 2, together with a brief description indicating the australite shape types and the finders of the specimens (in Table 1).

Notes on Table 1.

Specimen No. 25 was obtained from a sand blow, near hall, north side of Noradjuha—Horsham-road, 7 miles south-east of Horsham. All others are from a sand blow one mile west of the State School, Nurrabiel. The total weight of these 34 australites is 63·048 grams.

Arrangement in Tables 1 and 2 is according to different shape groups; the specimens constituting each shape group are listed in order of decreasing weight.

Specific gravity determinations were made on a chemical balance using distilled water (T = 14·4° C.).

The lowest specific gravity value obtained is for an australite button (No. 1, Table 1). The low value (2·374) may be due to internal bubbles, but none could be detected on holding the specimen to a strong light.

The distribution of the specific gravity values is shown in Figure 1.

TABLE 1.

Weights and specific gravity values of Nurrabiel australites.

	No.	Shape Type.	Plate No.	Weight (gms.).	Specific Gravity.	Finder.
ROUND FORMS	1	Button, with minute flange remnant ..	..	2·972	2·374	G. Baker
	2	Button, with minute flange remnant ..	I, F and G	2·563	2·393	E. Wall
	3	Button, with larger flange remnant ..	..	1·910	2·430	M. K. Baker
	4	Button, with larger flange remnant ..	III, E	1·746	2·456	G. Baker
	5	Button, with larger flange remnant ..	..	1·595	2·431	G. Baker
	6	Button, with larger flange remnant ..	II, A–C	0·932	2·421	M. K. Baker
	7	Core of button (conical from fracturing) ..	III, F	2·730	2·422	G. Baker
ELONGATED FORMS	8	Oval, with minute flange remnant ..	III, D	3·225	2·427	G. Baker
	9	Oval, with small flange remnants ..	III, G	0·879	2·462	E. Wall
	10	Boat, with flange remnants	III, A–C	2·387	2·423	M. K. Baker
	11	Small boat, with no flange remnants ..	..	0·527	2·417	M. K. Baker
	12	Dumbbell, core with flaked zone ..	IV, A–C	8·907	2·401	A. J. Wall
	13	Teardrop, without flange	V, A–C	11·050	2·416	G. Baker
	14	Teardrop, with small flange remnant ..	I, A–C	2·218	2·406	G. Baker
	15	Canoe, with flange remnants	II, G–I	0·096	2·400	M. K. Baker
	16	Elongated bowl..	II, D–F	0·100	2·422	M. K. Baker
	17	Complete detached flange	I, D–E	0·659	2·405	A. J. Wall
FRAGMENTS	18	Fragment of button plus flange	..	2·271	2·393	E. Barber
	19	Fragment of button with flange remnant ..	..	2·255	2·401	A. J. Wall
	20	Fragment of button with flange remnant ..	III, H	2·062	2·406	M. K. Baker
	21	Fragment of button with flange remnant ..	..	1·047	2·458	E. Wall
	22	Segment from flanged button	..	0·906	2·442	G. Baker
	23	Segment from flanged button	..	0·709	2·400	G. Baker
	24	Flange fragment from button	..	0·378	2·408	G. Baker
	25	Flange fragment from button	..	0·273	2·459	G. Baker
	26	Fragment of oval with flange remnants ..	..	2·028	2·429	E. Barber
	27	Fragment of oval with flange remnant ..	..	1·758	2·412	M. K. Baker
	28	Fragment of boat without flange remnants ..	..	1·081	2·423	M. K. Baker
	29	Nondescript fragment (?from edge of button)	..	1·077	2·420	E. Wall
	30	Nondescript fragment (?from edge of button)	..	0·107	2·414	M. K. Baker
	31	Nondescript fragment (flake–?aboriginal) ..	..	0·098	2·420	M. K. Baker
	32	Flake from australite (Aboriginal flake) ..	II, L–M	1·091	2·387	M. K. Baker
	33	Flake from australite (Aboriginal flake) ..	II, K	0·770	2·428	M. K. Baker
	34	Flake from australite (Aboriginal flake) ..	II, J	0·641	2·401	M. K. Baker

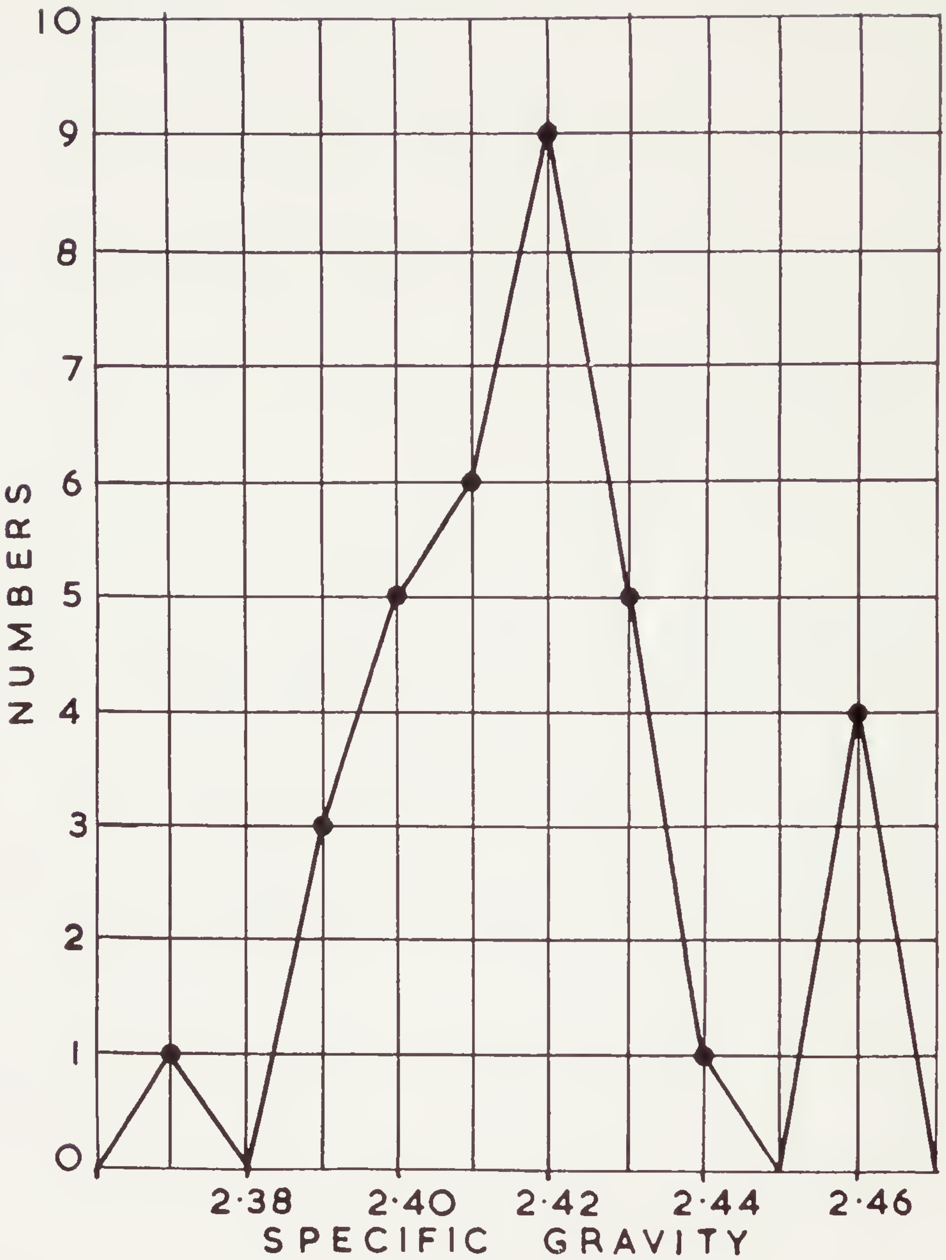

FIGURE 1.

