Australites from Harrow, Victoria.

By George Baker, M.Sc.

Department of Geology, Melbourne University, Australia.

[Taken as read January 27, 1955.]

THIRTY-FOUR specimens of australites were collected by Miss N. Jones and her brother Mr. Jones, during forty years while working on their property of 2000 acres, on the north bank of the Glenelg river. This is situated $3\frac{1}{2}$ miles due east of Harrow (37° 8′ S., 141° 33′ E.) in the western district of Victoria, 236 miles north of west of Melbourne. The collection was kindly submitted for examination through Mr. E. D. Gill of the National Museum, Melbourne.

The greater proportion (60 %) of the specimens in the collection consists of australite cores, the remainder being button-, lens-, boat-, and dumb-bell-shaped forms. Many are relatively well preserved, a few have been abraded. The total weight of australite glass represented by these specimens amounts to 305·05 grams, and the average specific gravity of the thirty-four specimens is 2·42.

Three alien specimens accompanied the collection of australites. One is a waterworn pebble of basalt with a specific gravity value of 3·08, which shows evidence of smoothing on one edge, evidently by aborigines. It is therefore surmised that this specimen was carried into the area by human agency. The other two alien specimens are abraded pebbles of smoky quartz (var. morion) having specific gravity values of 2·60 and 2·66, both of which are significantly greater than the specific gravity values of the australites. Thin splinters of these specimens are birefringent and uniaxial positive. They were also probably carried into the area by aborigines.

Two specimens of australites removed from the collection prior to this investigation are reported to be of the large dumb-bell type. The area upon which the australites were discovered consists typically of thick, red-coloured clayey soils.

Where not abraded, the australites display the characteristic flow lines, pits, and grooves found on most relatively well-preserved specimens from various parts of Australia. Some of the grooves have been deepened and widened by natural etching and infilled with hard, cemented clay derived from the surface materials on which the australites lay.

The weight, specific gravity, dimensions, and radii of curvature of the posterior (R_B) and anterior (R_F) surfaces of each australite in the collection are listed in table I.

TABLE I. Weight, specific gravity, dimensions, and radii of curvature of australites from Harrow.

No.	Shape type.	Weight gm.	Sp. gr.	Depth mm.	Diameter mm.	Width mm.	Length mm.	R_B mm.	R_F mm.
1	Button	3·914	2·420	11	17	—	—	9	11·5
2	,,	5·892	2·407	13	19	—	—	9·5	13
3	,,	5·370	2·413	12	21	—	—	13	12
4	,,	3·305	2·419	11	22	—	—	12·5	15
5	,,	2·339	2·431	9	16·5	—	—	10	10
6	,,	2·166	2·432	7	18	—	—	14	14
7	Lens	2·873	2·403	7·5	18	—	—	11·5	13·5
8	,,	2·783	2·415	9	17	—	—	10	11
9	,,	1·812	2·436	6	15·5	—	—	11	11
10	,,	1·230	2·453	7	12	—	—	6·5	8·5
11	Boat	3·477	2·418	9	—	14	23	7* 20·5**	7* 14·5**
12	Dumb-bell	4·286	2·419	7	—	12	23	6*	9*
13	,,	4·406	2·429	7	—	13	36	6·5*	8·5*
14	,,	29·528	2·421	16	—	21	64	11*	11*
15	Round core	5·384	2·440	14	17	—	—	13	12
16	,,	5·880	2·423	15·5	19·5	—	—	14·5	13·5
17	,,	6·180	2·418	14	20	—	—	17·5	11
18	,,	6·583	2·411	12·5	21	—	—	19	14
19	,,	8·188	2·411	14·5	22·5	—	—	18·5	14·5
20	,,	8·628	2·468	13	21·5	—	—	20	16
21	,,	13·402	2·413	17·5	26	—	—	17·5	15·5
22	,,	14·471	2·422	16	27	—	—	22	20
23	,,	17·833	2·401	18·5	29	—	—	21·5	19·5
24	,,	30·765	2·406	25·5	32	—	—	20	17·5
25	Oval core	13·084	2·428	17·5	—	23·5	26·5	17·5* 23·5**	17·5* 17·5**
26	,,	14·352	2·386	18·5	—	25	28·5	20* 19**	13* 15·5**
27	,,	33·782	2·426	22	—	34	36	26* 29·5**	24* 25·5**
28	Fragment of elongated core	2·396	2·446	—	—	—	27	—	—
29	Elongated core	4·087	2·425	12·5	—	13	22	25	16·5
30	,,	5·360	2·402	13	—	14·5	24	25	25·5
31	,,	7·504	2·401	15	—	17·5	25	19	16·5
32	,,	8·847	2·396	14	—	20	29·5	13* 33·5**	11* 33**
33	,,	11·385	2·408	17·5	—	18	28·5	23	25·5
34	,,	12·775	2·438	16	—	23	29·5	17* 25**	15·5* 27·5**

Measurements of the dimensions and radii of curvature listed in table I have been determined to the nearest 0·5 mm. In the R_B and R_F columns the asterisks connote values of the radii of curvature across the widths of the bulbous ends of the dumb-bells. Where two values are given for each of R_B and R_F of the boat, oval core, and elongated core types of australites, the first figure (one asterisk) refers to the radius of curvature across the width, while the second and usually larger figure (two asterisks) refers to the radius of curvature along the length.

