Rec. West. Aust. Mus. 1991, **15**(2): 371-381

Australites from three localities in south-western Australia

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Abstract

The morphology, weights and specific gravities of australites from three localities in south-western Australia are described and compared. Samples from Earaheedy Station at the northern margin of occurrence of the "normal australite" chemical type are like those of the Eastern Goldfields of Western Australia, except insofar as the quality of the sample has been affected by the circumstances of collection. Sampling from around Corrigin in the south-west of the "normal australite" area has been influenced by the natural abundance of very heavy australites up to weight 437g, the obscuring effect of vegetation, shallow burial in surface sand, and minor factors. Australites from near Hughes on the Nullarbor Plain include numerous flakes but no large specimens because of destructive use by Aborigines. The average weights of australites in the Corrigin, Eastern Goldfields and Nullarbor Plain samples are 30.03g, 1.86g and 0.55g respectively, suggesting that the average dimensions of australites in those samples are in the ratio 2.5:1:0.67.

The natural and human factors which influence the nature of australite locality samples are briefly discussed.

Introduction

Australites which fell in the southern half of Western Australia and adjoining part of South Australia belong to the "normal australite" chemical type of Chapman (1971). Seven locality samples of australites found in the Eastern Goldfields of Western Australia have been previously examined (Cleverly 1986, 1988, 1990, in Press). This paper concerns samples from three localities distant from the Eastern Goldfields. The localities, as stated relative to Kalgoorlie-Boulder (the business centre of the Eastern Goldfields), are Earaheedy Station (550 km north), the vicinity of Corrigin (390 km west-south-west) and a small part of the Nullarbor Plain near Hughes, South Australia (740 km east) (Figure 1).

General features and source of australite samples

1. Earaheedy Station, W.A. Earaheedy homestead is located 25°36'S, 121°35'E in marginal pastoral country with mean rainfall 234 mm/a. Drainage is internal to salt lakes, as in the Eastern Goldfields. Earaheedy and the adjoining Granite Peak Stations constitute the northernmost part of Western Australia where australites have been found in abundance (Cleverly 1976). Documented australites, including australite artifacts, found further north than Earaheedy Station (Cleverly and Dortch 1975; Cleverly 1976; Horwitz and Hudson 1977; Dortch 1979; Mason 1986), together with three solitary specimens reported to the Western Australian Museum, total fewer than 50. This figure contrasts with more than 2700 from Earaheedy Station in collections.

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The following australite collections from Earaheedy Station were examined: 1. Western Australian Museum (WAM) 57; 2. T. Wilks private collection 314; 3. Western Australian School of Mines (WASM) 1578; 4. Quartermaine family private collection 259. There are also at least 535 in other collections including WASM registered No. 11 597 of 175 specimens. The last mentioned was excluded from consideration because it is the rejected part of a collection made for sale, and 66% of the specimens are artifacts (Akerman 1975).

Item 1 above was collected from a single claypan and item 2 from two small lakes (Figure 2). These two items have been combined as the sample "Earaheedy A" representing the "lake country", a complex of small basins and dunes occupying much of the eastern half of Earaheedy Station.

Items 3 and 4 are partly from places visited in connection with station activities, such as mills and fence lines. Another major component is the result of searching the vicinity of Mesquite Swamp, Pope's Claypan and Hamilton's Claypan (Figure 2), which are natural water sources. Of 1138 australite specimens recovered from those localities, 285 (25%) are flakes or flaked cores. Worked flakes of chert and similar materials are also present in those areas, suggesting that the water sources were Aboriginal occupation sites and that the flaked australites are artifacts. Thus the sample "Earaheedy B", comprising items 3 and 4 from the station as a whole, has considerable bias.

A frequency diagram of specific gravity for Earaheedy australites has been presented by Chapman (1971, Figure 5(b)). The single mode in the 2.45-2.46 interval and lack of values >2.47 are typical features of the "normal australite" diagram (Chapman *op. cit.*, Figure 4(d)). Specific gravity values and analyses presented by Mason (1979) confirm that Earaheedy australites belong to the "normal australite" type.

