Some australite structures and their origin.

(With Plate XXII.)

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Introduction.

A NUMBER of specimens of core-like australites possess well-developed flaked equatorial zones (text-fig. 1), on which peculiar grooves and flutings are present. These markings are here referred to as 'bubble tracks', the term indicating their apparent mode of formation. The specimens displaying these features are round and elongate forms. The round forms vary in diameter from 34 to 41 mm., the elongate forms range in length from 30 to 75 mm., while the weights vary from 27½ to 96 grams. Australites of these sizes are of infrequent occurrence, only twenty-one having been previously recorded (9, pl. 4), (2, pl. 4), and (3, pl. 9); the illustrations of these examples show that they have comparable features, such as flaked equatorial zones and bubble tracks.

All of the specimens above referred to, and the features shown by them, suggest a mode of origin for core and bubble-track formation different from that of earlier explanations (3 and 4), which are based on the activity of superficial agencies operating on the earth's surface. The nature of the cores apparently substantiates a recently advanced hypothesis, in which core-like australites are thought to have been derived from spheres of australite glass by atmospheric flaking during flight (5, p. 202, fig. 2, stages 2 and 3); but an additional factor worthy of consideration is the effect upon the molten glass of hot gases accompanying the tektite during its pre-atmospheric stage of approach towards our planet (7).

Flaked equatorial zones.

The positions of the flaked equatorial zones on australite cores are diagrammatically represented in text-figs. 1A and 1B. These zones are delimited from the posterior surfaces of the australites by sharply defined rims, towards which they invariably recurve outwards (pl. XXII). The flaked zones in some forms are broader than in others, being as much as 15 mm. in a specimen from Harrow, Victoria (fig. 4); the width is more usually 8–10 mm. The zones are often marked with complex flow-line designs and occasional bubble pits (shallow depressions left on the surfaces of australites by escaping small gas bubbles), while bubble tracks often traverse the flaked zone parallel to the short axis of the australite (pl. XXII, figs. 1, 3, and 5).

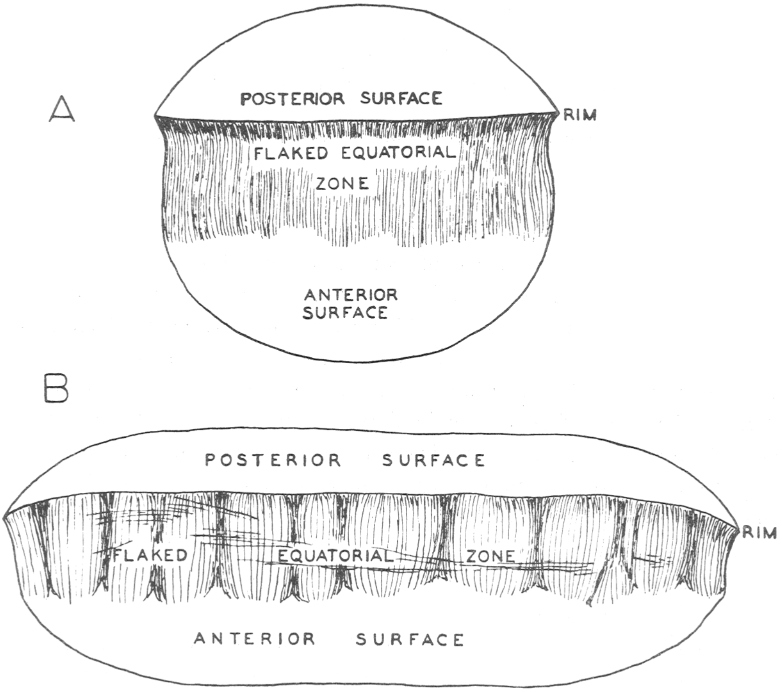

FIG. 1. Sketch diagrams of australite cores showing flaked equatorial zones.
A. Core of round form, illustrating recurving of flaked zone towards rim at junction with posterior surface.
B. Core of boat-shaped form. Darker shading represents ridges separating concave areas. Horizontal lines represent the more prominently developed flow-lines.