Specific gravity frequency polygon for Nurrabiel australites.

In Figure 1, the specific gravity values of 34 specimens of australites found in the Nurrabiel district have been plotted, irrespective of whether they are fragments or nearly complete forms. The mode of the frequency distribution (2·42 for the 34 specimens) is a little greater than the arithmetic mean value (2·418).

Table 2.

Dimensions of Nurrabiel australites.

No.	Diameter (mm.).	Depth (mm.).	Width of Flange (mm.).	Width (mm.).	Length (mm.).	RB (mm.).			RF (mm.).		
						Across Di.	Across Wi.	Across Le.	Across Di.	Across Wi.	Across Le.
1 ..	16·5	9	..	..	..	10·0	..	..	11·2	..	..
2 ..	15	8·5	..	..	..	9·3	..	..	11·1	..	..
3 ..	14	7·5	2	..	..	10·0	..	..	9·4	..	..
4 ..	15	6	3	..	..	13·6	..	..	11·8	..	..
5 ..	14	7	2	..	..	8·6	..	..	8·8	..	..
6 ..	10	6	3	..	..	6·2	..	..	8·6	..	..
7 ..	17	8·5	..	..	..	15·4	..	..	9·3	..	..
8 ..	..	8·5	..	15	19	..	9·8	10·2	..	16·0	14·8
9 ..	..	5·5	..	10	11·5	..	5·8	7·2	..	9·1	7·4
10 ..	..	6	2·5	11	22	..	6·4	∝	..	8·7	30·2
11 ..	..	4	..	7·5	11	..	5·8	7·4	..	12·3	10·7
12 ..	..	10·5	..	16	40	..	9·6	15·6	..	..	..
13 ..	..	15·5	..	19·5	31	..	11·7	..	..	10·0	..
14 ..	..	8·5	..	12	18	..	6·5	12·7	..	8·5	10·2
15 ..	..	1·5	1	4·5	16·5	..	+	+	..	7·1	16·8
16 ..	..	2	..	2 to 3	12·5	..	+	+	..	1·2	9·7
17 ..	15	3	3	..	..	..	..	..	..	..	..
18 ..	..	9·5	4	..	..	11·6	..	..	12·7	..	..
19 ..	21	8·5	2	..	..	11·4	..	..	..	..	..
20 ..	18·5	9	2·5	..	..	13·4	..	..	12·4	..	..
21 ..	..	7	3	..	..	..	..	..	..	..	..
22 ..	..	..	4 to 5	..	..	..	..	..	..	..	..
23 ..	..	..	4	..	..	..	..	..	..	..	..
24 ..	..	3·5	3	..	..	..	..	..	..	..	..
25 ..	..	4	3·5	..	..	..	..	..	..	..	..
26 ..	..	9·5	2·5	15·5	..	..	7·7	11·0	..	8·5	12·3
27 ..	..	7·5	3	..	17	..	9·5	16·7	..	7·4	20·0
28 ..	..	6·5	..	10·5	..	..	8·0	∝	..	6·1	9·7
29 ..	..	..	..	..	..	..	..	..	..	..	..
30 ..	..	..	..	..	..	..	..	..	..	..	..
31 ..	..	..	..	..	..	..	..	..	..	..	..
32 ..	..	3·5	..	10	17	..	..	..	..	..	..
33 ..	..	5	..	10	13·5	..	..	..	..	..	..
34 ..	..	4·5	..	7·5	17	..	..	..	..	..	..
Range ..	10–21	1·5–15·5	1–5	2–19·5	11–40	6·2–15·4	5·8–11·7	7·2–∝	8·6–12·7	1·2–16·0	7·4–30·2

Notes on Table 2.

Numbers in the first column refer to the same specimens listed in Table 1.

Measurements of diameter, depth (= thickness), width and length were made to the nearest 0·5 mm. Measurements and calculations for the radii of curvature of the posterior (back = RB) and anterior (front = RF) surfaces of the australites were taken to the nearest 0·1 mm., using enlarged silhouettes (× 7·5) for the measurements (cf. Baker, 1955A). Radii of curvature measurements could not be satisfactorily determined on several specimens owing to incompleteness of some due to fracturing, and extensive wear of others due to abrasion and advanced solution-etching. Silhouettes of the better preserved specimens were obtained by adjusting them so that the outline traces would be equivalent to sections through their polar regions.

Measurements of the nondescript fragments (Nos. 29–31, Tables 1 and 2) are not given because they do not appertain to any particular shape group. Measurements of the aboriginal flakes from the australites (Nos. 32–34, Tables 1 and 2) are given to indicate their size as micro-implements (Plate II., Figs. J–M), but again the measurements do not appertain to any particular australite shape group.

∝ refers to specimens with virtually flat, or nearly flat, surfaces along their longer axes, e.g., Nos. 10 and 28, Table 2 (cf. Plate III., Fig. B).

+ = arcs of curvature across widths and along longer axes of posterior surfaces of canoe-shaped form (No. 15, Table 2) and of elongated bowl (No. 16, Table 2) are negative in sense and radii therefore not given (cf. Plate II., Figs. H and E). Radii of arcs of curvature for the two teardrop-shaped forms (Nos. 13 and 14, Table 2) were determined for the "gibbose" portions of the specimens (i.e. neglecting the "tail" portions); it was not practicable to measure RB or RF along the length of specimen No. 13 (cf. Plate V., Fig. B), and the smaller "tail" portion of No. 14 (Plate I., Fig. B) was neglected. RB was determined for the dumbbell-shaped form (No. 12, Table 2) across the bulbous ends, each side of the waist, but RF was not determined because of the naturally flaked character of the anterior surface (cf. Plate IV., Figs. B and C).

Arcs of curvature across the diameters of round forms and across the widths of elongated forms, except where local tertiary modifications of erosion had occurred, satisfactorily coincided with the arcs of curvature of constructed circles (cf. Baker, 1955A) having the radii listed in Table 2. Small departures from coincidence along the lengths of elongated specimens, however, occurred in the magnified silhouettes (× 7·5) in the polar and equatorial regions of the curved surfaces of specimens Nos. 8, 10, 16, 27 and 28.