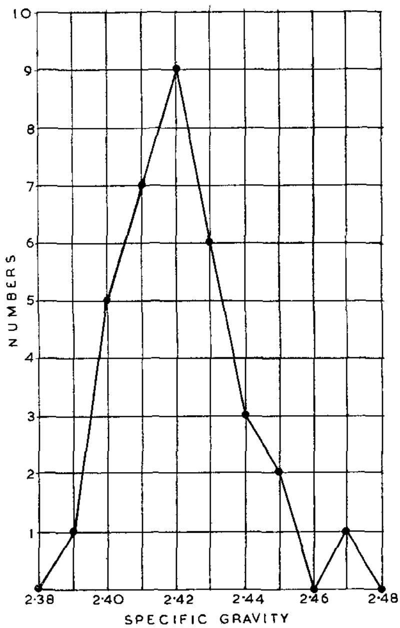

FIG. 1. Frequency diagram showing distribution of specific gravity values of australites from Harrow.

The specific gravity values were determined on an air-damped balance at 16° C. by Mr. G. C. Carlos. The average specific gravity of 2·42 for the collection has been determined from values ranging from 2·386 (for an oval core) to 2·468 (for a round core). The lower value of 2·386, which was checked and re-checked, is evidently due to the presence of a few gas bubbles of small size. The distribution of the specific gravity values is shown by the frequency diagram (fig. 1), where the mode is 2·42, thus agreeing with the calculated mean specific gravity.

The width values listed for the dumb-bell-shaped australites (table I) refer to their bulbous ends; the constricted waist regions were not measured.

The depth, diameter, width, length, and radii of curvature measurements were obtained from silhouette tracings of each form. Rotation of the round-form specimens in a beam of light revealed their symmetry about the polar axis; for in the 45° and 90° positions their silhouettes matched those of the original position from which the silhouette tracings were made.

The values for the radii of curvature of posterior (R_B) and anterior (R_F) surfaces were obtained from the silhouette tracings by constructing three chords for each curved surface and bisecting these chords. Normals to the chords through the bisectrices met in three-point intersections or occasionally with a small triangle of error. Since the silhouettes were traced at magnifications of 5·5 times, the triangles of error were negligible. The points of intersection were used as the foci for the construction of circles about each surface tracing. For all the round forms of the australites from Harrow it was found that the arcs of curvature of both the posterior and the anterior surfaces were coincident with portions of the arcs of curvature of the constructed circles. The curvature of each surface occupied approximately 25 % to 30 % of the arc of curvature of each circle. The same applied to silhouettes constructed in similar manner parallel with the shorter diameter (i.e. width) of all the elongated australites in the collection, but not always to those constructed parallel with the longer diameter (i.e. length), where it was found that the arc of curvature was flatter in the polar regions, steeper in equatorial regions. This indicates that the elongated australites were derived from slightly flattened original spheroids or ellipsoids, while the round forms of australites were evidently derived from original spheres.

The relationships between R_B and R_F, for values determined on round forms and values determined across the shorter diameters of elongated forms, are shown by the scatter diagram, fig. 2. It is observed from fig. 2 that there is a general increase of R_F, with increasing R_B from shape type to shape type.

The ranges in values and average values determined for the dimensions and radii of curvature of the australites are set out in tables II and III.

Comparisons of the values listed in tables II and III reveal that the australites from Harrow show the following features:

(1) Buttons are heavier (and larger) than lenses and heavier than the only boat-shaped specimen in the collection, but lighter (and smaller) than the dumb-bells, round cores, and elongated cores.

(2) The specific gravity values are uniform from shape type to shape type, with the average for lenses only 0·01 in excess of the averages for the other shape types. Consequently the frequency diagram (fig. 1), embracing the specific gravity values of all the shape types represented, reveals a relatively even distribution.

(3) The larger the dimensions of the australites, the greater becomes their individual weight, but there is nevertheless relative constancy of specific gravity, indicating that the source material must have been a well-mixed, more or less homogeneous substance.

(4) The depth values for all shape types increase from lenses, through buttons and dumb-bells to round and elongated cores.

(5) The diameter values of the round forms increase from lenses, through buttons to round cores.