The junction between the anterior surface and the flaked zone is occasionally pronounced and rim-like (figs. 3 and 8), but is never as sharply defined as the junction between the posterior surface and the flaked zone. Specimens such as this have two rims developed by flaking, the position of the well-defined posterior one being controlled by the initial position of the original rim (produced by rotation during flight), the poorly marked anterior one arising essentially from the removal (see later) of equatorial portions during flight. In most examples the anterior surfaces and the flaked zones merge imperceptibly into one another, without any marked signs of the formation of a second rim (figs. 4, 5, and 10).

The flaked zone of a boat-shaped australite from Port Campbell, Victoria (1, p. 169), is the best developed of any of the specimens examined, and is apparently totally unaffected by agents of erosion (fig. 9). Twenty depressed areas around this zone alternate with narrow ridge-like portions arranged parallel to the short axis of the form. Bubble tracks are usually confined to these ridges, while fine flow-lines are more common on the surfaces of the depressions than on the ridges. Short grooves on the unflaked portions of the anterior surface occur at the anterior ends of the ridges and at right angles to them.

The flaking of equatorial regions in the larger australites has not resulted in the loss of much material from posterior surfaces. Practically all of the australite glass flaked away has been removed from the equatorial regions of the anterior surfaces. That the flaking ended sharply at the posterior rim is indicated by a specimen from Caramut, Victoria (fig. 3), where seven-eighths of the periphery has been subjected to flaking with the formation of a sharply defined rim; the remaining unflaked portion, at the right-hand end of fig. 3, shows remnants of the less marked initial rim, continuous in position with the rim of the flaked zone.

There seems to be no doubt that these large australite cores have been produced by natural means. The flaked zones do not resemble secondarily chipped surfaces produced on australites by aboriginal flaking where the artificially flaked parts possess sharp ridges separating areas with marked conchoidal and ripple fracture, but no flow-lines or bubble tracks. Neither do they resemble the regions of flaking on smaller cores of conical shape (3, pl. 4, figs. A1f, 7–12) which have no marked structures comparable to those on flaked zones of the larger cores. The flaked zones of the larger cores are too intimately associated with flow phenomena to be adequately explained as due to agents such as abrasion, &c., considered responsible for the production of the smaller cores (4, p. 131, fig. 1).

The flaking process forming large australite cores seems best explained by a cutting action due to the frictional resistance of the atmosphere against the australite during its earthward flight. The formation of the flaked zones around the periphery of the forward (anterior) surface was probably aided by a process of gas-bubble accumulation in the outer portions of the equatorial zones. As the region in which the bubbles collected would be rendered partially plastic and therefore less stable by secondary fusion brought about by atmospheric friction during flight, this collecting of bubbles of gas in the outer portions would further weaken the equatorial zones and make them more susceptible to atmospheric ablation. Remnants of areas in which bubble collecting occurred are indicated in fig. 5, where numerous bubble tracks lead to a large bubble crater (a cavity produced by the collapse of a large gas bubble) on the posterior surface. The numerous bubble pits, flow-lines, flow-grooves, and bubble tracks on the anterior side of the equatorial region of the only unflaked form amongst the larger australites examined (fig. 2) probably represent an early stage in gas-bubble accumulation prior to flaking. The apparent development of an initial flaked equatorial zone is shown in the photograph of this specimen; at each end there appears to be a modified area suggestive of flaking. Such a zone as this, on being further riddled with bubble pits and bubble tracks, would be more readily removed by atmospheric carving during flight than would the denser portions comprising the bulk of the australite; with the removal of this weakened zone, a pronounced flaked equatorial zone, and hence a core-like australite, would be produced.

Portions carved away from the periphery in this manner would be honeycombed with gas bubbles and would most likely be completely consumed during flight. Any less gassy portions flaked off might possibly constitute the initial forms from which small disk- and plate-like australites developed. Evidence probably supporting this suggestion is forthcoming from Port Campbell, Victoria, where certain australite fragments apparently fell to the earth independently of the larger parent form undergoing flaking. During their separate flight they commenced to form small irregular fragments, and assumed shapes somewhat comparable to the more perfectly developed disk- and plate-shaped australites.