The ranges and average values of the weight and specific gravity, and the average dimensions of round forms, elongated forms and fragments are shown in Table 3. Average values of the dimensions are not given for fragmented forms as such, except where they reveal some dimensions applicable to the forms from which the fragments were broken.

Table 3.

Showing ranges and average values of weight and specific gravity, and average dimensions of round forms, elongated forms and fragments of australites from Nurrabiel, Western Victoria.

	Round Forms.	Elongated Forms.	Fragments of Round Forms.	Fragments of Elongated Forms.	Nondescript Fragments.	
Number of specimens	7	9	9	3	6	34
Range in weight (gms.)	0·932 to 2·972	0·096 to 11 050	0·273 to 2·271	1·081 to 2·028	0·098 to 1·091	0·096 to 11·050
Average weight (gms.)	2·064	3·265	1·173	1·622	0·631	1·854
Range in specific gravity ..	2·374 to 2·456	2·400 to 2·462	2·393 to 2·459	2·412 to 2·429	2·387 to 2·428	2·374 to 2·462
Average specific gravity	2·418	2·419	2·419	2·421	2·412	2·418
Average depth (mm.)	7·5	7·5	6·5	8·0	..	7·5
Average diameter (mm.)	14·5	..	18	..	..	15·5
Average width (mm.)	..	11	..	13	..	11·5
Average length (mm.)	..	20	..	..	..	20
Average flange width (mm.) ..	2·5	2·5	3	2·5	..	2·5
Average RB across diameter of round forms (mm.)	10·4	..	12·1	..	..	10·9
Average RF across diameter of round forms (mm.)	10·0	..	12·5	..	..	10·6
Average RB across width of elongated forms (mm.)	..	7·9	..	8·4	..	8·1
Average RF across width of elongated forms (mm.)	..	9·1	..	7·3	..	8·6

Surface Features and Characteristics.

Round forms.

Button-shaped forms.

The button-shaped australite shown in Plate I., Figs. F and G is typical of many that have lost the greater part of the circumferential flange by weathering, leaving only two small stumpy remnants on diametrically opposed sides of the equatorial edges of the form. Their presence serves to classify the specimen in the group of australite buttons. The secondarily developed anterior surface (cf. Baker, 1959A) of the form (Plate I., Fig. G) has been further modified by the tertiary effects of weathering, largely solution-etching (Baker, 1961D) which has accentuated the sub-surface internal schlieren, and removed all but traces of the originally sharp-crested flow ridges that are so well developed on excellently preserved australites (cf. Baker, 1944; 1959A; 1961A; 1962).

Although collected nearby, within a few yards, the smaller button shown in Plate II., Figs. A to C, is in a better state of preservation. Much of the flange has been lost by piecemeal fracturing and the still attached remnants subjected to solution-etching, particularly along inrolled planar spiral internal schlieren (cf. Baker, 1944; 1958). However, the posterior surface of the lens-like core (Plate II., Fig. B) has been little affected by solution-etching or by abrasion, and the crests of the concentric flow ridges (Baker, 1956) on the anterior surface are still sharply delineated.

Comparisons between the specimens shown in Plate I., Figs. F and G and Plate II., Figs. A to C, lead to the conclusion that in one and the same relatively small area, different degrees of solution-etching and abrasion can operate to produce differential weathering effects on australites. These two specimens were located relatively close to one another on an area where it is unlikely that either was moved by natural agencies more than a few feet from the original position where they landed upon the earth's surface. However, one specimen (Plate I., Figs. F and G) was evidently released from its soil environment earlier than the other (Plate II., Figs. A to C).

The anterior surface of a button-shaped australite with minor remnants of the flange still attached in diametrically opposed positions (left- and right-hand sides of Plate III., Fig. E), has been affected by solution-etching to the extent of the development of minute etch pitting and accentuation of occasional flow lines that radiate outwards from the stagnation point region (cf. Baker, 1961A) to the equatorial edge of the core. As a further consequence of etching effects, the innermost flow ridges have been reduced to low, vaguely defined structures, but the outermost flow ridge still reveals a sharp, clearly defined crest, in places interrupted in continuity by narrow, slightly overdeepened radial flow lines.

Core form.

The core of a round form (Plate III., Fig. F) is characteristically conical in side elevation, and thus typical of the manner in which buttons are affected by relatively advanced stages of weathering. The circumferential flange has been totally removed, followed by flaking of adjacent portions of the anterior surface rather regularly all around the periphery of the form. Inasmuch as the posterior surface, which is a primary feature of australites, has not been flaked away, and the flaked equatorial zone is evidently not an outcome of aboriginal workmanship, it would appear that the conical core is a stable remnant rather more resistant to terrestrial erosion than are either the secondarily produced circumferential flanges or anterior surface regions of australites.

Complete flange.

Plate I., Figs. D and E shows the smoother posterior and the contrasting flow-ridged anterior surfaces respectively of a complete, detached flange that is circular in plan aspect. It has been separated by natural processes from a central lens-like body core to which it was originally circumferentially attached to form a flanged australite button. There are only about 30 such complete detached flanges known, most of which (25 well-preserved specimens) are from Port Campbell, Victoria (cf. Baker, 1946, Plate XIII.) and two (poorly preserved examples) are from the Nirranda district (Baker, 1956, Plate I., Figs. 4 and 5), Western Victoria.

Elongated forms.

Oval-shaped forms.

The two oval forms (Plate III., Figs. D and G) reveal stages of weathering of a rather different type. Both have lost the greater part of the circumferential flange and all the flow ridges have been obliterated from the anterior surfaces. The larger oval (Plate III., Fig. D) has been dulled by abrasion and shows minor markings probably caused by collisional impact of smaller size material such as wind- and water-borne sand grains. The smaller oval (Plate III., Fig. G) retains a vitreous lustre due to accentuation by solution-etching, a process that evidently dominated the effects of abrasion.

The fact that circular and slightly elliptical cupules appear on the posterior and anterior surfaces of both the central lens-like core and the remnants of the circumferential flange, is evidence that these features are essentially solution etch pits, for the posterior surfaces of circumferential flanges and the anterior surfaces of australites in the well-preserved state, are typically free of such pittings. The pits are 0·25 mm. to 1·5 mm. across and range in depth from a fraction of a millimetre to 0·5 mm. Where the shallower pits are more crowded together, their walls meet as low, narrow arêtes, and the general appearance is that of hammered metal. Where flow lines have become accentuated by solution-etching, they can be occasionally observed trending across smoother, less pitted surfaces and continuing around the walls of the solution pits. Occasionally smaller pits are developed at the bottoms of the larger pits. Evidently these pits result from differential solution-etching along bundles and small swirls of schlieren trending normal to the surface and dipping into the body of the specimen as part of its complex internal flow line pattern.

