# Dentine in conodonts

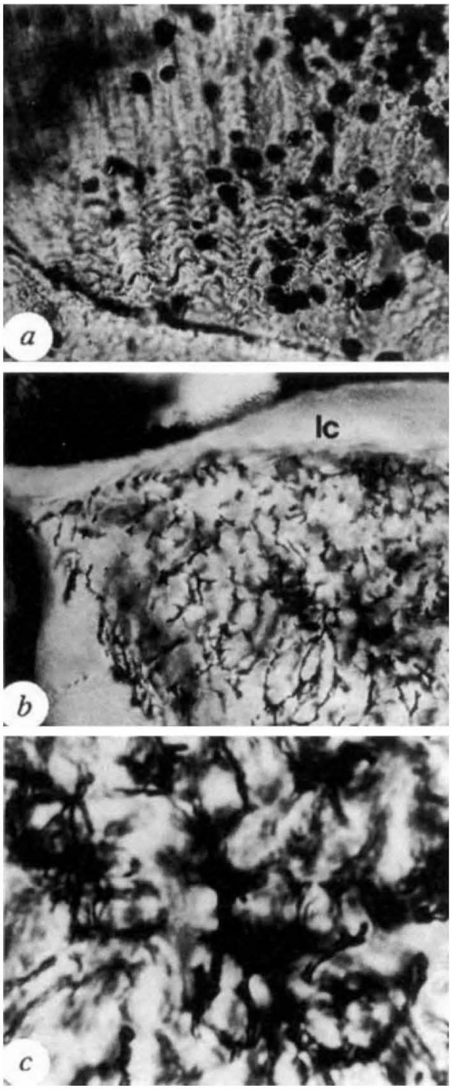
SIR — Recent work on conodont palaeobiology[1,2] has provided a substantial amount of data supporting their classification as vertebrates. Some have accepted this hypothesis[3], whereas others have not[4], because of the apparent absence of dentine in conodont elements, a tissue which has been assumed to be universal in vertebrates. Although histological studies have identified vertebrate hard tissues in conodont elements[2,5], none has yet conclusively identified dentine in the apatitic feeding structure. We now show evidence for the presence of dentine in conodonts, conclusively demonstrating that this group can be classified as vertebrate.

As part of a detailed investigation into the histology of hard tissues in the earliest vertebrates, we examined elements of various conodont taxa from the Late Ordovician (Caradoc) Harding Sandstone Formation of Colorado, a unit also containing at least three accepted early vertebrate genera with which direct histological comparison is possible.

The conodont *Chirognathus* Branson and Mehl has been reconstructed with a seximembrate oral apparatus, and the genus has a typical prioniodinid apparatus[6]. Histologically, the discrete elements are divisible into a crown overlying and enclosing a basal body. Although in many conodonts the element crown is differentiated into lamellar tissue (enamel homologue) surrounding denticle cores of white matter (cellular bone)[2], *Chirognathus* is representative of hyaline conodonts wherein the crown is formed entirely from the lamellar tissue. However, it is the nature of the underlying basal body upon which we focus here.

We examined double-polished thin sections (approximately 50 μm thick), cut through the basal bodies of *Chirognathus* using polarized and Nomarski differential interference contrast optics together with complimentary electron microscope techniques. The basal tissue in *Chirognathus* is characterized by a series of finely spaced growth lines which are generally scalloped and surround occasional, discrete calcospherites (*a* in the figure). The growth lines are disrupted by tubules (approximately 1 μm in diameter) which run perpendicular to the growth surface and are pervasive throughout the bulk of the tissue, a pattern characteristic of vertebrate dentines[7]. The scale of these features in the basal body of *Chirognathus* falls within the range of size seen in the dentines described from the well documented heterostracomorphs of the Harding Sandstone and its stratigraphic equivalent elsewhere in North America[7–11].

*Neocoleodus* Branson and Mehl, also from the Harding Sandstone, has been included within the Family Coleodontidae, although the lack of a clearly recognizable multi-element apparatus makes the ordinal classification problematic[6]. Elements referable to this genus are formed from typical conodont lamellar crown tissue which is underlain by a basal body (*b* in the figure). The basal body is unlike that identified in *Chirognathus* or those conodonts which we have previously examined histologically[2]. It lacks scalloped growth lines and a calcospheritic pattern, and is instead typified by branching tubules (approximately 1 μm in calibre) infilled by iron oxide during diagenesis (*b*, *c* in the figure). They have a varying alignment approximately perpendicular to the junction with the surrounding crown tissue. This tissue closely resembles the mesodentine found directly under the cap of odontodes referable to 'vertebrate indeterminate A' of Denison[12], both in dimension and appearance of the tubule network. It thus represents an additional tissue found in the basal body of conodont elements.




*a*, Thin section through an element of *C. duodactylus* Branson and Mehl, from the Harding Sandstone Formation (specimen BU 2251, Lapworth Museum, University of Birmingham, UK), showing the presence of scalloped growth lines with perpendicular traces of tubules. Field width, 50 μm. *b*, Nomarski interference micrograph of a transverse section through an element of *Neocoleodus* Branson and Mehl, from the Harding Sandstone (BU 2257), branching tubules, filled with iron oxide, in the basal body of the specimen appear to have a general alignment perpendicular to the lamellar crown (*c*). Field width, 175 μm. *c*, Nomarski interference micrograph of the basal body core in the specimen illustrated in *b*. The larger rounded structures may represent cell lacunae, and are approximately 5 μm across. Field width, 75 μm.

The identification of diverse dentine types in conodont elements from the Harding Sandstone offers additional and conclusive evidence for the vertebrate nature of conodonts. The presence of two forms of dentine forming basal bodies in the taxa described here contrasts with the putative globular calcified cartilage which has been identified in the same position in elements of *Cordylodus* Pander[2]. It seems that both conodonts and agnathans[7,9] experimented with many tissue types and tissue associations in the early history of vertebrate biomineralization.

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