TABLE II. Ranges in values for complete or nearly complete australites from Harrow.

Shape type.	Weight gm.	Sp. gr.	Depth mm.	Diameter mm.	Width mm.	Length mm.	R_B mm.	R_F mm.
Buttons ...	2·17 to 5·89	2·41 to 2·43	7 to 13	16·5 to 22	—	—	9 to 14	10 to 15
Lenses ...	1·23 to 2·87	2·40 to 2·45	6 to 9	12 to 18	—	—	6·5 to 11·5	8·5 to 13·5
Boat	3·48	2·42	9	—	14	23	{7* 20·5**	{7* 14·5**
Dumb-bells ...	4·29 to 29·53	2·42 to 2·43	7 to 16	—	12 to 21	23 to 64	6 to 11*	9 to 11*
Round cores ...	5·38 to 30·77	2·40 to 2·47	12·5 to 26·5	17 to 32	—	—	13 to 22	11 to 20
Elongated cores ...	4·09 to 33·78	2·39 to 2·45	12·5 to 22	—	13 to 34	22 to 36	{13 to 26* 19 to 33·5**	{11 to 25·5* 15·5 to 33**
Totals ...	1·23 to 33·78	2·39 to 2·47	6 to 25·5	12 to 32	12 to 34	22 to 64	6·5 to 26*	7 to 25·5*

* and **—as for comments on table I.

Total weight of all specimens = 305·05 gm.

TABLE III. Average values for complete or nearly complete australites from Harrow.

Shape type.	Weight gm.	Sp. gr.	Depth mm.	Diameter mm.	Width mm.	Length mm.	R_B mm.	R_F mm.
Buttons	3·99	2·42	10·5	18	—	—	11·5	12·5
Lenses	2·38	2·43	7	15	—	—	10	11
Boat	3·48	2·42	9	—	14	23	7* 20·5**	7* 14·5**
Dumb-bells ...	12·74	2·42	9·5	—	14	41	8*	9·5*
Round cores ...	11·73	2·42	15·5	22·5	—	—	18·5	15·5
Elongated cores	12·35	2·42	14·5	—	19·5	27	20·5* 26**	18·5* 24**
Total average ...	8·97	2·42	13	19·5	17·5	29·5	—	—

* and **—as for comments on table I.

(6) The width values of elongated forms increase from boats, through dumb-bells to elongated cores.

(7) The length values of the elongated forms increase from boats, through elongated cores to dumb-bells.

(8) There is an increase in depth with increase in diameter among the round forms, and an increase in depth with increase in width and length among the elongated forms.

(9) Width increases as the length increases in the elongated forms.

(10) Whereas R_F is slightly greater in value than R_B for buttons and lenses, the reverse applies to the round cores (cf. scatter diagram, fig. 2). This means that the arc of curvature of anterior surfaces is a little flatter than that of posterior surfaces of buttons and lenses, but steeper for round cores.

Such effects as those indicated in item (10) arise from greater degrees of ablation of the front surfaces of buttons and lenses in proportion to the sizes of the primary forms (spheres) from which they were derived, compared to the primary forms (larger spheres) from which the round

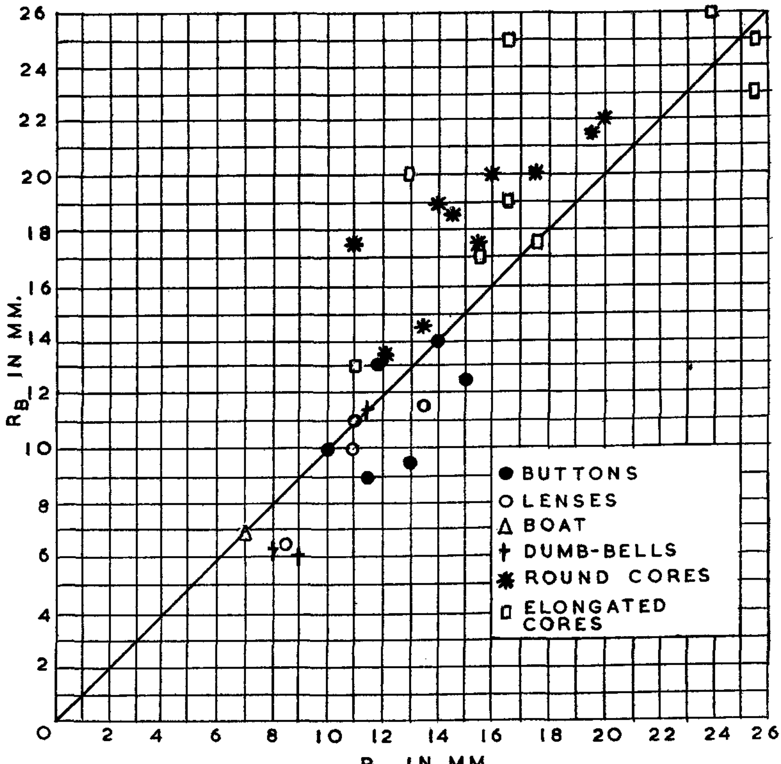

FIG. 2. Scatter diagram showing relationships of R_B and R_F values of australites from Harrow. (R_B and R_F = radius of curvature of posterior and anterior surfaces respectively.)