Boat-shaped form.

The boat-shaped form (Plate III., Figs. A–C) is less-weathered than the two ovals; it shows some signs of abrasion and solution-etching, and has lost approximately 65 per cent. of its circumferential flange by fracturing. The posterior surface (Plate III., Fig. A) reveals an elongated flow-swirled area occupying the greater part of the surface and with its longer axis parallel with the long axis of the boat-shaped form. In side aspect the flat-topped nature of the posterior surface (left-hand side of Plate III., Fig. B) contrasts with the arc of curvature of the anterior surface (right-hand side of Plate III., Fig. B) but in end-on aspect, the appearance is that of flanged buttons such as shown by Plate II., Fig. B. The anterior surface (Plate III., Fig. C) reveals the concentric nature of the flow ridges which parallel the outline of the boat-shaped form and are crossed in places (see bottom right of Plate III., Fig. C) by flow lines made prominent by solution-etching.

Dumbbell-shaped form.

The dumbbell-shaped form (Plate IV., Figs. A to C) has been subjected to fairly considerable natural flaking of the equatorial regions and anterior surface, producing a marked flaked equatorial zone (Baker, 1940, p. 488) somewhat similar to that of the round core shown in Plate III., Fig. F. One effect of the flaking by weathering has been to expose an internal bubble-cavity 9 mm. in diameter in one of the gibbose portions of the dumbbell—(left-hand end, Plate IV., Figs. B and C).

The walls of internal bubbles in australites invariably reveal a highly vitreous lustre (" hot polish ") in the freshly exposed condition (Baker, 1959A; 1961B). The fact that the walls of the cavity in this dumbbell are as dulled as the flaked surfaces, indicates some degree of antiquity since the initiation of flaking and the exposure of the internal cavity. Small amounts of solution-etching have accentuated some of the internal schlieren, producing fine, shallow, narrow depressions along the flow-line directions.

No australite dumbbell has been observed previously with an internal cavity as large as the one in this specimen from Nurrabiel, but larger internal cavities are known in round forms (australite buttons, lenses and cores) and in other elongated forms (australite ovals and boats). Most of the common shape groups of australites are thus now known to contain specimens with relatively large internal cavities, the observed range in size of which is from 5 mm. to nearly 50 mm. (cf. Baker, 1961B) across. Internal cavities have so far been more frequently observed in the round forms of australites. Smaller cavities are more common from under 5 mm. down to a fraction of a millimetre in size.

Whereas one gibbose portion of this dumbbell contained an internal bubble of significant proportions, it is evident from the normal specific gravity value of the specimen (No. 12, Table 1) that neither the waist region nor the other gibbose portion contains bubbles of any significance. Furthermore, holding the specimen to a strong beam of light does not reveal the translucency that would be expected if large internal cavities were present in such parts. Then again, there is no evidence to show that larger internal cavities were present in either the waist region or in the more solid gibbose portion prior to fracturing. The significance of this occurence lies in the fact that despite the existence of an internal cavity in one gibbose portion and solid glass throughout elsewhere, the dumbbell-shaped form maintained aerodynamic stability in the line of flight during the phase of atmospheric frictional heating. Only under conditions of high entry velocity (cf. Baker, 1958; Chapman, 1960) could this be reasonably expected.

The posterior surface of the dumbbell (Plate IV., Fig. A) reveals smooth, flow swirled regions surmounting each gibbosity, with occasional bubble pitted areas, principally in the waist region. These are original features which have been accentuated in parts and partially to almost completely obliterated from other parts of the posterior surface as a consequence of terrestrial weathering.

Teardrop-shaped forms.

Plate I., Figs. A to C illustrates a relatively well-preserved teardrop-shaped australite on which little of the flange structure remains. It was developed as an apioid of revolution in the primary molten phase when generated in its extraterrestrial birthplace. Its present form is modified on one surface, and it provides convincing support for the contention that australites were not shaped while spinning as completely molten or plastic glass bodies through the earth's atmosphere. The formative stages of the secondarily produced anterior surface with its remarkable but characteristic features (Plate I., Fig. C), arose during a phase of atmospheric frictional heating, when, at ultrasupersonic speeds of non-rotary earthward infall, thin film melting occurred on the forwardly directed (i.e. anterior) surface of an originally cold, pre-formed shape that maintained aerodynamic equilibrium while the high speeds of entry prevailed. Temperatures sufficiently high to cause some ablation as well as melting were thereby attained, resulting in obliteration of the primary sculpture, and the generation of new sculptural elements on a surface that had progressively receded all over, including the stagnation point (i.e. front polar) regions right out to the peripheral regions of the form. The development of the anterior surface, with its spiral clockwise flow ridge (Plate I., Fig. C), is thus best explained in terms of the Aerodynamical Control Theory (Baker, 1958). Considerable difficulties arise if attempts are made to explain such a structure as developing on an imaginary molten or plastic body of tektite glass spinning rapidly during earthward flight. It is observed from Plate I., Figs. A to C, that the clockwise helical spiral shape assumed by the flow ridge is confined to one particular surface only, and that its axis (right to left in Plate I., Fig. B, and front to back in Plate I., Fig. C) is normal to the long axis (top to bottom in Plate I., Figs. A to C) of the original apioid. The longer axis would have been the spin axis of the primary form, hence, even if it is possible, though rather unlikely, for a descending helical spiral flow structure to develop on a falling, spinning, molten or plastic apioid, it would have to be located normal to the long axis, and situated around the wider, lower end of the gibbose portion, with its point of origin at the bottom of the form, and its trend following around all parts of the gibbosity. Hence it would pass around the regions occupied by the anterior and posterior surfaces of the form, and there would be no distinctive anterior or posterior surfaces of the kinds shown by the specimen. Since this is obviously not the state of affairs, it becomes apparent that a falling, molten or plastic apioid, spinning about its long axis, would not produce the two differently sculptured surfaces revealed by the specimen, and generate a descending helical spiral flow ridge on one of those surfaces only. It is also inconceivable that rapid spinning of a similar body in either of the two planes normal to that containing the long axis of the specimen, could produce either the observed surfaces and structures, or the configuration of the form itself.

The formation of the helical character of the flow ridge in terms of the Aerodynamical Control Theory of the secondary shaping and sculpturing of australites (Baker, 1958), is best explained in the same way as for the clockwise helical spiral flow ridge developed on a perfectly preserved, complete, flanged oval australite from Port Campbell, Victoria (Baker, 1961A). An ablation pit that was evidently responsible for controlling the helical nature of the spiral ridge on the Port Campbell specimen, is not present on the Nurrabiel specimen. At the level of ablation attained, however, such a pit could have been just obliterated at the moment that the aerodynamical frictional heating effects ceased and the last formed features became frozen-in place.

