The first record of the Kimmeridgian (Late Jurassic) ammonite *Aulacostephanus yo* (d'Orbigny) *in situ* in the UK and its stratigraphical significance

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The Kimmeridgian ammonite *Aulacostephanus yo* (d'Orbigny) has been recorded from the *Aulacostephanus eudoxus* Zone and its correlatives over a geographically large area ranging from the French Channel coast to southern France, and eastwards into Germany and Russia, but has not previously been recorded *in situ* in the UK. It forms one of the few Kimmeridgian ammonite marker beds that is present in both the Subboreal and Submediterranean faunal provinces and provides an important link between the different provincial ammonite zonal schemes. Its discovery at a stratigraphically well-defined level in the Kimmeridge Clay at Kimmeridge, Dorset in a succession that is more complete than any other late Kimmeridgian succession in NW Europe, has clarified the relationship between the Boreal-derived (cooler water) and Tethyan-derived (warmer water) ammonite marker beds in the late Kimmeridgian.

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Introduction

The Kimmeridgian Stage in NW Europe is represented by laterally variable successions of mudstones and limestones that were deposited in wholly marine environments that ranged from near-shore to outer shelf (Énay, 1980). Differentiation of the faunas in the Late Jurassic Boreal and Tethyan Faunal Realms resulted in Kimmeridgian times in a cooler-water Subboreal Province which included southern England and northern France, and a warmer-water Submediterranean Province which included central and southern France, SW Germany and Switzerland (Figure 1). This has given rise to different regional zonal and subzonal schemes, all of which are based on ammonites. The boundary between the two provinces was an extensive transitional area, named the Middle Europe Shelf by Énay (1980). It extended eastwards from the French Atlantic coast into southern Germany, Switzerland and east of the Anglo Brabant Massif as far as Poland. The western part was named the Western European Swell by Hantzpergue (1987, 1989). Notwithstanding the faunal differentiation at that time, marine pathways were present from time to time that allowed ammonites to migrate between the two provinces via the shallower water area of the Swell (Énay, 1980). These included northern and southern species of *Aulacostephanus* and warm-water species of *Aspidoceras* and its microconch *Sutneria, Crussoliceras* and *Gravesia* that have well defined stratigraphical ranges in the Kimmeridge Clay Formation (Callomon and Cope, 1971; Gallois and Cox, 1976; Énay *et al.*, 2014). They enable broad correlations to be made at some stratigraphical levels between the regional zonal schemes.

More detailed correlations between the provinces are largely dependent on the recognition of short-lived influxes of particular ammonite species that were probably influenced by changes in water temperature and/or the opening of previously unavailable migration pathways. Such occurrences have been referred to as *fossiliferous episodes* (Mattéi, 1974), *flood occurrences* or *eco-events* (Wood *et al.*, 1984) and *horizons* (Hantzpergue, 1989). The last-named recognised 28 ammonite horizons in the correlative successions of the Kimmeridge Clay in central and southern France. The index forms include ammonites that originated either in the warmer-water Submediterranean Province or in the cooler-water Subboreal Province and adapted to the conditions of the swell, with the result that not all have been recorded in areas distant from the swell. A few of the named horizons have been recognised in the Kimmeridge Clay and in the equivalent successions on the Normandy and Boulonnais coasts. For example, Hantzpergue (1989) identified the Orthocera Horizon (*Orthaspidoceras orthocera* (d'Orbigny)) at the base of the Eudoxus Zone in the Kimmeridge Clay at Westbury, Wiltshire (Bed M 21 of Birkelund *et al.*,1983; KC 24 of Gallois, in press), and Samson *et al.* (1996) recognised the same horizon at the base of the Argiles d'Ecqueville on the Normandy coast. One of the more widely distributed horizons, that of *Aulacostephanus yo*, has been recognised at all the localities shown in Figure 1 except Kimmeridge. The most northerly recorded occurrences in NW Europe are those on the Boulonnais coast where d'Orbigny (1850), Rigaux (1894) and Dr Alain Vadet (Vadet Collection No. 1345) recorded examples. The last of these was found *in situ* in the upper part of the Calcaires du Moulin Wibert Formation. The others probably came from the same formation (Alain Vadet pers. comm.).