2. Vicinity of Corrigin, W.A. Corrigin is located 32°20'S, 117°52'E in what was previously light woodland. Mean rainfall in 379 mm/a, with strong mid-year (winter) maximum. The author assembled the bulk of the australite sample by farmhouse visits within an arbitrary 50 km radius of the town. The sample comprised 244 privately owned specimens and 39 from various public collections, in all 283 australites from 41 sources. This meagre number from an area of c.8000 km^2 is nevertheless greater than the number known from the balance of the country south-west of a line from Geraldton to Esperance (Figure 1), an area of nearly 200,000 km^2 (Cleverly 1976).

The sites to find are known for a little more than half the sample. The collection of F. Davis (59 specimens) was found on his farm. The collection of N. Ioannisci (72 specimens) and several smaller collections were obtained by watching the unloading and spreading of "gravel" (pisolitic laterite) during road construction. The sources of the australites were the various borrow pits, which are specifically known for some specimens.

3. Vicinity of Hughes, S.A. The sample area is on the Nullarbor Plain c. 30 km north-west of Hughes at approximately 30°30'S, 129°15'E (Figure 1). The sample area is midway between Forrest, W.A. (mean rainfall 186 mm/a) and Cook, S.A. (174 mm/a). The australite sample of 344 specimens is the Australian Museum share of the 1437 collected by a joint Australian and American party (Mason 1968; Chalmers *et al.* 1976). It is not known how well the Australian Museum holdings are representative of the whole collection.

Specific gravities and analyses presented by Mason (1979) indicate that australites from the Hughes area belong to the "normal australite" type of Chapman (1971).

Morphology, mean weights and specific gravity

Each sample was classified morphologically and extracts of salient features including mean weights were made (Table 1) according to the system of Cleverly (1986).

Adequate specific gravity studies of australites from Earaheedy and Hughes have been noted above. The specific gravities of 239 australites from the Corrigin area were determined, and a frequency diagram is presented in Figure 3.

Table 1. Features of australite samples. 1.* Earaheedy A; 2. Earaheedy B; 3. Vicinity of Corrigin; 4. 30 km north-west of Hughes; 5. Eastern Goldfields (average of seven samples).

	1	2	3	4	5
1 Complete forms of essentially so %	38.0	38.8	84.4	17.7	37.3
2 Incomplete but classifiable %	11.3	11.8	6.4	8.7	12.9
3 Unclassifiable, largely abraded or fragments %	47.7	27.0	9.2	59.2	48.6
4 Flakes and flaked cores %	3.0	22.4	—	14.4	1.2
5 Round forms %	70.8	63.2	72.3	51.3	68.2
6 Broad oval forms %	7.9	15.2	17.2	9.1	8.4
7 Narrow oval forms %	8.4	8.8	4.7	2.3	7.7
8 Boat forms %	5.6	4.4	0.4	3.4	5.1
9 Dumbbell forms %	3.9	5.1	4.7	12.5	7.3
10 Teardrop forms %	3.4	3.3	0.4	11.4	3.3
11 Flanged forms, discs & plates, bowls, canoes %	1.1	2.0	—	4.5	2.3
12 Indicators I %	—	1.2	—	1.1	1.8
13 Lens-forms %	34.3	42.1	9.0	88.7	61.6
14 Indicators II %	2.2	3.3	3.9	—	1.1
15 Cores %	62.4	51.4	87.1	5.7	33.2
16 Number of essentially complete australites	141	713	239	59	
17 Mean weight of above (g)	2.92	3.73	32.94	0.80	2.74
18 Total number in sample	371	1837	283	334	
19 Mean weight of all specimens (g)	2.36	2.34	30.03	0.55	1.86
20 Cores/lens-forms	1.82	1.22	9.65	0.06	0.54

*1-4. This work. 5. From Cleverly (1986, 1988, 1990, in press).

