

Composition and significance of the Katian (Upper Ordovician) conodont fauna of the Vaux Limestone ('Calcaire des Vaux') in Normandy, France

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Abstract. Study of new conodont collections from the Vaux Limestone exposed at its classical locality at Saint-Hilaire-la-Gérard in the Sées syncline, the conodont fauna of which was previously described in a preliminary way by Weyant et al. (1977, Un épisode calcaire ashgillien dans l'est du Massif armoricain; incidence sur l'âge des dépôts glacio-marins fini-ordoviciens. *Comptes Rendus de l'Académie des Sciences*, Paris, 284, Série D, 1147–1149), has provided significant new information about Late Ordovician conodonts from Normandy. A more precise age of this formation has been established based on an unexpectedly abundant conodont fauna of low diversity. Representatives of *Amorphognathus*, *Hamarodus*, *Sagittodontina*, *Scabbardella* and *Eocarniodus* are present and the fauna is referable to the middle Katian–lower Hirnantian *A. ordovicicus* Zone. Our study, the first illustrating Ordovician conodonts from Normandy, shows that the fauna is closely similar to middle Katian faunas from other parts of continental Europe and represents the *Sagittodontina robusta*–*Scabbardella altipes* biofacies of the Mediterranean Province.

Key words: conodonts, Late Ordovician, biostratigraphy, Normandy, France.

INTRODUCTION

The Late Ordovician limestone unit exposed locally in continental Europe has long been known as being the only significant calcareous deposit in Ordovician successions otherwise dominated by siliciclastic sediments. Its thickness varies from a few centimetres (e.g. in Germany: Ferretti & Barnes 1997) to some dozens of metres or more (e.g. in Spain: Del Moral & Sarmiento 2008). Shelly fossils such as trilobites and brachiopods, echinoderms and bryozoans are generally abundant. Conodonts have been reported as well from several localities (e.g. Knüpfner 1967; Serpagli 1967, both using form taxonomy). Sweet & Bergström (1984) made the first attempt of a global assessment of the conodont fauna from continental Europe identifying a specific Mediterranean Province, distinct from the approximately coeval British and Baltoscandic provinces, and documented there two different biofacies: the dominant *Sagittodontina robusta*–*Scabbardella altipes* biofacies (Spain, northwestern France and Thuringia) and the *Hamarodus brevirameus*–*Dapsilodus mutatus*–*Scabbardella altipes* (HDS) biofacies (Carnic Alps). Sardinia was later assigned to the same HDS biofacies

(Ferretti & Serpagli 1999), suggesting that this area and the Carnic Alps in Katian time occupied a lower latitude as the same biofacies had been reported in the British and Baltoscandic provinces (Sweet & Bergström 1984). More recently, several papers have been published establishing the age of these European faunas in terms of the new global classification of the Ordovician System (e.g. Bergström et al. 2009). For a review of these studies, see Ferretti et al. (2014a).

The purpose of this paper is to briefly describe, discuss and establish the age of a new conodont fauna that has recently been recovered from the Vaux Limestone ('Calcaire des Vaux') in southern Normandy, northern France.

GEOLOGICAL SETTING

Although Ordovician and Silurian rocks are well represented in France, they are predominantly developed in clastic facies with only rare limestone occurrences. Different palaeogeographic regions have been documented. Particularly significant is the Armorican Massif in northwestern France (Fig. 1A), as the Palaeozoic series

