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'Burnt' beetles (Insecta: Coleoptera) from the Wealden of southern England

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Abstract. Insect remains preserved as fusain (mineral charcoal) are reported from the Lower Weald Clay (early Cretaceous: Hauterivian) of the English Weald. The ultrastructure, geochemistry and a new species *Coleopteron semicrematus* sp. nov. are described. Fusainised Coleoptera may represent a bush community prone to wildfire.

Key words: beetles, charcoal, Cretaceous, Wealden, new species.

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I. EVIDENCE OF BURNT BEETLES IN THE WEALDEN

Fusain is fossil charcoal, representing incomplete combustion (charring as opposed to burning) of organic material, and provides evidence of ancient wildfire. Plant fusain has been much discussed in the palaeobotanical literature, including its exact origin, preservation, palaeoenvironmental significance, and early Cretaceous occurrence in the English Wealden (HARRIS 1981). Animal fusain has, however, received much less interest (JARZEMBOWSKI 1987). Fusainised Coleoptera (beetles) and other insect remains may be found in the Weald Clay (Upper Wealden) of southeast England (JARZEMBOWSKI 1995: Fig. 2). The fossils occur especially in scour fills of late Hauterivian age which were deposited in a muddy wetland now represented by the Lower Weald Clay (loc. cit.); this is the first detailed publication on the subject.

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II. PHYSICAL CHARACTERISTICS

Amongst the elytra and other beetle remains in the Weald Clay may be found occasionally examples with an unusual preservation. The normal material consists of impressions with a very thin, discontinuous coating of organic matter of a matt black or brown colour. This organic matter shows no observable structure under the light microscope. In the unusually preserved examples the lining

of the impressions is black and shiny and has an observable thickness under the light microscope, even at low power, and shows details of the surface ornament. Also the lining forms a continuous layer which when broken comes away cleanly from the matrix and shows a brittle fracture.

Black colour, shiny reflectance, brittle fracture and three-dimensional preservation are characteristics of Wealden plant remains which were naturally fusainised (i.e. charcoalified) prior to burial (HARRIS 1981). The unusually preserved beetle remains often occur on the same bedding plane as fusainised wood fragments and a common origin seems feasible. To supplement the above physical observations, geochemical and structural properties were investigated.

III. GEOCHEMICAL INVESTIGATION

An obvious geochemical analysis would be to test for elemental carbon in the unusually preserved beetle remains, but this has practical difficulties associated with organic analysis of such small samples (G. JONES, personal communication). However, electron probe microanalysis can readily identify cations, and can therefore provide information on the diagenetic history of the fossil material and enclosed matrix.

An elytron (No. MNEMG 2002.5 [CH873v]) was selected from a scour fill at Clockhouse Brickworks in the Lower Weald Clay from which some of the presumed fusainised cuticle had broken away revealing an 'impression' of the elytron in the matrix. The results of an E.P.M. scan are shown in Fig. 3.

Fig. 3a shows the area of the elytron analysed. The dark area with an evenly curved upper margin and reflective, broken lower margin is the remaining cuticle of the elytron in dorsal view. Above the cuticle is ordinary rock matrix and the roughly clathrate area below the cuticle is the ventral 'impression' of the elytron.

Fig. 3b shows the distribution of silicon (Si) in the same area as Fig. 3a (the light grey areas indicate cation positive, the black areas cation negative). Figs 3c,d show the distribution of iron (Fe) and calcium (Ca) respectively.

Scanning showed that the 'impression' of the elytron was rich in Ca and Si which is what one would expect because the elytron is preserved in calcareous siltstone. The cuticle, however, was negative for the same cations which showed that it was not calcified nor silicified. Iron proved generally absent and further scans for sulphur (S), manganese (Mn) and phosphorus (P) compounds, which might be expected in fossiliferous sediments, showed only trace quantities. No significant mineralisation of the cuticle was detected which is consistent with the comparatively unreactive (inert) nature of fusain.