Discussion

Earaheedy A: This sample (Table 1, col. 1) is generally similar to those from the Eastern Goldfields. The un-weighted average figures for seven samples from the Eastern Goldfields (Cleverly 1986, 1988, 1990, in Press) are shown for comparison in Table 1, col. 5. Thus the total classifiable specimens in Earaheedy A (Table 1, items 1 and 2) is 49.3%,

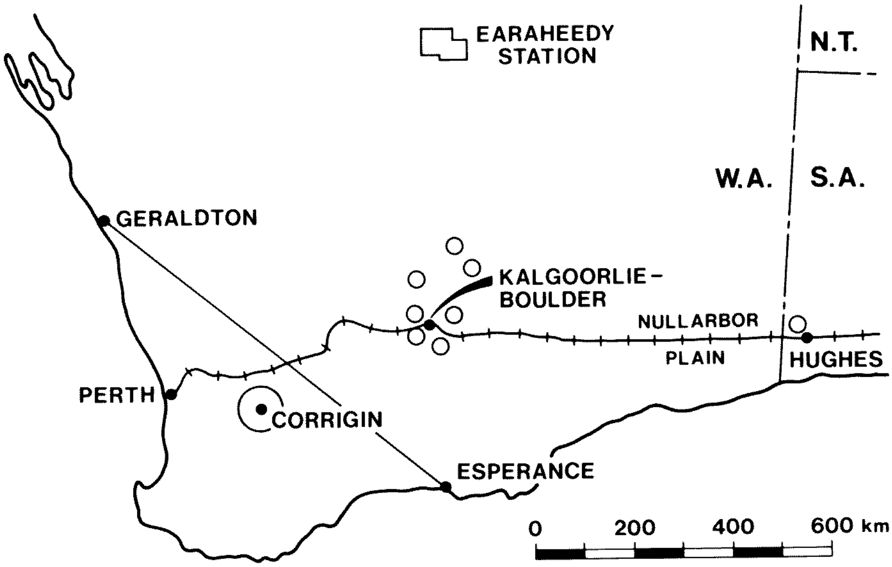

Figure 1. Map of south-western Australia showing find sites of the Earaheedy Station, Corrigin and Hughes australite samples. Sites of Eastern Goldfields samples previously examined are shown by small open circles around Kalgoorlie-Boulder.

and for the Eastern Goldfields 50.2%: round plus broad oval forms (items 5 and 6) total 78.7% of identifiable forms in Earaheedy A and 76.6% for the Eastern Goldfields. The major differences are in the abundances of cores and lens-forms (items 15 and 13), and hence in the cores/lens-forms ratio of 1.82 (Eastern Goldfields 0.54). If the Earaheedy sample is representative, the ratio reflects the higher mean weight of the Earaheedy australites (items 17 and 19).

Earaheedy B: This sample (Table 1, col. 2) has a higher mean weight (3.73 g) for complete specimens than Earaheedy A (item 17), which could be attributable to casual and unsystematic collecting and the high 22.4% of flakes (item 4) resulting from search around water sources. In other respects, it is of the Eastern Goldfields type. The mean weight of 2.34 g for all specimens (item 19) is distinctly higher than the 1.86 g for the Eastern Goldfields samples, despite the presence of 411 flakes averaging less than 1 g each. Classifiable specimens which have not yet been reduced to cores or lens-forms (items 11, 12 and 14) total 6.5%, nearly twice the 3.3% surviving in the harsher conditions of the "lake country" (col. 1).

Corrigin sample (Table 1, col. 3). The outstanding features of the Corrigin sample are the irregular, sometimes almost faceted, posterior surfaces of certain cores, and the abundance of heavy specimens, which include the heaviest known australite.