Bubble tracks.

Grooves and flutings in flaked equatorial zones and on unflaked portions of the anterior surfaces of the larger forms of australites, are referred to as *bubble tracks* because in some examples they are chain-like arrangements of coalesced gas bubbles, often with vermicular segmented appearances (pl. XXII, fig. 1); in others the tracks are large bubble pits drawn out by the flowage of plastic australite glass. The bubble tracks are comparable with, but are neither as wide nor as deep as, grooves and flutings on certain forms of billitonites (8, p. 202). Flow-lines cutting the tracks at right angles to their length also intercept the rim in parts of some examples, so that both the bubble tracks and the rim were formed prior to the development of this particular set of flow-lines.

As regards the origin of bubble tracks, it has been suggested that comparable features referred to as grooves and flutings on other australites (4, p. 139) and on tektites in general (6, p. 64) are due to the chemical corrosion of specimens which have been buried in moist soils for long periods, i.e. to partial solution by humic acids or alkalis in soils. This fails to explain the chain-like arrangement and segmented appearance of many of the bubble tracks. Moreover, at Port Campbell, Victoria, where the positions (i.e. as to which surface was uppermost) of 388 australites were carefully noted at the time of discovery, it was found that flaked boat-shaped and round core-like forms with bubble tracks occurred on similar soils close to other forms of australites which show no such markings.

Since the bubble tracks fail to interrupt the sharply marked rims between posterior surfaces and flaked zones and are never present on posterior surfaces, there is no reason to suppose that humic acids or alkalis in soils should confine their activities to flaked zones and anterior surfaces, especially when it is the posterior surfaces which are invariably in contact with the ground. This is the stable position of rest for australites, so that the posterior surfaces should be more prone to the suggested corrosion, as they were in contact with soils for longer periods than were anterior surfaces; in fact, in several examples, the anterior surfaces may never have been buried in soils, as the specimens may have rested on hard ground with their posterior surfaces downwards ever since they assumed their stable position of rest after striking the surface of the earth. None of the specimens so far examined ever show bubble-track markings on posterior surfaces.

An australite was immersed in concentrated hydrochloric acid for two months, and an australite which had been ground and polished was immersed in concentrated potassium hydroxide for a similar period; at the end of this time no markings whatsoever had developed either on the natural or on the artificially prepared surfaces, whether in acid or in alkali. This suggests that australite glass would be stable towards weak acids and alkalis in soils, and that it is homogeneous, so there is no reason for supposing that one part of an australite any more than another should be susceptible to corrosion whilst buried in moist soils. Linck has succeeded in corroding crystal-bearing tektites from Paucartambo in Peru by using hydrofluoric acid and sulphuric acid, and he thinks that similar etch marks could be caused naturally by corrosion of the tektite glass with hot accompanying gases or by the escape of these gases on the surfaces of the tektites (7, p. 231). He arrives at the conclusion that the origin of the sculpture of tektites cannot be due to etching by feeble corrosion whilst buried in the deposits in which they are found, as such corrosion would lead in the first place to hydration, and such a thing is never observed.

Moreover, it does not seem valid to interpret the bubble-track markings on australites as due to humic acids or alkalis in soils when bubble pits are regarded as original structures (3, p. 66). The markings are no more than grooves formed by chains of bubbles which have coalesced, or large elongated single bubbles, in all of the specimens containing them. When both are present bubble tracks and bubble pits are intimately associated on anterior surfaces and flaked zones, many of the tracks apparently starting or ending in pronounced pits or cavities; gas bubbles have fused together in an elaborate structure in much the same way as on other varieties of tektites (7, p. 231). The bubble tracks most likely resulted from the movement of lines of gas bubbles away from high-pressure regions (anterior surfaces) towards the equatorial regions against the resistance of the partially plastic australite glass. This process would occur partly during the phase of secondary fusion in the atmospheric stage of flight, but was probably initiated in the pre-atmospheric stage of the movement of these glass meteorites towards the earth, when strong corrosion may have been brought about by the action of hot accompanying gases.