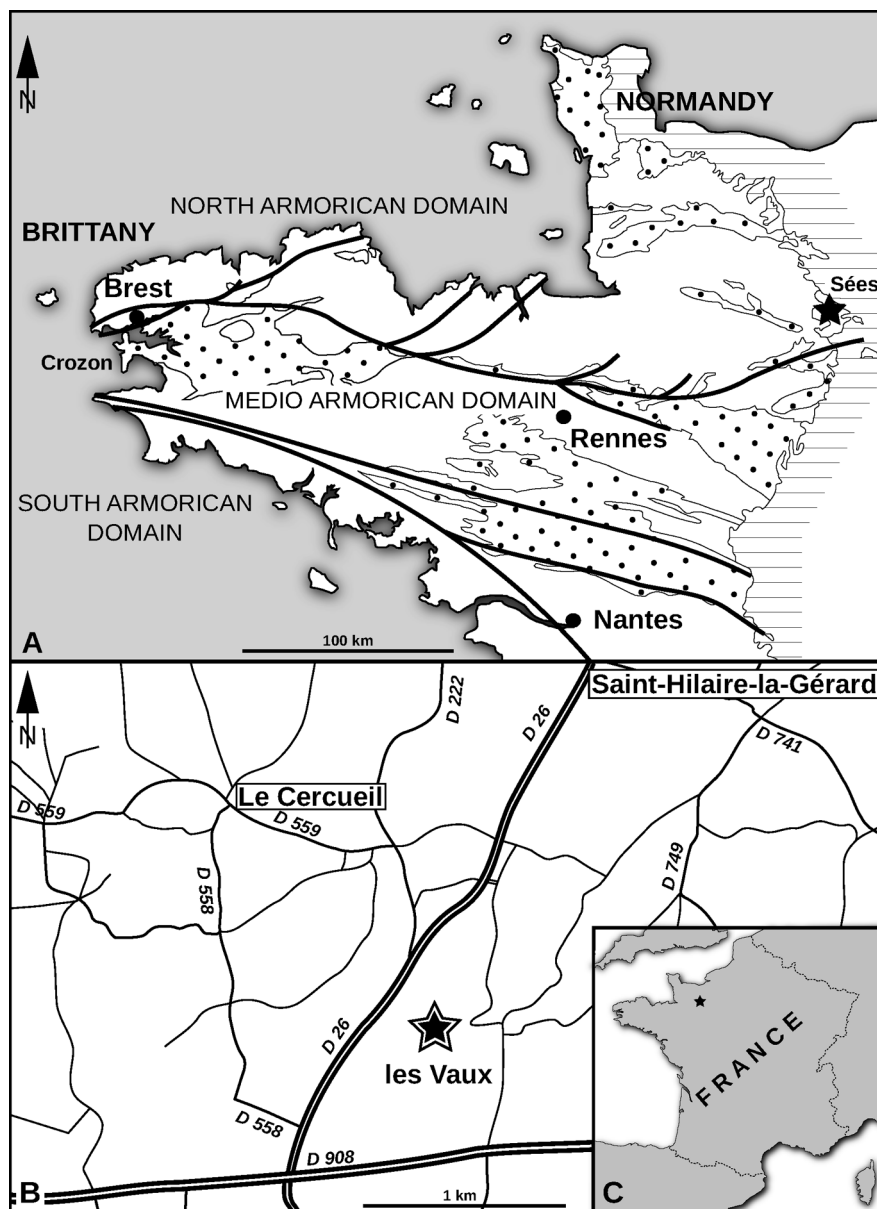


Fig. 1. **A**, geological sketch of the Armorican Massif (redrawn after Vidal et al. 2011). Stippling indicates Palaeozoic units, horizontal lines represent Mesozoic units, white refers to Proterozoic and Cadomian units and to igneous Variscan units. The black star indicates the investigated outcrop in the Sées syncline. **B**, **C**, sketch-map showing the location of the studied section about 2 km SW of Saint-Hilaire-la-Gérard (**B**) and generalized map (**C**) of the Vaux Limestone locality in Normandy (northern France).

exposed there played a crucial role in the sedimentary and faunal evolution of the Gondwana margin (Vidal et al. 2011).

As regards the Upper Ordovician exposed in southern Normandy, based on conodonts and other fossils, the Vaux Limestone as well as limestone olistoliths in the overlying ‘Tillite de Feugueroles’ (‘Pélites à fragments’) were dated as Ashgillian (Weyant et al. 1977), an age later confirmed by chitinozoans (Babin

et al. 1988). Conodonts were reported in form taxonomy, but no description or illustration of the elements was provided. The ‘Calcaire de Rosan’ (Rosan Formation) in Brittany, which traditionally has been regarded as coeval with the Vaux Limestone (Fig. 2), has also yielded a conodont fauna described by Lindström & Pelhate (1971) and Paris et al. (1981). A latest Ordovician Hirnantian brachiopod fauna from Camaret (Crozon Peninsula) has also been reported by Mélou (1987).