Furthermore, the primary flow lines revealed on the posterior surface of the Nurrabiel teardrop-shaped australite (Plate I., Fig. A), trend towards the tail of the specimen, while immediately opposite on the anterior surface of the tail region, primary flow lines have been obliterated, the surface is generally smoother with the dominating features being the flow ridge and a few fine, radial flow lines trending across the surface of the intervening flow troughs (Plate I., Fig. C).

The larger teardrop-shaped australite (Plate V., Figs. A to C) does not reveal flow ridges on its anterior surface (Plate V., Fig. C) like the smaller teardrop (Plate I., Fig. C). If originally present, they have been completely removed by weathering. Well-preserved forms of the size of this larger teardrop are particularly rare and reveal wrinkled and rippled ridges, as on a teardrop nearly 4 cms. long from Port Campbell, Victoria (Baker, 1959, Fig. 15, p. 67).

The radius of curvature across the width of the gibbose portion of the larger teardrop from Nurrabiel is less for the anterior than for the posterior surface, whereas the reverse holds for the smaller teardrop (cf. Nos. 13 and 14, Table 2). It is five times heavier than the smaller teardrop and has a slightly greater specific gravity. Both the anterior and posterior surfaces of the larger teardrop are equally weathered, and the rim separating these two surfaces (Plate V., Fig. B) is somewhat rounded but nevertheless distinct. There is evidence to show that some of the attenuated tail portion has been broken off, whereas in the smaller teardrop, much of the tail is preserved (Plate I., Fig. A), although not greatly attenuated.

Canoe-shaped form.

Incomplete because of the loss by fracturing of portions of its fragile, upturned, tapering extremities and its thin, narrow flange, the long and slender canoe-shaped australite (Plate II., Figs. G to I) nevertheless has lost little glass by weathering. It is the smallest, lightest-weight specimen (Table 1, No. 15) yet recorded in this shape group of the australites, and is unmatched for delicacy among the 45,000 or so australites known. It is so thin (0·5 mm. to 1·5 mm.) that the tektite glass is translucent throughout the whole of the specimen, even without strong illumination. Weighing 0·096 grams now, its original weight prior to loss of small portions by fracturing would have been little over 0·10 grams for the complete form. Obviously such a thin, elongated, delicate, flanged canoe-shaped form could not have been formed from the rotation of molten or plastic glass falling through the atmosphere. It is best interpreted as the thin end product of an ablated, originally larger canoe-shaped form, that was subjected to the comparable effects of aerodynamical phenomena that shaped and sculptured the other australites.

Fine, long flow lines parallel with the long axis of the form are evident on the posterior surface (Plate II., Fig. G) but the anterior surface is smooth (Plate II., Fig. I). The curvature and the backwardly directed nature of the tapered ends is seen in Plate II., Fig. H, in which the anterior surface is uppermost. This is the surface that was directed forward along the flight path during ultrasupersonic transit through the atmosphere.

Bowl-like form.

The remarkable elongated, bowl-like form (Plate II., Figs. D to E) which is pinched-in towards its central regions (Plate II., Figs. D and F), suggesting dumbbell-like characteristics, is likewise not quite complete. It is also thin, translucent throughout, and light in weight (0·10 grams). The walls of the bowl, which are only 0·5 mm. to 0·75 mm. thick, are minutely etch-pitted.

Natural fracture fragments.

The button fragment illustrated in Plate III., Fig. H is rather worn and reveals a so-called " saw-mark " (bottom of photograph) which is actually a curved groove overdeepened and widened by natural solution-etching along bundles of schlieren. It is frequently this type of groove that delineates the surfaces of conical cores (as in Plate III., Fig. F) and segments of buttons that become detached from them.

One of the oval fragments (No. 26, Table 1) reveals an internal cavity 5 mm. in diameter and 2 mm. deep on the fracture surface which trends across the width of the specimen. As usual, the internal cavity is situated nearer to the posterior than to the anterior surface of the specimen (cf. Baker, 1961B). The distance from the rear wall of the internal cavity to the posterior surface of the oval fragment is 0·5 mm. (in the narrowest part), whereas the front wall of the cavity is 4·0 mm. from the anterior surface. The depth of the specimen containing the cavity is nearly 9·5 mm. Reconstruction of the original oval form indicates that the cavity was approximately half way along the longer diameter, but it is displaced off-centre along the shorter diameter of the form. Its presence by no means affected the development of the normal sculptural elements, and the form evidently maintained a position of stable aerodynamic orientation while high speeds prevailed.

The remaining incomplete specimens and fragments of australites in the collection from Nurrabiel (Table 1, Nos. 18, 19, 21–25, and 27–31) are not described in detail as they show no important features. Principal interest in them centres around the fact that they are relatively strongly weathered. They show more or less equally developed etch-pitting on all surfaces of both the flange remnants and the remaining portions of central cores, except where abrasion has been dominant.

Aboriginal flakes.

The characteristic conchoidal fracture of the Australian tektite glass is well illustrated on the broken surfaces of the aboriginal flakes (Plate II., Figs. J to M). A subsidiary ripple fracture pattern is evident on some of the conchoidal surfaces, e.g., Plate II., Figs. J and K, and the relatively fresh appearance and vitreous, only slightly dulled lustre of the broken surfaces, points to no great age since these flakes were deliberately fractured by man from australites.

The specimen illustrated in Plate II., Figs. L and M shows the best re-touching by pressure micro-flaking around its edges; it is evidently a relatively flat, worked flake obtained from the posterior surface region of one of the larger types of australites —possibly a large boat-shaped form. The natural sculpture of the posterior surface of the original australite is preserved, but is rather more weathered than the fracture surfaces.

The specimen shown in Plate II., Fig. J was likewise derived from the posterior surface region of an australite. The original surface reveals pitting and an arc of curvature suggestive of derivation from an australite button.

The third aboriginal flake (Plate II., Fig. K) was fractured from the edge of an already much worn australite. The rim separating the pitted posterior surface remnant from a weathered equatorial zone, although rounded off by erosion, is nevertheless clearly marked. This fragment was probably derived from the edge of a specimen resembling the conical core illustrated in Plate III., Fig. F. Some weathering of the fracture surfaces has resulted in the initial manifestation of the schlieren in the glass as a faint but complex internal flow pattern.

Comparisons with Neighbouring Regions.

Nearby regions where australites have been found in sufficient numbers (fragments excluded) for comparison with those from Nurrabiel are situated at distances varying from 8 miles to 33 miles to the south, south-southwest and southwest of Nurrabiel. These regions are at Mount Talbot near Toolondo, Telangatuk East, Kanagulk, Balmoral and Harrow. This area of distribution covers some 600 square miles, which is approximately 0·03 per cent. of the total known australite strewnfield, and the number of australite specimens recovered from the area constitutes 0·35 per cent. of the total number found so far throughout the vast strewnfield.

The average weight, average specific gravity, range in the specific gravity values, and the radii of curvature of the posterior (RB) and anterior (RF) surfaces of these separated groups of australites are shown in Table 4.

TABLE 4.

Comparison between australites from the Nurrabiel-Harrow-Balmoral regions of Western Victoria.