Cores.

It is proposed that an australite *core* should be defined as 'the ultimate shape of any form of australite which has been reduced in size through loss of material from the periphery by a process of natural flaking. A pronounced flaked zone around the equator of the australite is produced by the action of terrestrial or atmospheric agencies, either on the earth's surface, or during flight'.

Such cores can be divided into three groups, according to their mode of origin. First, there are the cores described as developing from regular button-shaped australites from which the flanges were broken off after fall by abrasion, temperature variation, &c., after which further flaking occurred around the equatorial zone (3, pp. 68 and 74). Many of the smaller varieties of cores, 20 mm. and under in diameter, belong to this group. Examples from Charlotte Waters in Central Australia and from Port Campbell, Victoria, have remnants of smooth bands, 2 mm. wide, indicating positions from which flanges have flaked away, and showing that the original unflaked forms were button-shaped australites. The flaking away of these flanges apparently developed after the arrival of the australites at the earth's surface, as there has been no modification of the original regions of flange attachment, such as would develop if flaking had occurred during flight, when subsequent flowage would produce secondary flow phenomena.

A second group of cores is made up of smaller round cores which show no evidence that flanges have been flaked away from them. Such cores were probably developed from original lens forms (with rims) rather than from button forms (with flanges), probably in a manner analogous to core formation from button-shaped australites.

The larger core-like australites with structures described above constitute a third group of australite cores. In a recently elaborated theory, cores (and the so-called bungs) similar to these are intermediate stages in the evolution of round forms of australites (i.e. buttons and lenses, which are round in posterior and anterior aspects) from original glass spheres, by cracking and flaking off of unstable portions during atmospheric flight (5, p. 202). The structures on such australites as those shown in plate XXII and on those cores figured by Walcott (9), Dunn (2), and Fenner (3) are considered to substantiate this latest view of core formation. Additional evidence for the possibility of such fragmentation occurring during flight has been indicated earlier (1, p. 175).

These three processes of core formation refer to round forms of australites, but they are also applicable to elongate forms, since oval, boat, dumb-bell, and teardrop-shaped australites may all possess flaked equatorial zones with markings comparable with those shown on round cores.

Whether round or elongate in shape, none of these larger australite cores constituting the third group appear to have been formed from flanged australites, because large specimens with attached flanges have never been recorded, and flange fragments of requisite size to suit these larger forms have never been found. Moreover, the larger australites do not possess the flow-ridges so characteristically developed on the anterior (forward) surfaces of smaller forms (fig. 6). Presumably their anterior surfaces were insufficiently plastic for flowage to produce flow-ridges and ultimately flanges.