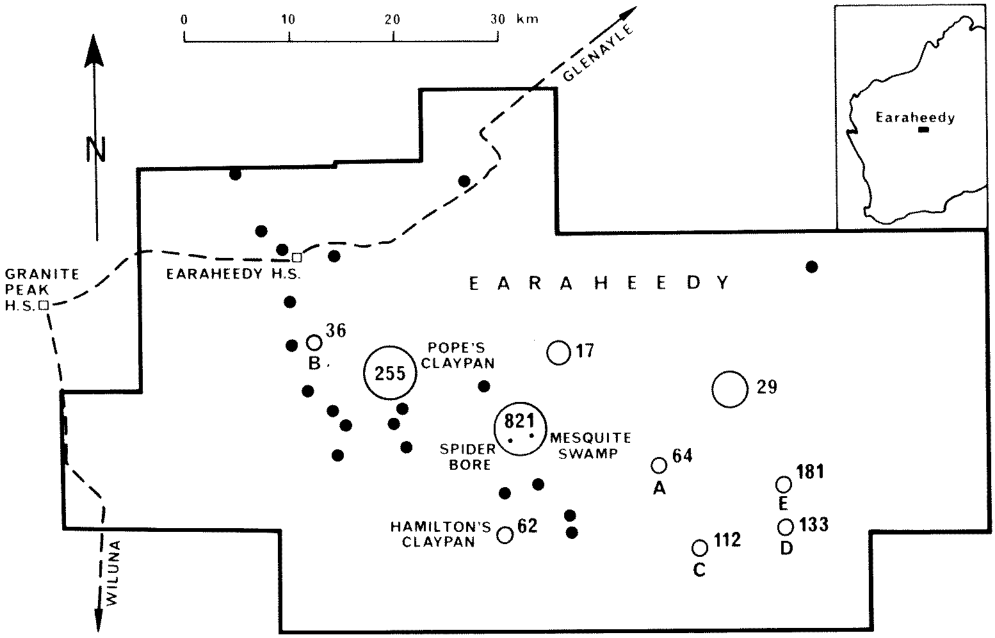

Figure 2. Map of Earaheedy Station, Western Australia showing areas of recovery of australites circled with numbers of specimens. A is the approximate find site of australites in the Western Australian Museum collection, B and C the Smithsonian Institution collection, D and E the T. Wilks private collection. Balance is in other collections. Small solid circles represent 5-10 australites.

Chapman (1964) estimated that about two thirds of the primary cores of round or nearly round shape found within 200 km of Kulin have irregularly contoured, often somewhat faceted "bases" (posterior surfaces). The Corrigin sample was collected within the 200 km circle around Kulin, and therefore provides an opportunity to check Chapman's estimate.

"Primary" is taken to mean those larger cores from which the stress shell spalled spontaneously, as distinct from the generally smaller cores formed as the result of piecemeal losses during weathering (Cleverly 1986, Figure 3). Chapman (1964) has figured a "primary" core from Woyerling (within the sample area) weighing only 18.0 grams. An arbitrary minimum weight of 18 g for primary cores was adopted for the purposes of this investigation. "Round or nearly round" was also given an arbitrary limit of elongation (length/width) of 1.1. Such cores have formed from non-rotating or slowly rotating masses. Irregular posterior surfaces have not been observed on the more elongated oval, boat, or dumbbell-shaped australites, presumably because centrifugal force, which also enters the equation of shape, assisted surface tension in producing a smoothly curved, equilibrated surface.

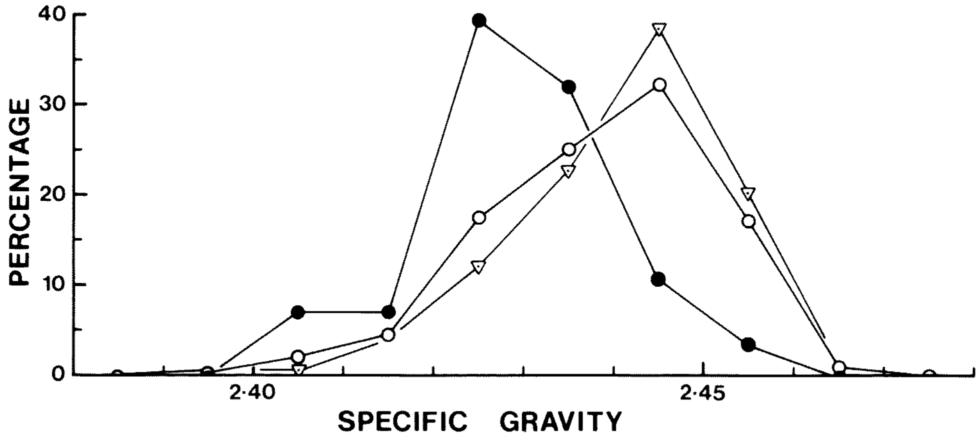

Figure 3. Specific gravity frequency diagrams for australites from the vicinity of Corrigin. Open circles: sample of 239 australites. Filled circles: 56 australites in the sample weighing ≥ 40 g each. Triangles: balance of 183 australites in the sample weighing ≤ 40 g each.