IV. STRUCTURAL COMPARISONS

A Recent British click beetle (elaterid), previously killed, set and dried in the usual entomological manner, was fusainised basically following the method described for fern pinnules by HARRIS (1981). The specimen was heated in a pyrex test tube fitted with a cotton wool plug to reduce air circulation. However, instead of a Bunsen burner, the source of heat was a roaring domestic wood fire. The beetle was heated for three to five minutes in the hottest part of the fire. A tube filled with small wood fragments was also heated to check that the conditions were right for charcoal formation. The experiment was repeated with a single elytron from a second specimen. It was noted that the detached elytron, unlike the elytra on the body, became slightly twisted longitudinally during heating.

The fusainised elaterid body was broken and the broken edge of the elytra examined under a stereo-electron microscope (S.E.M., Fig. 5). The appearance was quite unlike a normal Recent beetle elytron whether examined under S.E.M. or in thin section. Broken normal Recent cuticle had a ragged margin (Figs 6, 7). In section, this shows longitudinal canals and tracheae between three lay-

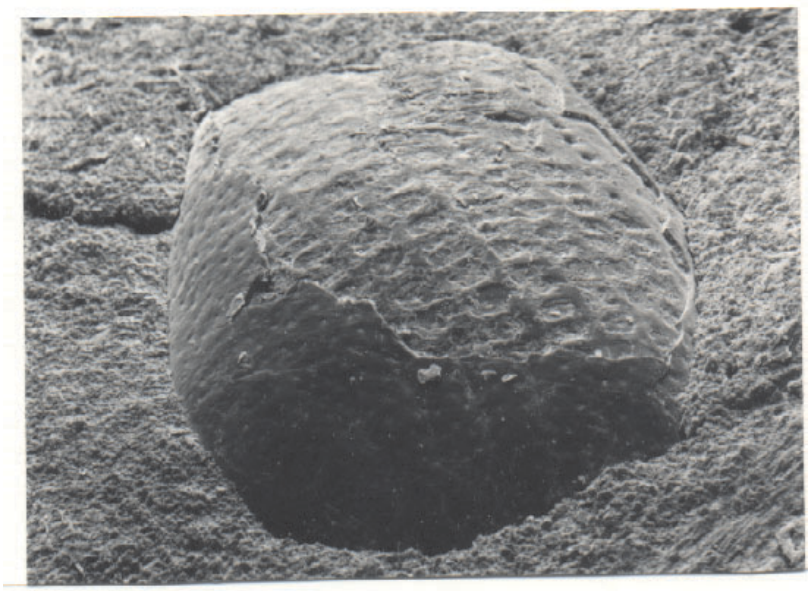


Fig. 1. S.E.M. photograph of oblique longitudinal view of beetle elytron, Weald Clay, Clockhouse Brickworks ([CH 873v]; × 80).

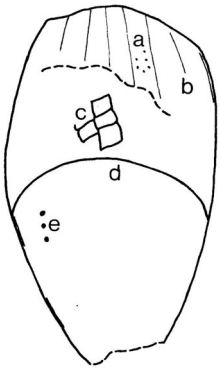


Fig. 2. Diagram of holotype of *Coleopteron semicrematus* sp. nov. External and internal ornament separated by dashed line. Explanation in text.

ers of cuticle supported by pillars or trabeculae (CROWSON 1981; KRZELJ 1969). The cavities of longitudinal ducts were clear in the fusainised modern elytron (Fig. 5, large black area). The cuticle above these showed smooth broken faces with no structure other than bunches of small cavities. The fusainised cuticle had fractured slightly irregularly in the vicinity of the cavities.

The broken edge of the cuticle of the Wealden elytron was also examined under S.E.M. (Fig. 4). It showed a similar structure to the fusainised Recent elytron except that only the upper part of the cuticle could be seen and no ducts were visible (the light area at the bottom of Fig. 4 corresponds to the 'impression' of the elytron in section III). The close structural resemblance between the fossil cuticle and upper part of the Recent fusainised cuticle also showed that the former had not undergone any compression.