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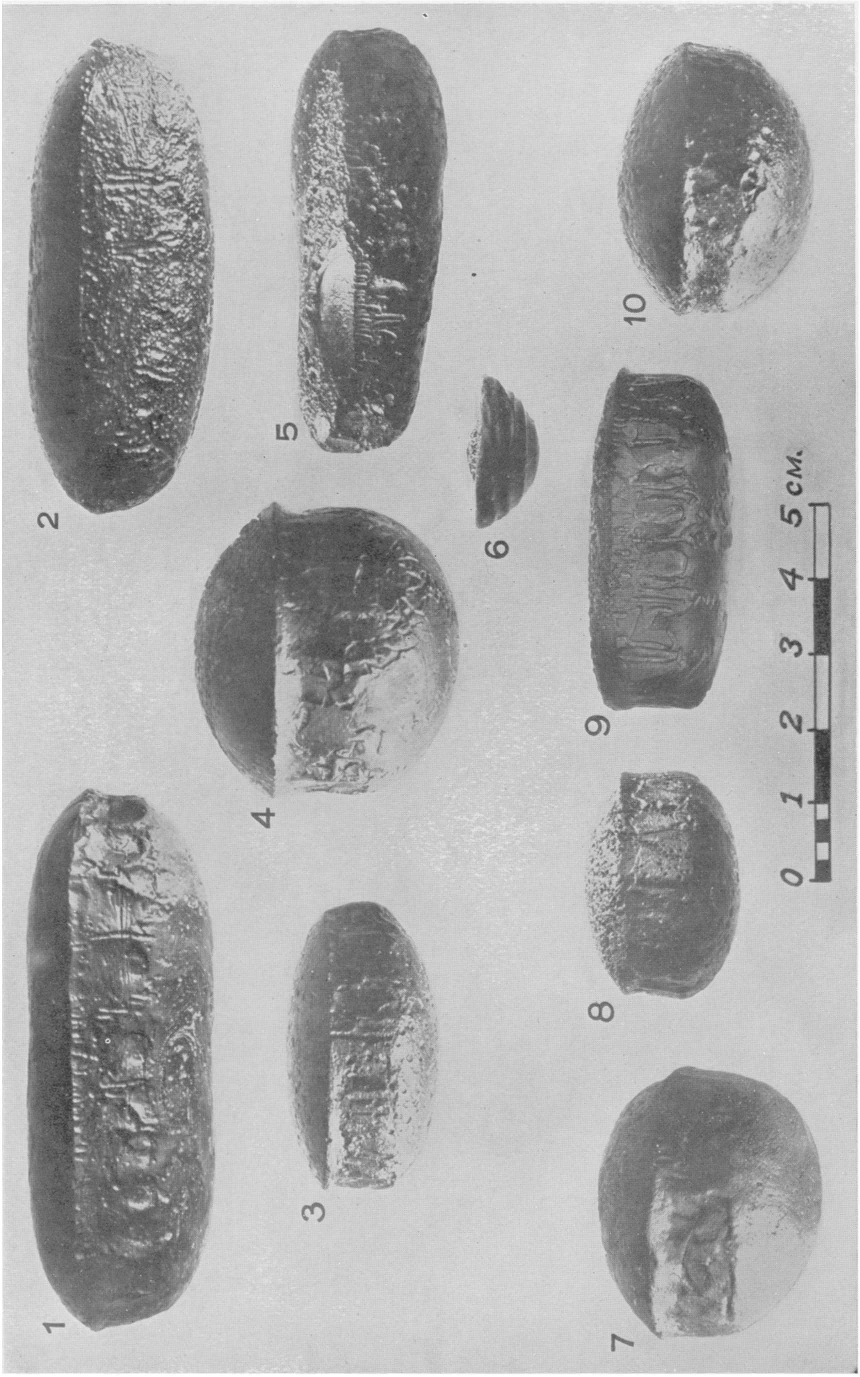
Description of Plate XXII.

Australites showing the core-like nature of some larger forms, with flaked equatorial zones and bubble tracks.

Photographs, natural size, by J. Spencer Mann. Posterior surfaces are uppermost in each photograph. Figures in brackets refer to the register numbers in the Melbourne University collection.

Fig. 1. Boat-shaped core. Kaniva, Victoria. (3045.)
Fig. 2. Unflaked boat-shaped form. Corop, Victoria. (3046.)
Fig. 3. Oval-shaped core showing unflaked remnant at right-hand end. Caramut, Victoria. (3099.)
Fig. 4. Core of round form. Harrow, Victoria. (2539.)
Fig. 5. Boat-shaped core with large bubble crater on posterior surface, to which numerous bubble tracks lead. Ellerslie, Victoria. (2572.)
Fig. 6. Button-shaped australite showing flow-ridges on anterior surface, and flange. Inverell, New South Wales. (3101.)
Fig. 7. Abraded core of round form. Harrow, Victoria. (2540.)
Fig. 8. Oval-shaped core. Ellerslie, Victoria. (2573.)
Fig. 9. Boat-shaped core with perfectly developed flaked equatorial zone and bubble tracks. Port Campbell, Victoria. (2970.)
Fig. 10. Abraded core of round form. Kalgoorlie, Western Australia. (3100.)



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