Chapman (1964, Figure 11) has included with cores having irregular "bases" a specimen from Bullaring with abundantly vesicular areas on the posterior surface. Irregular depressions on such cores may have resulted from the weathering out of the weakened, cellular areas. However, the persistence rather than collapse of the vesicles, is a likely result of the lower temperature and resultant higher viscosity envisaged by Chapman, and the inclusion of such cores may therefore be justified.

Sixty two percent of the "primary" cores of weight ≥ 18 g and of elongation ≤ 1.1 in the Corrigin sample have irregular posterior surfaces, a result in close agreement with Chapman's estimate of two thirds.

Australites from south-western Australia may thus show peculiarities of the posterior surface, such as irregular curvature, peaked or almost faceted shape, and unusual abundance of vesicles. Less commonly, they may show peculiarities of the secondarily produced surfaces also, such as spalling of the stress shell extending to the posterior surface (Cleverly 1981), a double rim (Cleverly 1987) and a groove around the anterior surface, as on a core in the collection of N. Ioanissci. The generally large size of the Corrigin specimens is suggested by the high mean weights of 32.94 g for whole specimens and 30.03 g for all specimens (Table 1, items 17 and 19). The sample area lies entirely within the western of two sectors of occurrence of large australites (Cleverly and Scrymgour 1978). The sample of only 283 specimens, a fraction of 1% of those in collections, nevertheless contains 10 of the 22 heaviest known australites (Table 2, upper 10). At the other end of the size range, only 16% of the essentially complete specimens weigh less than 5 g each, compared with 87% of those in an Eastern Goldfields sample (Cleverly 1986, Figure 3).

The mean weight of 30.03 g for the Corrigin specimens contrasts with 1.86 g for Eastern Goldfields collections (Table 1, item 19). The Corrigin specimens thus average 16.15 times as heavy, and have average dimensions more than 2.5 times as great (third root of 16.15) as those in the Eastern Goldfields sample. Deductions of that kind are valid because mean specific gravities of australite samples from within the "normal australite" region vary so little. Some mean specific gravities for samples of 50 specimens are: Farm of F. Davis, Corrigin area 2.436; "Lake country" NW of Kalgoorlie 2.452; Leonora district, 210 km N of Kalgoorlie 2.446; Mulga (north) meteorite strewnfield, Nullarbor Plain 2.442. The above values differ mutually by less than 1%. Mean weights of representative samples are therefore a reliable guide to mean size.

High mean weights arising from an abundance of large australites unequalled elsewhere in Australia, have been further exaggerated by several factors. The large average size and small number of australite recoveries could be partly accountable to the difficulty of detection in well vegetated country, which constrast with the bare ground and dry lake basins of the Eastern Goldfields (Cleverly 1976). The burial of australites in the drifting surface sands of the region (the leached soil horizon over laterite) has not been adequately recognised, though examples have long been known. Public collections contain examples of australites recovered from a post-hole, pipeline cutting, drain, sand pit, diggings for poison weed, and excavations of soaks and earthwork dams. At numerous roadside borrow pits, the surface sand has been stripped to reveal the underlying pisolitic laterite, which is quarried for road building. Australites have been recovered from several such quarries, and also by watching the distribution of the laterite during road building. Some australites were found later on "gravelled" roads. No australites are known to have been taken out of the laterite in the quarry faces i.e. there is no suggestion that they are pre-lateritisation in age. More likely, carelessly or incompletely stripped surface sand containing australites has fallen into the quarries or been incorporated in loads of laterite. Most australites in the Corrigin sample were either ploughed up or otherwise exhumed from shallow burial. These circumstances do not favour detection of small specimens.

Another factor which may have influenced the nature of the australite sample is that the occurrence of very large australites has conditioned some people to expect only large ones. A typical attitude was an apology for the "small" size of four medium to large specimens (weighing 27.3-62.4 g) offered for examination by a farmer who knew that an australite weighing 197.4 g (Cleverly 1981) had been found on his farm by previous owners.