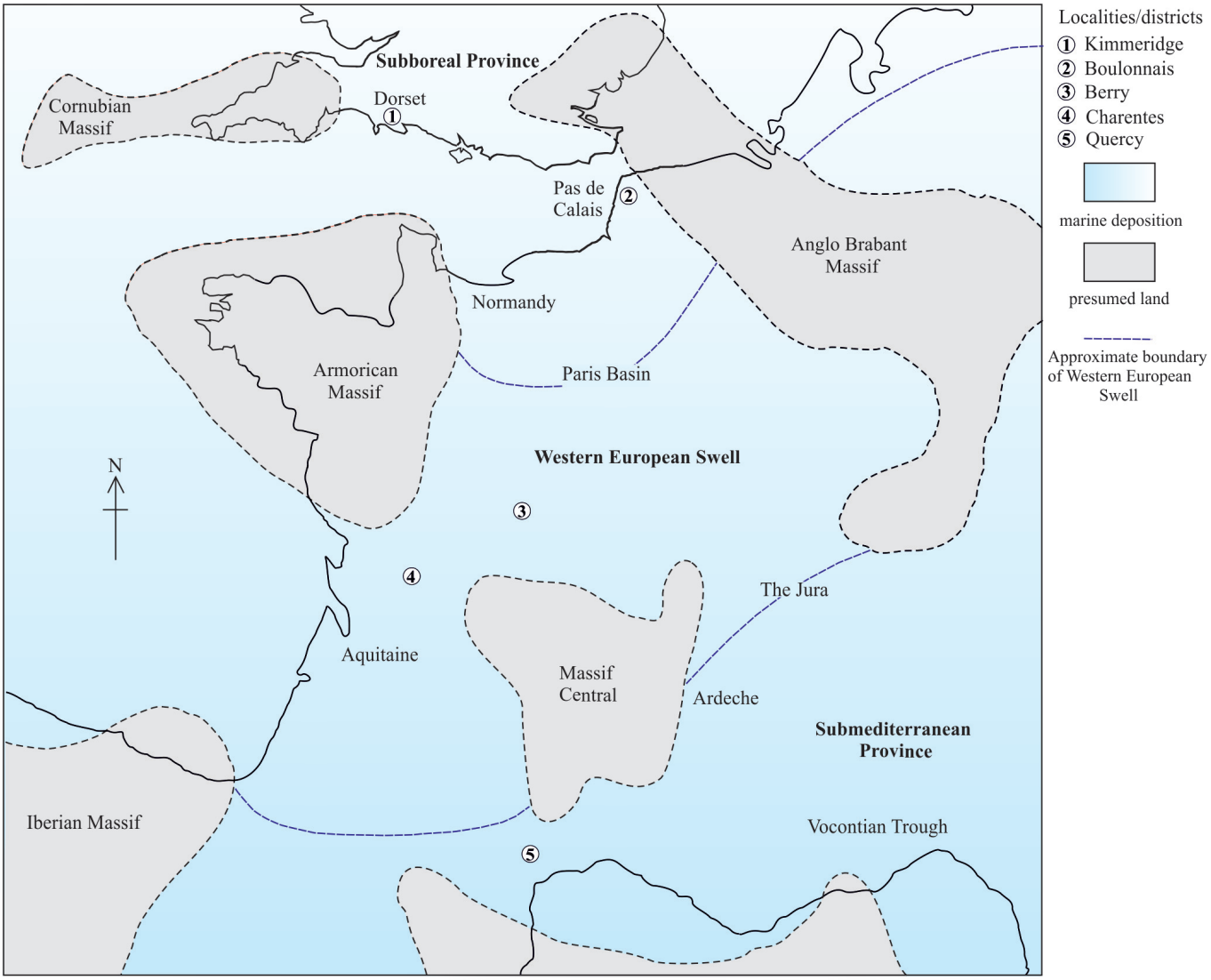

Figure 1. *Palaeogeography of western Europe during the Kimmeridgian Stage showing the positions of localities referred to in the text (after Enay* et al.*, 2014).*