Locality.	Number of Speci-mens.*	Average Weight (gms.).	Range in Specific Gravity.	Average Specific Gravity.	Round Forms.		Elongated Forms.†	
					Average RB (mm.).	Average RF (mm.).	Average RB (mm.).	Average RF (mm.).
Kanagulk ..	29	9·75	2·38–2·44	2·40	13·1	12·2	14·7	12·6
Telangatuk East ..	9	6·69	2·38–2·44	2·41	13·4	13·6	11·6	10·8
Mt. Talbot, Toolondo ..	5	2·97	2·39–2·42	2·41	11·7	10·6	..	..
Balmoral.. ..	8	1·81	2·36–2·43	2·41	n.d.	n.d.	n.d.	n.d.
Nurrabiel ..	16	2·74	2·37–2·46	2·41	11·0	10·5	8·1	8·6
Harrow	33	8·97	2·39–2·47	2·42	14·8	13·7	16·6	14·7

*—Fragments excluded.

†—Measurements made across the shortest diameter.

Table 4 reveals that, based on average values, larger, heavier forms have been collected at Kanagulk, Harrow and Telangatuk East, while smaller, lighter weight forms occurred at Balmoral, Nurrabiel and Mount Talbot near Toolondo. This distribution of specimen size does not produce any particular pattern in the 600 square miles which it represents in the vast australite strewnfield of 2,000,000 square miles. There is, however, a tendency for lower specific gravity values to occur in the eastern part of the 600 square miles region, and higher specific gravity values (Harrow) to occur in the western part. A similar trend can be detected in the RB values of the round forms. This means that the diameters of the original australite spheres from which australite buttons were produced were lower (22–23 mm.) in the eastern parts and greater (29·5 mm.) in the western parts of this portion of the australite strewnfield.

The distribution of shape types in five of the six australite concentration centres Balmoral details not available) listed in Table 5, are shown in Table 5.

TABLE 5.

Distribution of australite shape types at five neighbouring concentration centres in Western Victoria.

Shape Types.*	Kanagulk.	Mt. Talbot, Toolondo.	Telangatuk East.	Nurrabiel.	Harrow.	Totals.
Round Forms.						
Buttons..	10	2	2	7	6	27
Lenses	4	3	1	0	4	12
Cores	5	0	2	1	10	18
Discs (flat)	0	0	0	0	0	0
Hollow forms	0	0	0	0	0	0
Bowls	0	0	0	0	0	0
Elongated Forms.						
Ovals	2	0	0	2	0	4
Boats	0	0	0	2	1	3
Cores	7	0	2	1	9	19
Dumbbells	0	0	1	1	3	5
Teardrops	0	0	1	2	0	3
" Aerial-bombs " ..	1	0	0	0	0	1
Canoes	0	0	0	2	0	2
Hollow forms	0	0	0	0	0	0
Plates (flat)	0	0	0	0	0	0
Bowls	0	0	0	1	0	1
Aberrants	0	0	0	0	0	0
Fragments.						
Complete flange	0	0	0	1	0	1
Flange fragments ..	0	0	0	2	0	2
Round form fragments ..	2	0	0	6	0	8
Round hollow form fragments	1	0	0	0	0	1
Elongated form fragments..	2	0	0	3	1	6
Nondescript fragments ..	0	0	0	8†	0	8
TOTALS	34	5	9	39	34	121

* Certain shape types are not represented at any of these five concentration centres. They are included for completeness; all of those listed occur in the Port Campbell concentration centre on the south coast of Western Victoria.

† Includes 3 flakes manufactured by aboriginal craftsmen.

Table 5 reveals that round forms and round form fragments together constitute 57 per cent. of the total number of forms collected, elongated forms and fragments of elongated forms constitute 36 per cent., and nondescript fragments 7 per cent. Button-shaped australites constitute the greatest percentage (22 per cent.) of any shape types, followed by round and elongated cores which are approximately the same (15 per cent. and 16 per cent.) as each other. Apart from lens-shaped forms (10 per cent.), all other shape types represented are each less than 4·5 per cent.

The greatest number of shape types is represented among the Nurrabiel australites, there being approximately twice as many as in the other concentration centres, although compared with the rich Port Campbell concentration centre, they contain only approximately two thirds of the known shape types. This may be largely a result of more detailed and more intensive searching in the Port Campbell concentration centre.

Conclusions.

Although lacking in well-preserved, perfectly complete specimens, the australites from the Nurrabiel district near Horsham nevertheless reveal some sculptural features of real significance that add further support to the " Aerodynamical Control Theory " of the shaping and sculpturing of australites (cf. Baker, 1958).

Sufficient of their external configuration remains to show that, like several other concentration centres in the more temperate regions of Australia where australites are usually in the better states of preservation than in arid and sub-arid parts of the strewnfield, the characteristic variety of a small number of shape types is represented. This indicates that the assemblage of shape types discovered is more likely an outcome of natural phenomena than of selective accumulation by aboriginal man. Even though found in association with aboriginal flakes and worked implements at Nurrabiel, on a relatively small area formerly under aboriginal occupation, it is considered likely that these australites occurred more or less where they originally fell. Some of the specimens were transported short distances (a few yards) across the slightly sloping surface on which they were found as a result of sheet run-off of occasional heavy rainfall, and a few were evidently used locally by the aboriginal occupants. Other, rather better preserved specimens have been much more recently released by slight amounts of erosion of the old soil surface on which they occur; such specimens were evidently not exposed at the time of aboriginal occupation.

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Description of Plates.

Plate I. (all × 2·5).

A to C—teardrop. A—posterior surface showing flow lines and pits. B—side view showing contrasting structures of posterior (on left) and anterior (on right) surfaces. C—anterior surface showing clockwise spiral flow ridge and radially trending flow lines. (*Note*: The anterior surface was directed down the flight path during ultrasupersonic flight through the atmosphere.)

D to E—complete flange naturally detached from an australite button. D—smooth posterior surface. E—flow-ridged anterior surface.

F to G—core of australite button with minor attached remnants of circumferential flange. F—posterior surface showing flow swirl and pitting. G—anterior surface showing sub-surface flow line pattern exposed by natural solution-etching.

Plate II. (all × 2·5).

A to C—small australite button with remnants of circumferential flange. A—posterior surface; B—side aspect with posterior surface uppermost; C—anterior surface. Outer edge of flange jagged (see B) due to solution-etching along inrolled planar spiral schlieren.

D to F—slender, elongated bowl-shaped australite, broken and worn at right-hand end.

D—posterior surface showing bowl-like interior, and narrowing of form at right-hand end;

E—side aspect, showing curvature of anterior surface;

F—anterior surface showing minute etch-pits.

G to I—slender thin (translucent) canoe-shaped australite.