The occurrence of large australites is also dependent upon their survival. Destructive use by aborigines, as discussed for the Hughes sample below, is not known to have occurred in the Corrigin area, though there are numerous aboriginal occupation sites (L. Lewis, pers. comm.).

Various items in Table 1, col. 3 contribute to, or are influenced by, the high mean weights. Thus the round plus broad oval forms (items 5 and 6) constitute an unusually high 89.8% of identifiable forms. Lists of large australites (e.g. Cleverly 1974, Table 2)

Table 2. Heavy australites found in Corrigin area.

Weight g	R.W.[1] g	Core shape	Locality	Ref.[2]
437.5		Broad oval	c. 3 km W of Notting	1
233.9		Broad oval	c. 14 km W of Kondinin	1
225.1		Teardrop	Near Shackleton	2
218.0		Round	Lake Yealering	1
200.5		Round	c. 7 km S of W of Gorge Rock	3
197.4		Round	c. 10 km SE of Babakin	3
194.4		Round	c. 7 km E of Gorge Rock	1
171.4		Round	8 km WNW of Wogerlin Hill	
168.0		Round	c. 5 km SE of Corrigin	1
167.0	176	Broad oval	15 km SW of Billericay	
147.0		Round	Near Corrigin	1
117.7		Round	7 km NE of Wogerlin Hill	
116.9		Broad oval	c. 22 km N or E of Wickepin	1
113.1	117	Broad oval	Babakin	1
99.9		Round	2 km N of E of Bilbarin	
97.7		Broad oval	23 km E of Corrigin	
95.1		Round	Kulin	
93.9		Round	c. 20 km S of Corrigin	
86.8	100	Broad oval	Jubuk	1
85.7		Round	Near Corrigin	
84.1		Round	7.5 km NNW of Kulin	
81.0		Round	Shackleton	
80.1	>100	(?) Round	6 km SW of Gorge Rock	3

[1]Estimated restored weights for artifically damaged specimens.
[2]References to descriptions. 1. Cleverly (1974); 2. Scrymgour (1978); 3. Cleverly (1981).

show the dominance of such shapes amongst large australites. The low percentage of the smaller, lens-type specimens and high percentage of the generally larger cores (items 13 and 15) yield an exceptionally high cores/lens-forms ratio of 9.65 (item 20).

The frequency diagram of specific gravity for 239 specimens from the Corrigin area (Figure 3) has the general features of the "normal australite" type (Chapman 1971), but the mode in the 2.44-2.45 interval contains only 32% of the sample, and the diagram is convex upward on the lower value side of the mode. The 33 known australites from the south-west region having weight >100 g (Cleverly 1974, 1981, This Paper; Scrymgour 1978) have the distinctly lower mean specific gravity and standard deviation 2.425±0.012. This observation prompted consideration of the heavier specimens in the Corrigin sample. The diagram for the 56 specimens in the Corrigin sample, each weighing >40g, has its mode in the same low interval (2.42-2.43) as the convexity. If those 56 specimens are excluded from the general sample, the frequency diagram has an increased mode and no convexity (Figure 3). The abundance of heavy specimens is therefore at least partly responsible for the unusual features of the original diagram.

Hughes sample (Table 1, col. 4). The mean weight of 0.55 g (item 19) is at the other end of the scale from the Corrigin sample, and in close agreement with the mean of 0.57 g for 1933 specimens in 17 widespread Nullarbor Plain samples (calculated from data of Chalmers *et al.* 1976). The mean weight of the Hughes sample is only 0.296 of the 1.86 g mean for Eastern Goldfields specimens. The average dimensions are therefore only two thirds those of Goldfields specimens.

The low percentage (26.4%) of classifiable specimens (items 4 and 5) is partly accountable to the high percentage (14.4%) of flaked material (item 4). In collecting this sample, search was not knowingly directed towards water sources, as was the case for the sample Earaheedy B. A sample of 102 australites from the strewnfield of the Mulga (north) meteorite, on the Nullarbor Plain 270 km WNW of Hughes (Cleverly 1972) has comparable abundance (15.7%) of australite flakes. The percentage may be much higher around aboriginal occupation sites, even 100% (Edwards 1966; Cleverly 1976).