Kimmeridge Clay occurrences

The new specimen (Figure 2a) was found in the lower part of the intertidal area [SY 8954 7906] in Hobarrow Bay 2.3 km WSW of Kimmeridge village at a level that is commonly covered by beach deposits (Figure 2f). It was found *in situ* in an organic-rich mudstone (HB3) in Kimmeridge Clay Chronosubzone KC 32 in the upper part of the Eudoxus Zone (Figure 3), a few centimetres below coccolith-rich marker Bed EU 3 of Gallois and Medd (1979) (Figure 2g). This is close below two other marker beds, the Hoplocardioceras Bed of Van der Vyver (1986) and the Nannocardioceras Cementstone of Cox and Gallois (1981). Following the discovery of the Hobarrow Bay specimen, a second possible *A.* aff. *yo* (Figure 2c) was identified in the Etches Collection (K153) in one of the Weymouth Nodules (see below) collected loose from Ringstead Bay 15 km W of Kimmeridge.

In addition, the British Geological Survey (BGS) Collection includes a specimen (No. 69818: Figure 2b) identified by the late L. F. Spath as *Aulacostephanus* aff. *yo* from "*Osmington and White nose*", Dorset. It is one of several hundred specimens donated to BGS in 1870 by a local collector, J. Gardner of Weymouth. Other specimens from the same collection and locality include the ammonites *Aspidoceras* cf. *longispinum* (Sowerby), *Amoeboceras* (*Amoebites*) sp., *Aulacostephanus* cf. *eudoxus* (d'Orbigny) and *A.* aff. *pseudomutabilis* (de Loriol). They are collectively indicative of the Eudoxus Zone and could, in theory, have come from the deeply weathered Kimmeridge Clay outcrops between Black Head [SY 756 820] and Osmington Mills [SY 734 818] or from the landslide debris in that area. The specimen is preserved in a mudstone in such a good state of preservation that it almost certainly came from an *in situ* cliff or from a fallen block adjacent to such a cliff. The only exposures in Weymouth Bay that fit this description at this stratigraphical level are low cliffs [SY 763 814] in Ringstead Bay, 500 m W of White Nothe, where the upper part of the Eudoxus Zone has been at times well exposed (Cox and Gallois, 1981). Extensive museum collections from this area also include fossiliferous calcareous concretions found loose on the beaches around Weymouth Bay which Van der Vyver (1986) referred to as the Weymouth Nodules, and in which he recorded Eudoxus and possible Autissiodorensis Zone ammonites. In addition to Hobarrow Bay, the Nannocardioceras Cementstone has also been recorded in the low cliffs at Ringstead Bay which suggests that the BGS specimen may have come from a similar level in the late Eudoxus Zone as the Hobarrow Bay specimen.

All three specimens have features in common with two morphologically similar ammonites, *Aulacostephanus contejeani* (Thurmann) from the middle part of the Eudoxus Zone and *A. yo* (d'Orbigny) from the later part of the zone (Hantzpergue, 1989). None of the specimens is sufficiently