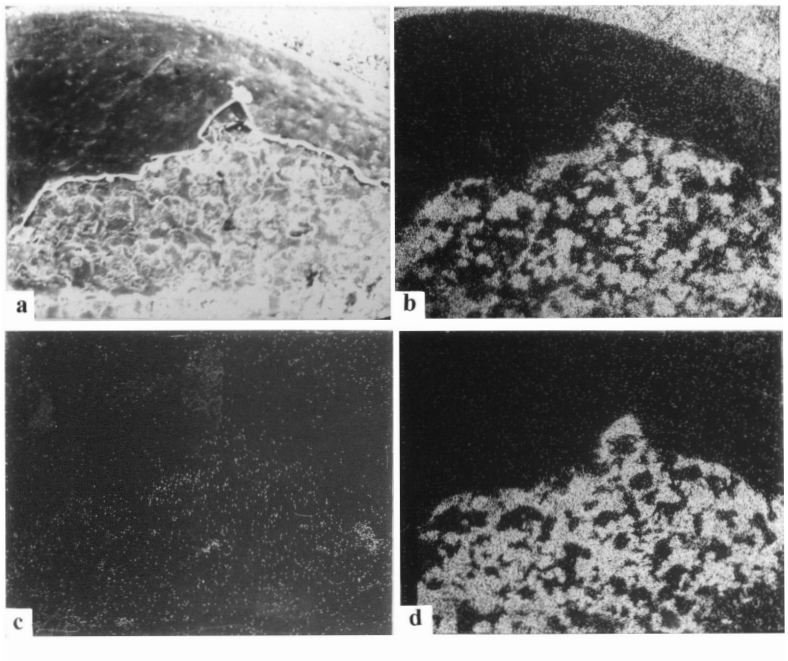


Fig. 3. Photographs of Electron Probe Microanalysis of beetle elytron from Weald Clay ([CH 873v]). Explanation in text.

V. DISCUSSION

The physical characteristics and association of the unusually preserved Wealden beetle remains suggested that the cuticle has been fusainised (section II). E.P.M. showed that the characteristics cannot be attributed to mineralisation (section III) a common process during diagenesis and fossilisation. Structures observed under S.E.M. in the fossil cuticle (section IV) showed that small detail was preserved in three-dimensions. This ultrastructure was similar to preparations of fusainised Recent beetle elytra, thus supporting the interpretation of the cuticle as representing natural charcoal or fusain. Similarly, the microstructure of fusainised Wealden plants is resistant to compaction and is characteristically preserved (HARRIS 1981).

An interesting difference between the fossil and Recent elytra is that evidence of fusainisation in the former was confined to the upper part of the cuticle. The rock 'impression' of the fossil elytron clearly showed different ornamentation from the associated cuticle (Figs 1, 3a). An elytron was therefore detached from an elaterid and the lower or ventral surface was examined under a light microscope. This showed a lattice-like ornament resembling the 'impression' of the fusainised elytron. (This lattice-like ornament should not be confused with the clathrate appearance of cupedid elytra found in the Wealden: in the latter it is on the upper surface of the elytron). Clearly the Wealden elytron had been preserved in two distinct layers. Examination under S.E.M. (Fig. 1) showed that the boundary between the two did not follow the same plane. One part of the 'impression' on the right of the figure shows a slightly elevated area showing details (punctures) associated with the upper part of the elytron. The fact that these punctures and clathrate ornament were not superimposed suggests that some local permineralisation of the elytron had taken place and that we are not seeing a simple negative impression of the underside of the elytron. For this reason, I have used 'impression' in inverted commas. Permineralisation would also fill in ducts and would explain their apparent absence in section IV. The comparative rigidity of the upper, fusainised cuticle could have facilitated permineralisation of the normal, lower cuticle during diagenesis.

The preparations of comparative Recent fusain in section IV used dead insects which were completely fusainised. When the experiment was repeated with a freshly caught insect (common wasp) it was noted that the insect boiled in its own body fluids before becoming fusainised. It is therefore possible that a Wealden beetle overtaken by a rapidly moving wildfire could have been boiled and slightly charred externally rather than completely fusainised.