The terrestrial changes of australite shapes (Cleverly 1986, Figure 3), accelerated by semi-arid climatic conditions, are shown in the abundance (94.4%) of lens-forms and cores (items 13 plus 15), the identifiable end products of the smaller and larger primary bodies respectively. However, cores comprise only 5.7% and lens-forms 88.7% of classifiable specimens, quite the inverse of the Corrigin sample. The resulting cores/lens-forms ratio is only 0.06 (item 20). The abundance of the smaller lens-forms, paucity of cores, and resultant low mean weights can be explained by the joint circumstances of ready visibility of small australites and the destruction of larger australites by Aborigines. The heaviest specimen in the Hughes sample is a fragment weighing 3.4 grams. The heaviest specimen known to the writer from anywhere on the Nullarbor Plain is an artifically detached fragment weighing 27.1 g found east of Rawlinna (A. Levy private coll.). The report of a 98 g core from the Nullarbor Plain (Fenner 1955) is erroneous. The specimen (SAM T510) was found in the vicinity of Kalgoorlie and has the etch pattern developed in highly saline environments (Cleverly 1986), but unknown on cores from the Nullarbor Plain.

Conclusions

The nature of an australite sample depends upon both natural and human factors. Patches of unusual australite abundance which cannot be attributed to terrestrial transporting agents (e.g. Cleverly 1986: 82) are common and indicate that the shower varied in density. There was probably also a variation in the sizes of the primary bodies from place to place. The sizes and size distribution influenced the numbers of cores formed by spontaneous spalling of the stress shell and number of lens-forms resulting from loss of flange in flight during aerodynamic (secondary) modification of the primary form, thus establishing the initial cores/lens-forms ratio. Differences in the intensity and nature of erosion and weathering processes during subsequent terrestrial residence caused losses of flanges and stress shells, which vary in percentage completion from place to place. Some australites, especially frail and smaller ones, have been reduced beyond cores and lens-forms to unidentifiable shapes. Australites may become enclosed in surficial sand or sediments and re-exposed by natural agencies such as stream erosion.

They may therefore be affected by chemical corrosion in moist soils and by erosion at different stages of their terrestrial history, each modifying, or even erasing the earlier effects. Ideally, the preceding and allied natural factors would be responsible for the nature of an australite locality sample, but human factors may also have an influence.

Where vegetation obscures the ground, only the most painstaking search can yield a representative sample with a full quota of smaller specimens. This difficulty is less in semi-arid places such as the Eastern Goldfields, and almost non-existent in desert regions. However, casual or careless collection, even in places of ready visibility, can result in an undue number of the larger, core-type specimens in the sample. Shallowly buried australites may be re-exposed by a variety of human activities, such as clearing of vegetation, ploughing, engineering excavation and mining. The expectation of finding only large australites may have influenced the nature of the sample in some areas. The widespread occurrence of artifacts made on australites in places such as the Nullarbor Plain, where alternative materials are limited in quality or variety, may result in samples containing unusually high numbers of flaked specimens and few large ones. Samples from near natural water sources are likely to contain exaggerated percentages of artifacts. On the other hand, the survival of larger australites may be dependent upon a lack of Aboriginal interest in them as raw materials. Non-destructive use of australites by Aborigines as charms, medicine stones, or death-pointers (Baker 1957) may have resulted in their movement along Aboriginal trade routes and their eventual recovery in places where australites did not fall (Cleverly 1976).

There may yet be clues to australite origins in their distribution pattern. While current theories of tektite origins agree only to differ, it is desirable that collecting be very thorough to ensure that the sample is truly representative, and that the natural and human factors responsible for the nature of the sample be assessed as carefully as possible.

Acknowledgements

It is possible to thank only collectively the more than 50 people who lent me australites from their private collections or from the public collections in their charge. The staff and science students of the Corrigin District High School were especially helpful to me. Figures 1-3 were drafted by Ms J. M. Wearne.

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Received 10 October 1990 Accepted 12 February 1991 Published 28 June 1991