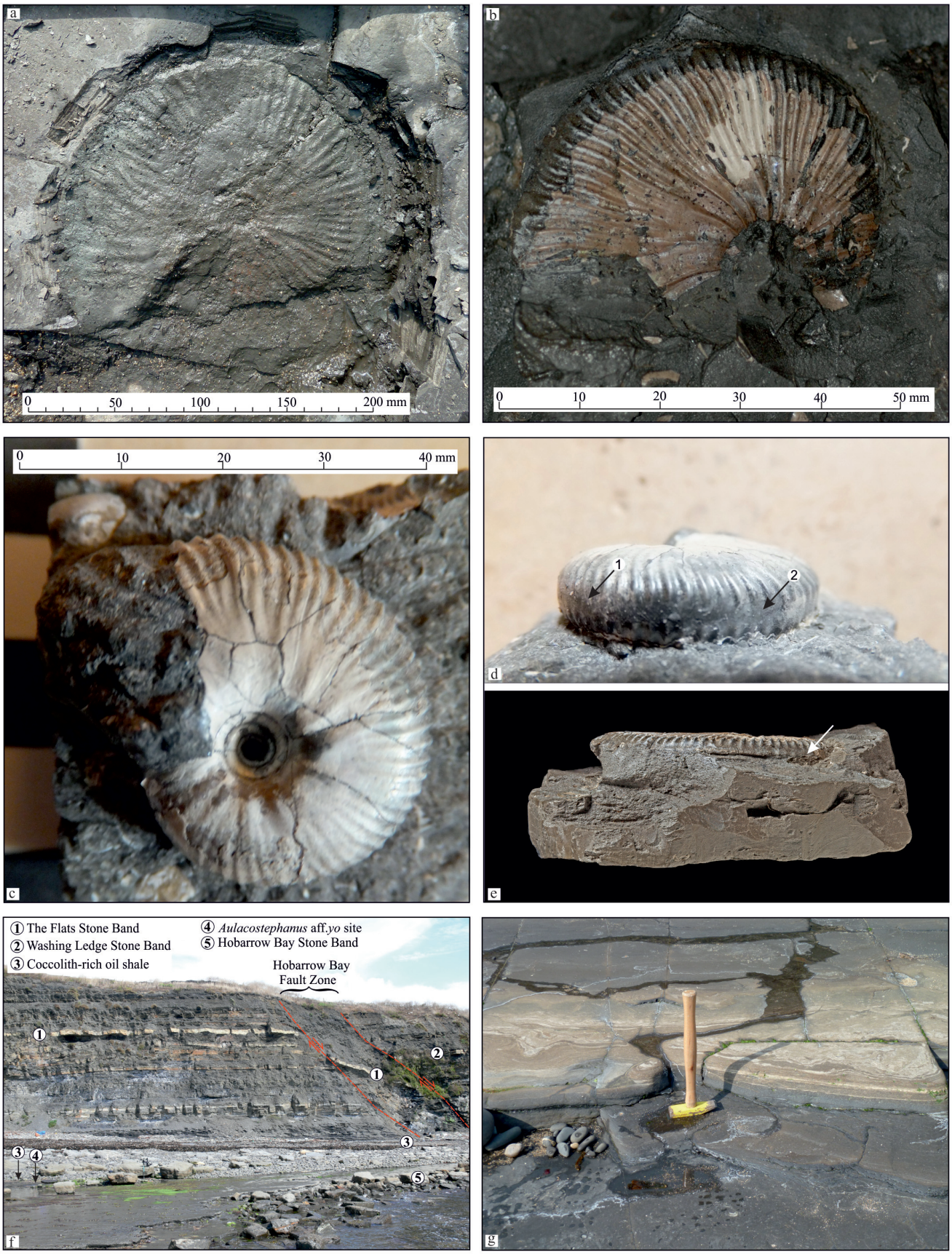

Figure 2. *(**a**)* A. *aff.* yo *found in situ in the upper part of the Eudoxus Zone at Brandy Bay, Kimmeridge.* *(**b**)* Aulacostephanus *identified as* A. *aff.* yo *by the late L. F. Spath, BGS Specimen No.69818 found loose, probably from the Eudoxus Zone at Ringstead Bay. Photographed by Simon Harris, BGS: copyright NERC.* *(**c**)* A. *aff.* yo *found loose in a Weymouth Nodule at Ringstead Bay, Etches Collection K153.* *(**d**) Detail of the venter of K153: photograph shows the primary ribs (arrow 1) crossing the venter unbroken at 25 mm diameter and a smooth ventral band (arrow 2) at 35 mm diameter. Copyright Etches Collection.* *(**e**) Detail of the venter of Specimen No.69818 showing the smooth ventral band (arrowed): copyright NERC.* *(**f**) Hobarrow Bay cliff and foreshore showing the principal marker beds. Hammer head rests on the oil shale with* A. *aff.* yo. *(**g**) Coccolith-rich bed EU3 of Gallois and Medd (1979) at the base of Rhythm HB4; see Figure 3 for stratigraphical succession.*