All the parts of the Recent beetle fusainised in section IV were fused together. In the Wealden, however, I have only observed fusain in dissociated beetle remains. Either the beetles were already dead and dissociated, or charred beetles became dissociated subsequently during transport to the site of deposition. The first possibility seems less likely, because the detached Recent elytron fusainised in section IV was observed to twist during the experiment and I have not observed similar distortion on fossil specimens.

To try to obtain some modern field evidence on fusainisation of insects I visited Scrubs Wood in West London shortly after a fire had swept through a 300 sq. m. south-facing grassland in August, 1984. The wind blew away a lot of the white ash and the soil surface was covered with numerous fusainised plant remains. Amongst them were many calcined land snail shells, but there was no evidence of insects which are abundant in adjacent unburnt grassland. A sample of the fusainised debris was collected and examined under a light microscope but this also yielded no insect remains. This is consistent with studies of a heath fire in Dorset which yielded abundant fusainised bracken but only one insect, the forebody of a beetle (Dr M. E. COLLINSON, personal communication). Fusainised beetle remains are also rare in the Wealden (less than 0.1% of all fossil insect remains).

A possible reason for the low frequency of fusainised insects in nature may be the mobility of living insects. Observations on savannah fires in Uganda have shown that many insects are flushed out in front of the flames, or are lifted by the strong up-draught and deposited behind the fire, often unharmed, although prone to predation (Dr P. E. S. WHALLEY, personal communication). For an insect to become fusainised it would have to be trapped in the oxygen-poor part of the fire and this may account for the comparative scarcity of fusainised insects.

VI. SYSTEMATIC PART

ORDER COLEOPTERA L., 1758

Genus ***Coleopteron*** HANDLIRSCH, 1906

R e m a r k s. I am here using the genus as a collective group (rather than a form genus or parataxon) in compliance with ICZN (1999).

Coleopteron semicrematus, sp. nov.

Figs 1, 2, 3, 4.

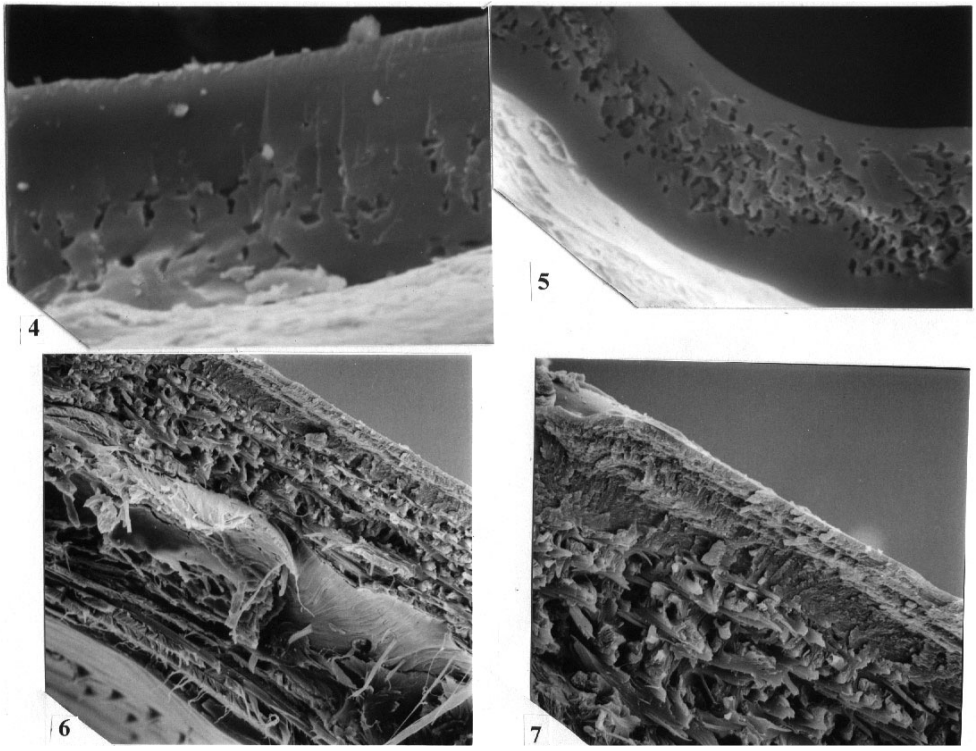
D i a g n o s i s. Differs from *Coleopteron* sp. JARZEMBOWSKI 1995 by a smaller, squatter elytron and unpunctured striae.