SYSTEM	STAGE	STRATIGRAPHIC UNIT	
		BRITTANY (Crozon Peninsula)	NORMANDY (Caen-Alençon)
SIL.		La Tavelle Fm.	'Schistes à fucoides'
ORDOVICIAN	HIRN.	Le Cosquer Fm.	'Pêlites à fragments' ?
	KATIAN	Rosan Fm.	Vaux Lm. ?
		Kermeur Fm.	Pont de Caen Fm. ?
			May Fm.
	SAND.	Postolonnec Fm.	
	DARR.		

Fig. 2. Summary stratigraphic diagram showing inferred relations between Upper Ordovician units exposed in Brittany (Crozon Peninsula) and Normandy (Caen-Alençon) (mostly after Paris & Le Hérisse 1992; Avoine et al. 2011; Vidal et al. 2011).

The limited natural outcrop, located 2 km SW of Saint-Hilaire-la-Gérard in the Sées syncline (Fig. 1B) and described earlier by Weyant et al. (1977), was restudied and sampled for conodonts during fieldwork in 2006 and 2007. A calcareous succession is exposed there in a discarded quarry that is now part of the Normandie-Maine Regional Natural Park. It represents a single 1-m-thick bed that has been faulted and repeated several times in the diverse spots of the little outcrop, with erosion surfaces present both below and above the Vaux

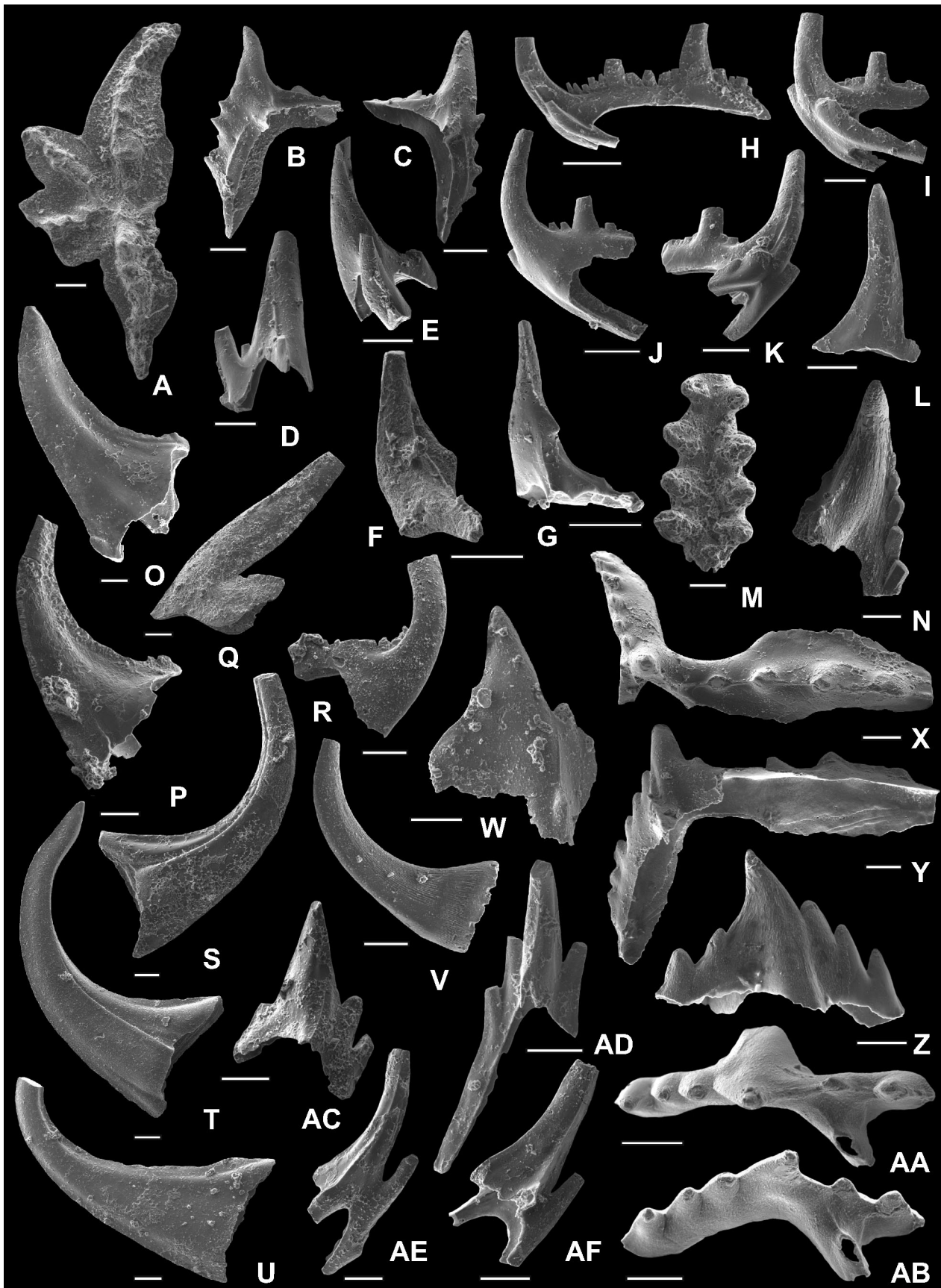
Limestone, indicating gaps in the succession (Avoine et al. 2011). The unit consists of hard massive micritic limestone without any distinct macrofossils exposed. The dominant microfacies in the conodont-productive intervals consists of a bryozoan–echinoderm packstone with subordinate trilobites, gastropods and brachiopods. A distinctive iron ooid horizon was also located in a single exposure. This ferruginous level represents a widespread and recurrent time-specific facies known from the Upper Ordovician as well as from other specific intervals in the Palaeozoic (Brett et al. 2012).