completely or well preserved to allow it to be allocated to one of these species with certainty. Borrelli (2014) noted that the macroconchs of *A. contejeani* and *A. yo* are distinguished from other species of *Aulacostephanus* by their strong involution, and *A. yo* from *A. contejeani* by the presence of a smooth ventral band throughout the inner whorls. Comparison of the umbilical width/maximum diameter ratios (N of Schlegelmilch, 1992) of the Kimmeridge Clay specimens with those of figured examples of *A. contejeani* and *A. yo* suggests that they cannot be assigned to either *A. yo* or *A. contejeani* on this feature alone. Borrelli (2014) figured the holotype of *A. contejeani*, a partial phragmocone (95 mm diameter) with ribs unbroken across the venter (Planche II, 4; N = *c.* 16%), and larger specimens (Planche II, 6 and 7; 239 mm and 530 mm diameter) for which N = *c.* 11% and *c.* 10% respectively. In addition, Comment *et al.*, (2015, Planche V, 4) figured a moderately large (215 mm diameter) highly involute example of *A. contejeani* for which N = *c.* 6%. Baier and Schweigert (2001, fig. 2) figured two specimens of *A. yo*, a fragment and a large (310 mm diameter), highly involute form in which N = <5%. Other authors have figured examples of *A. yo* in which N = 8% to 10%.

For the Hobarrow Bay specimen N = *c.* 9%, but given that it is crushed it may have been a little lower. It is more involute than the holotype of *A. contejeani*, but falls within the ranges of N of figured specimens of both species. However, there are too few specimens figured at different growth stages to be able to define the ranges of N that would allow each species to be identified with confidence on the basis of this criterion alone. Given the poor state of preservation of the Hobarrow Bay specimen the best interpretation in our current state of knowledge is to describe it as *A.* aff. *yo*.

The degree of involution of the Etches Collection and the BGS specimens, for which N= *c.* 18% and *c.* 16% respectively, is similar to that of the holotype of *A. contejeani*. However, Borelli (2014) noted that the early stages of *A. yo* up to a diameter of 40 mm were not known, and hence there is no published description with which to compare the degree of involution of specimens as small as the Etches Collection and BGS specimens. He also noted that *A. contejeani* is distinguished from *A. yo* by the absence of a smooth ventral band until the intermediate growth stage, as for example in the holotype (Borrelli, 2014, Planche II, 4). Both of the small Kimmeridge Clay specimens have a smooth ventral band (Figures 2d and 2e). Based on this criterion alone, they cannot be *A. contejeani*. As with the Hobarrow Bay specimen, *A.* aff. *yo* is the most suitable identification until such time that the growth stages and population and geographical variations of *A. contejeani* and *A. yo* are better known.