cores were developed on ablation. Reduction of the primary forms, composed of relatively homogeneous tektite glass, to produce the secondary forms possessed by australites, evidently occurred during the atmospherical phase of earthward flight of these extra-terrestrial objects. For the production of sufficiently high temperatures leading to front surface ablation in progressive stages, primary forms of glass bodies are considered to have entered the earth's outer atmosphere as cold objects. All temperature and pressure effects operating upon their forwardly directed surfaces were generated by virtue of their traversing the atmosphere at very high velocities. Under such circumstances, the sculpturing of the anterior surfaces of australites and their reduction in volume by ablation can be explained in terms of gas dynamics at high speeds of flight.[1] Similar conditions were responsible for the shaping and sculpturing of the forward surfaces of the elongated australites (derived from original spheroids, ellipsoids, apioids, and dumb-bells of revolution).

Comparisons between the average specific gravity values and the average weights of complete specimens of australites from Harrow, with these properties for significant numbers of other south-west Victorian australites, are shown in table IV.

TABLE IV. Average specific gravity values and average weights of complete specimens from three australite concentration centres in south-western Victoria.

Concentration centre.	Average specific gravity.	Average weight (gm.) of complete specimens.
Harrow	2·42	8·97
Nirranda	2·41	2·56
Port Campbell ...	2·40	2·73

The average weight of complete specimens from Harrow is much greater than for Nirranda and Port Campbell, where larger numbers of the smaller button- and lens-shaped forms have been collected in proportion to the number of larger australite cores. At Harrow, which is the most westerly of these three concentration centres in the south-western Victoria strewnfield, the complete forms of australites are not only the heaviest, but they also possess the greater average specific gravity values. There is noted an increase in average specific gravity values from Port Campbell, the most easterly of these occurrences, through Nirranda to Harrow. Such a trend fits in well with the scheme of a provincial distribution of australites according to chemical composition across Australia, where, as a generality, and considering only those areas from which significant numbers of specimens have been collected, it is found that forms with the lower specific gravity occur in the east, and forms with the higher specific gravity occur in the west of the continent.

Since the specific gravity of australite glass is related to its silica

[1] G. Baker, Nirranda strewnfield australites, southeast of Warrnambool, western Victoria. Mem. Nat. Mus. Victoria, 1954. (In press.)

content, the specific gravity increasing with decrease in silica content, it thus follows that the more acidic examples occur in the east and less acidic examples in the west, indicating a general chemical gradient across Australia.[1] In like manner, there is an increase in refractive index of natural glasses with decrease in silica. Tilley[2] has shown that the average specific refractivity of four australites (two from Mt. William in the Grampians, Victoria, and two from unknown localities) is 0·2109. The average for the two Mt. William specimens is 0·2117, and that for two australites from Harrow has been determined as 0·2109 from the formula $K = (n-1)/d$, where K is the specific refractivity, n the refractive index of the australite glass, and d its specific gravity or density. Tilley found that a graphical plot of density and specific refractivity (K) relations was broken up into fields separating tektites generally from terrestrial volcanic glasses, thus confirming divergences of the properties of tektites from those of terrestrial glasses of natural origin, and lending support to the theory of the extra-terrestrial origin of tektite glass. The specific refractivities of the two Harrow examples are given in table V for comparison with those determined by Tilley (1922) for the Mt. William australites.

TABLE V. Specific gravity, refractive index, and specific refractivity comparisons between australites from Harrow and Mt. William.

Locality.	Specific gravity.	n_{Na}.	K.	Author.
Mt. William, Victoria	2·393	1·504	0·2106	Tilley (1922)
,, ,,	2·443	1·520	0·2128	,, ,,
Harrow, Victoria	2·431	1·512	0·2103	Baker (this paper)
,, ,,	2·446	1·517	0·2114	,, ,,

The first example from Harrow is a button-shaped australite, the second is an elongated core (possibly originally a boat-shaped form). These are numbers 5 and 28 respectively in table I.

[1] G. Baker and H. C. Forster, The specific gravity relationships of australites. Amer. Journ. Sci., 1943, vol. 241, pp. 377–406. [M.A. **9**–303.]

[2] C. E. Tilley, Density, refractivity, and composition relations of some natural glasses. Min. Mag., 1922, vol. 19, pp. 275–294.