G—posterior surface showing thin flange partly fractured from body portion at right-hand end;

H—side aspect with anterior surface uppermost;

I—anterior surface;

J—Aboriginal flake from an australite, showing conchoidal fracture surfaces with secondary ripple fracturing;

K—Aboriginal flake (?semi-discoidal scraper) from an australite, showing fracture surfaces with vitreous lustre.

L to M—Aboriginal flake from an australite.

L—showing fracture surface and re-touched edges of the australite glass;

M—showing portion of the posterior surface of the australite with solution-etch marks.

Plate III. (all × 2·5).

A to C—boat-shaped australite with remnants of attached flange.

A—posterior surface showing flow lines parallel with outline of the central core, elongated nature of the form, and more or less straight, parallel flange—core contact on left-hand side;

B—side aspect showing thickness of the form, (anterior surface on right-hand side);

C—anterior surface showing elongated flow ridges paralleling the outline of the form, and flow lines cutting across the flow ridges at bottom right-hand side;

D—posterior surface of broad oval-shaped australite with minute attached flange remnant at top right; showing minutely etched surface;

E—anterior surface of button core with minor flange remnants (= bulges in outline on left- and right-hand side); showing vitreous lustre and etched surface, with flow lines accentuated but flow ridges almost destroyed by solution-etching;

F—side aspect of conical core eroded from round (in plan aspect) australite. Posterior surface uppermost showing minute pits and sharply defined rim separating posterior surface and flaked equatorial zone;

G—posterior surface of smaller oval showing vitreous lustre and numerous pits; minute remnant of flange at bottom of photograph;

H—posterior surface of broken button showing solution-etch pitting of both central body core and attached circumferential flange. Solution "saw-groove" (bottom, centre) with infiltrated clay containing fine quartz sand.

Plate IV. (all × 2·5).

A to C—worn and flaked dumbbell-shaped australite.

A—posterior surface showing smoother flow-lined areas, occasional bubble pits, and constricted waist region;

B—side aspect showing waist region and flaked equatorial zone. Posterior surface is uppermost;

C—anterior surface, naturally flaked and eroded to reveal internal bubble cavity (at left-hand end).

Plate V. (all × 2·5).

A to C—larger teardrop-shaped australite.

A—posterior surface;

B—side aspect showing "rim" separating posterior (on left) from anterior (on right) surface;

C—anterior surface.

All surfaces are rather worn and have been affected by solution-etch pitting.

Addendum.

A large, almost round core from the earth bank of a dam at Lower Norton, 8 miles south-west of Horsham, has been recently loaned to the National Museum of Victoria by Mrs. J. Hannan of Horsham. The specimen was kindly made available by Dr. A. W. Beasley, Curator of Minerals at the Museum, for investigation.

It measures 50·5 mm. by 49 mm. and is 30·5 mm. deep. Its weight is 115·92 grams and the specific gravity, determined in distilled water at T = 12·5° C., is 2·429. The radius of curvature of the rear surface (RB) is 39 mm., that of the front surface (RF) is 45·5 mm.

Both the posterior and the anterior surfaces reveal a number of relatively shallow, circular to semi-circular etch marks 2 mm. to 5 mm. in diameter and resembling the "höfchen" and "tischschen" structures encountered on the surfaces of some specimens of the billitonites (= tektites found on the Island of Billiton). The specimen reveals a marked flaked equatorial zone (cf. Baker, 1940A) that is sharply delineated from the posterior surface by a strongly defined rim, but which grades less perceptibly, without so abrupt a change, into the anterior surface.

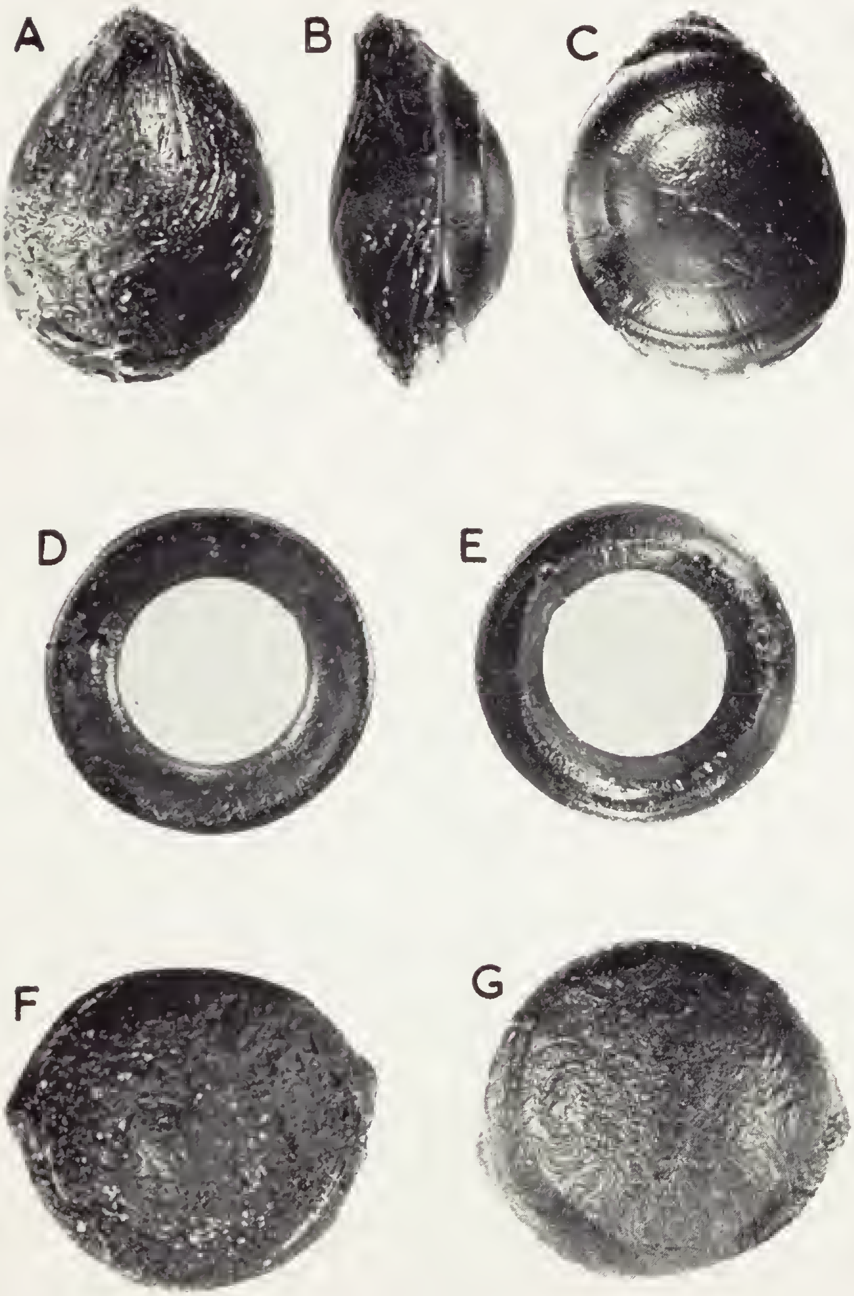

PLATE I.