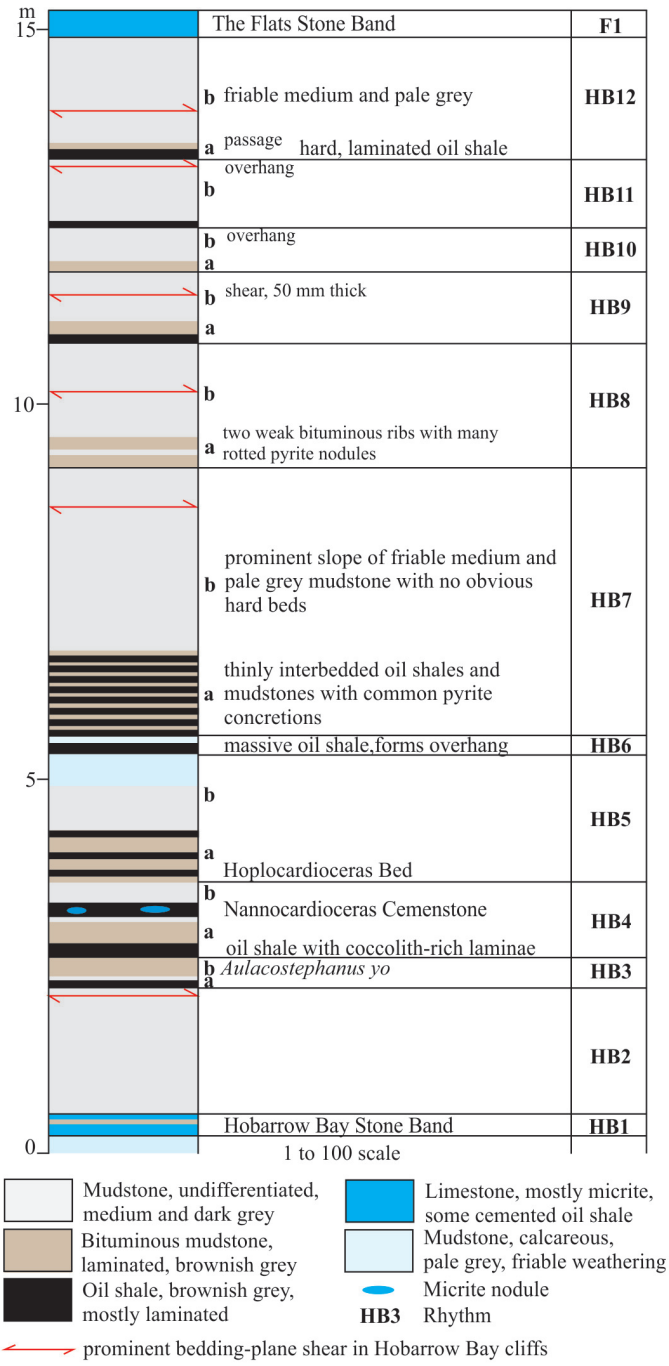

Figure 3. *The Hobarrow Bay Mudstone succession exposed in the cliffs and intertidal area at Hobarrow Bay.*

Summary and conclusions

To paraphrase an old proverb, one *Aulacostephanus yo* does not an internationally significant marker bed make. However, the Hobarrow Bay *A.* aff. *yo* specimen and the ranges of *Aspidoceras, Aulacostephanus, Nannocardioceras* and *Sutneria* in the later part of the Eudoxus Zone and the early part of the Autissiodorensis Zone can be closely correlated with stratigraphical successions in France where the Yo and other horizons are present (Figure 4). The lateral and stratigraphical distribution of ammonites in the late Kimmeridgian in NW Europe shows a consistent pattern of species that have a long stratigraphical range in one region passing into cooler or warmer water areas where they are present over a narrow stratigraphical range. Examples of this in the Kimmeridge Clay are *A. autissiodorensis* (Cotteau) and *Gravesia irius* Salfeld which are present throughout Chronosubzones KC 33 and KC 35 respectively in Dorset, but are restricted to faunal horizons in southern France (Figure 4). In contrast, the Reboltzi (*Sutneria rebholtzi* (Berckhemer) and Volgae (*Nannocardioceras volgae* (Pavlov)) Beds, which also have short stratigraphical ranges in Subboreal successions in England, Poland and Russia (Rogov, 2008), are presumed to be migrants from the Boreal Faunal Realm that did not reach as far south as the Mid European Swell. Similarly, the Tethyan form *Aspidoceras catalaunicum* (de Loriol) of the Catalaunicum Horizon of the Autissiodorensis Zone has not been recorded as far north as the Dorset coast.