A total of 13 levels were sampled and more than 90 kg of limestone was processed in formic acid using standard methods of conodont extraction. All samples were productive and yielded abundant conodonts. Lithological samples, residues and conodont elements are housed in the 'Inventario Paleontologia Università di Modena e Reggio Emilia-IPUM' at the Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Modena e Reggio Emilia, Modena, Italy.

CONODONT FAUNA

All samples produced conodonts. Brachiopods, bryozoans, ostracodes, gastropods and silicified echinoderm fragments were found as well. An unexpectedly abundant collection of conodonts of several thousand elements representing 12 multielement taxa was recovered. Preservation of specimens is highly variable, ranging from well-preserved specimens to more or less encrusted elements. The conodont specimens exhibit a CAI (Colour Alteration Index; cf. Epstein et al. 1977) of 4–5, indicating a heating of 300–400 °C. No significant change in the composition of the conodont fauna through the study material was observed. The following taxa were identified:

Fig. 3. Selected conodonts from the Late Ordovician of Normandy, France. A–C, H–K, *Amorphognathus* sp.: A, Pa element, upper view of IPUM 28749, Level C; B, C, Pb elements, lateral views of IPUM 28750 and IPUM 28751, Level C and Level 1 respectively; H, Sa element, lateral view of IPUM 28755, Level C; I, Sb element, lateral view of IPUM 28756, Level 1; J, Sc element, lateral view of IPUM 28757, Level C; K, Sd element, lateral view of IPUM 28758, Level 4. D, E, *Amorphognathus ordovicicus* Branson & Mehl, 1933: M element, posterior (D) and outer-lateral (E) views of IPUM 28752, Level 4. F, G, *Amorphognathus dufionus* Rhodes, 1955: F, M element, postero-lateral view of IPUM 28753, Level 6 top; G, M element, outer-lateral view of IPUM 28754, Level 4. L, *Istorinus erectus* Knüpfner, 1967: IPUM 28759, Level 1. M, N, *Icriodella* cf. *superba* Rhodes, 1953: M, Pa element, upper view of IPUM 28760, Level C; N, S element, lateral view of IPUM 28761, Level B. O–R, *Hamarodus brevirameus* (Walliser, 1964): O, Pa element, lateral view of IPUM 28762, Level B; P, Pb element, lateral view of IPUM 28763, Level B; Q, M element, lateral view of IPUM 28764, Level C; R, Sc element, lateral view of IPUM 28765, Level 1. S–U, *Scabbardella altipes* (Henningmoen, 1948): S, lateral view of IPUM 28766, Level 2; T, lateral view of IPUM 28767, Level 2; U, lateral view of IPUM 28768, Level 1. V, *Panderodus gracilis* (Branson & Mehl, 1933), lateral view of IPUM 28769, Level B. W, Z–AF, *Sagittodontina