T y p e m a t e r i a l. Holotype: specimen No. MNEMG 2002.5 [CH 873v], Maidstone Museum & Bentlif Art Gallery, JARZEMBOWSKI collection, Lower Weald Clay beneath Clockhouse Sand (British Geological Survey sandstone bed 3), Clockhouse Brickworks, near Capel, Surrey (lat. 51° 8'N, long. 0° 19.5' W); late Hauterivian (RASNITSYN, JARZEMBOWSKI & ROSS 1998).

E t y m o l o g y. Latin for half-burned.

D e s c r i p t i o n. The material is described as exposed in a normal bedding plane fracture. No further mechanical preparation has been undertaken to avoid loss of the brittle upper (external) cuticle although it has been prepared for S.E.M. in the usual way.

The species is based on a single small, part-fusainised, part-permineralised elytron, width 1.0 mm, maximum preserved length 1.7 mm. Estimated actual length less than 2 mm. Elytron short and



Figs 4-7. Fig. 4. S.E.M. photograph of broken edge of fossil beetle elytron, Weald Clay, Clockhouse Brickworks ([CH 873v]; × 4,400). Fig. 5. S.E.M. photograph of broken edge of fusainised Recent beetle elytron (T.S., × 3,200). Fig. 6. S.E.M. photograph of broken edge of normal Recent beetle (elaterid) elytron (T.S., x 1,300). Fig. 7. S.E.M. photograph of upper cuticle of specimen in Fig. 6 (× 3,000).

broad, about half as broad as long, convex in profile (Fig. 2d) with outer (costal) edge curved. Outer and sutural edges apparently faintly rimmed. Thickness of upper cuticle 26 microns. External (dorsal) ornament of six faint, grooved, linear striae in the anterior disc (Fig. 7b); total number of striae probably at least nine. Interstriae (interstices) with fine punctures (Figs 1, 2a, 3a). Internal detail with pillars (resembling coarse punctures: Fig. 2e). Inner (ventral) ornament clathrate (Fig. 2c).

D i s c u s s i o n. A natural classification of the fossil elytra of higher Coleoptera is not yet available although they correspond to the forewings of other pterygotes upon which many species are based. Not surprisingly, no coleopteran taxa based on body fossils have yet been described from the English Wealden. I have therefore formally described this species as names are needed at the start of a new fauna.

VII. CONCLUSION

Coleoptera were the first animals from the Wealden to have provided evidence of natural burnings. Some of their remains have shown characteristics consistent with the presence of fusain and which could not be attributed to diagenesis. These unusual fossils are the first Wealden insects to show three-dimensional ultrastructure. Study of one such elytron, however, showed that only the outer part was fusainised suggesting a short-lived fire.

Investigation of fusainised insects and plants could help reveal fire-prone communities. Their habitats would have been liable to erosion with sedimentary as well as palaeoentomological consequences. Insects are beginning to provide evidence of Wealden seasonality (wet/dry: JARZEMBOWSKI 1995; JARZEMBOWSKI in press). Fusainised plants point to bush fires on the Weald floodplain, produced by lightning at the end of the dry season, prior to the onset of the rainy season (BATTEN 1998). This paper therefore suggests that a third, transitional insect assemblage may be recognised, marking a change in the weather.

Wealden charcoal is considered to have been washed in by swollen rivers (loc. cit.), but small charcoal is light and would have been airborne, an alternative mode of transport. Specks in the white micrites of the Lulworth Formation suggest that the investigation could be usefully extended to the subjacent Purbeck Group which has rich Berriasian insect beds.

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