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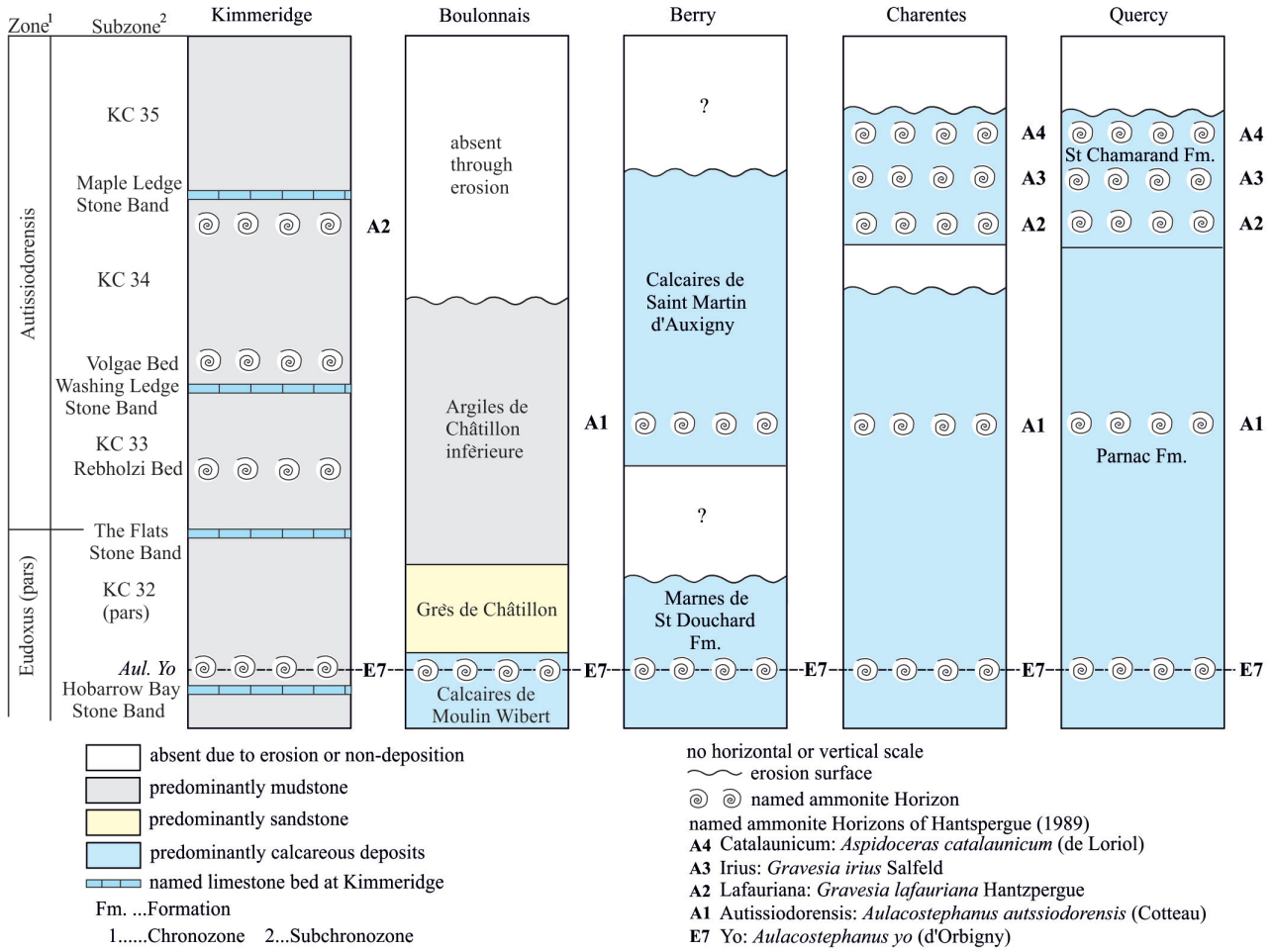

Figure 4. *Correlation of the ammonite marker horizons in selected successions in NW Europe. See Figure 1 for location of sections. Boulonnais after Vadet (pers. comm.); Berry, Charentes and Quercy after Hantzpergue (1989).*

References

BAIER, J. and SCHWEIGERT, G. 2001. Zum Vorkommen von *Aulacostephanus yo* (d'Orbigny) im Schwäbischen Jura (Ober-Kimmeridgium, SW-Deutschland). *Neues Jahrbuch für Geologie und Paläontologie,* **2001**, 184-192.

BIRKELUND, T., CALLOMON, J.H., CLAUSEN, C.K., NØHR HANSEN, H. and SALINAS, I. 1983. The Lower Kimmeridge Clay at Westbury, Wiltshire, England. *Proceedings of the Geologists' Association,* **94**, 289-309.

BORRELLI, L. 2014. Les Aulacostephanidae du Kimméridgien supérieur: systématique, évolution et biochronologie. *Revue de Paléobiologie, Genève,* **33**, 1-37.

CALLOMON, J.H. and COPE, J.C.W. 1971. The stratigraphy and ammonite succession of the Oxford and Kimmeridge Clays in the Warlingham Borehole. *Bulletin of the Geological Survey of Great Britain,* **36**, 147-176.