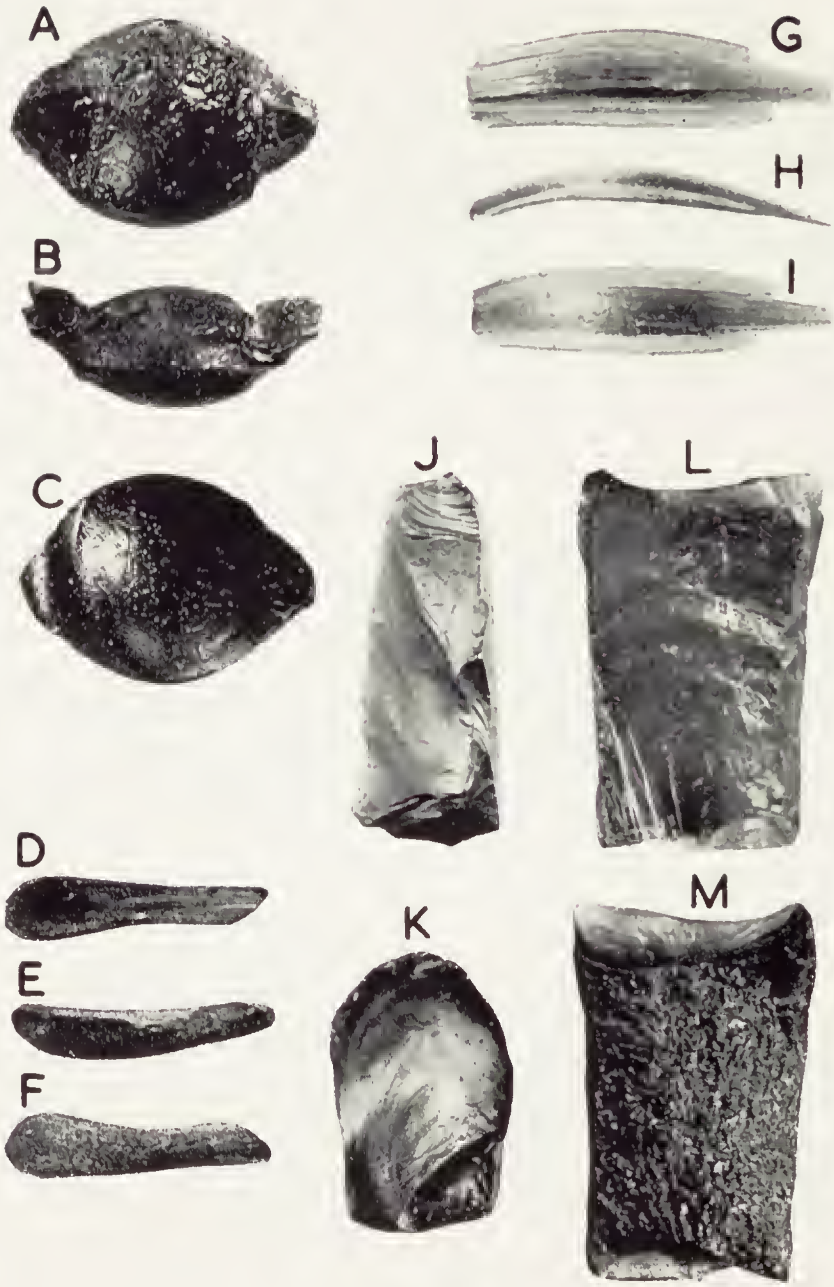

PLATE II.

Plate III.

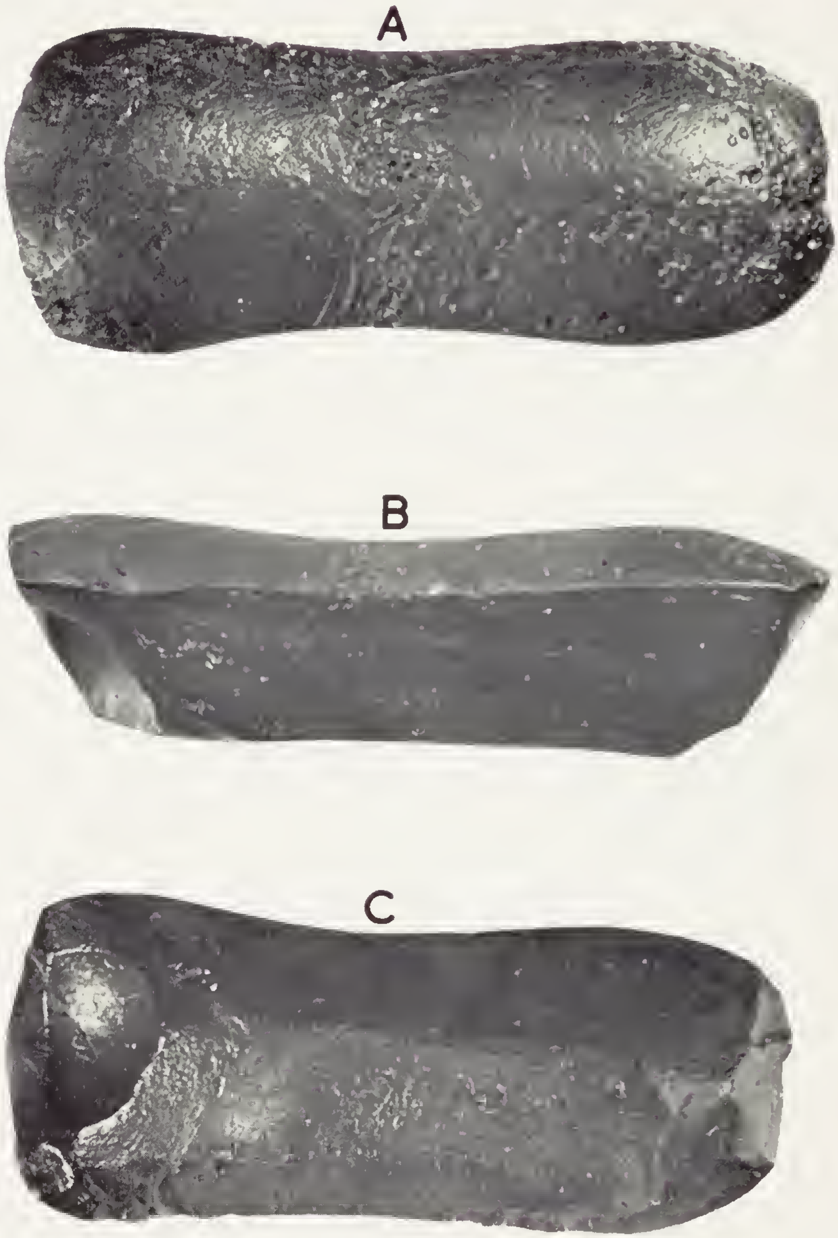

Plate IV.

Plate V.