robusta* Knüpfner, 1967: W, P element, lateral view of IPUM 28770, Level B; Z–AB, P element, lateral, upper and upper-lateral views of IPUM 28772, Level C; AC, M element, posterior view of IPUM 28773, Level 1; AD, Sa element, posterior view of IPUM 28774, Level 1; AE, Sb element, lateral view of IPUM 28775, Level 1; AF, Sd element, postero-lateral view of IPUM 28776, Level 6 top. X, Y, ?*Baltoniodus* sp., Pb element, upper and lateral views of IPUM 28771, Level 1. Scale bar represents 100 µm for all photos.



Amorphognathus duftonus Rhodes, 1955
Amorphognathus ordovicicus Branson & Mehl, 1933
 ?*Baltoniodus* sp.
Dapsilodus mutatus (Branson & Mehl, 1933)
Eocarniodus gracilis (Rhodes, 1955)
Hamarodus brevirameus (Walliser, 1964)
Icriodella cf. *superba* Rhodes, 1953
Istorinus erectus Knüpfner, 1967
Panderodus gracilis (Branson & Mehl, 1933)
Sagittodontina robusta Knüpfner, 1967
Scabbardella altipes (Henningsmoen, 1948)
 ?*Walliserodus* sp.

Amorphognathus and *Scabbardella* are dominating the fauna but *Hamarodus* and *Sagittodontina* are also common, with the former being abundant in some intervals. Remarkably, the Vaux fauna contains *Hamarodus brevirameus*, which appears to be absent in the Rosan fauna from Brittany (Lindström & Pelhate 1971; Paris et al. 1981). Simple-cone taxa (*Dapsilodus*, *Panderodus*) are less frequent. The presence of *A. ordovicicus*, *A. duftonus* and *Sagittodontina robusta* indicates that the fauna represents the *A. ordovicicus* Zone and is possibly of middle Katian age (Stage Slices 3–4 of Bergström et al. 2009). Similar co-occurrences of *A. ordovicicus* and *A. duftonus* are also documented in continental Europe from the Carnic Alps (e.g. Serpagli 1967; Bagnoli et al. 1988; Ferretti & Schönlaub 2001), Sardinia (Ferretti & Serpagli 1991, 1999), Poland (Dzik 1999), Spain (Ferretti 1992; Del Moral & Sarmiento 2008) and possibly Bohemia (Ferretti 1998). The Vaux conodont fauna strikingly differs in diversity and composition from coeval middle–upper Katian faunas from the United Kingdom, such as the Sholeshook Limestone from South Wales (Ferretti et al. 2013, 2014a) and the Keisley Limestone of northern England (Rhodes 1955; Bergström & Ferretti, in press) and the Portrane Limestone of Ireland (Ferretti et al. 2014b).

The composition of the conodont fauna indicates that it represents the *Sagittodontina robusta*–*Scabbardella altipes* biofacies of Sweet & Bergström (1984), which is characteristic of this limestone interval in the Upper Ordovician of continental Europe.

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