COMMENT, G., LEFORT, A., KOPPKA, J. and HANTZPERGUE, P. 2015. Le Kimméridgien d'Ajoie (Jura, Suisse): lithostratigraphie et biostratigraphie de la Formation de Reuchenette. *Revue de Paléobiologie, Genève,* **34**, 161-194.

COX, B.M. and GALLOIS, R.W. 1981. The Kimmeridge Clay of the Dorset type area and its correlation with other Kimmeridgian sequences. *Report of the Institute of Geological Sciences,* **80/4**, 1-44.

D'ORBIGNY, A. 1850. *Division des terrains jurassiques en étages. Paléontologie Francaise, Terrain Jurassique. I Cephalopdes,* 600-611. Victor Masson, Paris.

ÉNAY, R. 1980. Indices d'émersions et d'influences continentales dans l'Oxfordien supérieur-Kimméridgien inférieur de la France. Interprétation paléogéographique et conséquences paléobiogéographiques. *Bulletin de la Société géologique de France,* **22**, 581-590.

ÉNAY, R., GALLOIS, R.W. and ETCHES, S.M. 2014. Origin of the Kimmeridgian-Tithonian Boreal perisphinctid faunas: migration and descendants of the Tethyan genera *Crussoliceras* and *Garnierisphinctes*. *Revue de Paléobiologie, Genève,* **33**, 299-377.

GALLOIS, R.W. in press. The stratigraphy of the Kimmeridge Clay Formation (Jurassic) at Westbury, Wiltshire, U.K. *Proceedings of the Geologists' Association.*

GALLOIS, R.W. and COX, B.M. 1976. The stratigraphy of the Lower Kimmeridge Clay of eastern England. *Proceedings of the Yorkshire Geological Society,* **41**, 13-26.

GALLOIS, R.W. and MEDD, A.W. 1979. Coccolith marker bands in the English Kimmeridge Clay. *Geological Magazine,* **116**, 247-260.

HANTZPERGUE, P. 1987. *Les ammonites kimméridgiennes du haut-fond d'Europe occidentale (Perisphinctidae, Aulacostephanidae, Aspidoceratidae).* Unpublished Thèse de Doctorat d'Etat, Université de Poitiers.

HANTZPERGUE, P. 1989. *Les ammonites kimméridgiennes du haut-fond d'Europe occidentale: biochronologie, systématique, évolution, paléobiogéographie.* Cahiers de Paléontologie, CNRS, Paris.

MATTÉI, J. 1974. Analyse des termes fossilifères domériens dans les Causses du Sud du Massif Central français. Essai d'étude biostratigraphique. Colloque du Jurassique, Luxembourg, 1967. *Mémoires du Bureau de Recherches Géologiques et Minières,* **75**, 547-566.

RIGAUX, R. 1894. Notice géologique sur le bas Boulonnais. *Memoires de la Société Académique de l'arrondissement de Boulogne sur mer,* **16**, 1-108.

ROGOV, M. 2008. Comparison of latest Kimmeridgian to early Volgian ammonite faunas of Polish Lowland and Middle Volga area and its significance for palaeogeography. *Geologia,* **34**, 201-203.

SAMSON, Y., LEPAGE, G, HANTZPERGUE, P., GUYADER, J., SAINT-GERMÈS, M., BAUDIN, F. and. BIGNOT G. 1996. Révisions lithostratigraphique et biostratigraphique du Kimméridgien de la région havraise (Normandie). *Géologie de la France,* **3**, 3-19.

SCHLEGELMILCH, R. 1992. *Die Ammoniten des süddeutschen Lias.* Springer, Stuttgart.

VAN DER VYVER, G.P. 1986. *The stratigraphy and ammonite faunas of the Lower Kimmeridgian rocks of Britain*. Unpublished PhD thesis, University of Wales.

WOOD, C.J., ERNST, G. and RASEMANN, G. 1984. The Turonian-Coniacian stage boundary in Lower Saxony (Germany) and adjacent areas: the Salzgitter-Salder Quarry as a proposed international standard section. *Bulletin of the*