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Geomaterials (Sedimentology)

Correlation of the Kimmeridgian succession of the Normandy coast, northern France with that of the Dorset-type area, southern England

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Abstract

The Kimmeridgian Stage is represented in the cliffs of the Dorset-type area and those in Normandy by richly fossiliferous marine mudstones and limestones. Taken together, these coastal exposures provide the only complete composite outcrop through this part of the Jurassic in the Sub-boreal Faunal Province. Detailed correlations between the two successions are presented here: these enable the Normandy-coast sections to be more accurately placed than previously within in their regional chronostratigraphical context. The Normandy succession is more completely exposed than that in Dorset, and is situated midway between Dorset and the Sub-Tethyan succession of the Berry region. It therefore offers a better prospect than any English section for inter-province correlation at this stratigraphical level. ***To cite this article: R. Gallois, C. R. Geoscience 337 (2005).***

Résumé

Corrélation de la succession du Kimméridgien entre la côte de Normandie, Nord de la France, et la région type du Dorset, Sud de la Grande-Bretagne. L'étage du Kimméridgien est représenté par les falaises de la région type du Dorset et de Normandie par des calcaires et des *mudstones* très riches en fossiles. Considérés ensemble, ces affleurements sont les seuls à exposer, de manière complète et composite, cette partie du Jurassique dans la province faunique sub-boréale. Des corrélations détaillées entre les deux successions stratigraphiques sont ici présentées : celles-ci permettent de replacer, plus précisément qu'auparavant, les coupes de la côte normande dans leur contexte chronostratigraphique régional. La succession stratigraphique de Normandie affleure plus largement que celle du Dorset et celle, sub-téthysienne, du Berry. Elle offre ainsi un meilleur prospect que toute autre coupe anglaise, pour une corrélation interrégionale relative à cet étage stratigraphique. ***Pour citer cet article : R. Gallois, C. R. Geoscience 337 (2005).***

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Mots-clés : Normandie ; Dorset ; Kimméridgien ; Stratigraphie ; Corrélation ; France ; Grande-Bretagne

1. Introduction

In England, the Kimmeridgian Stage is represented by the almost wholly argillaceous Lower Kimmeridge Clay Member of the Kimmeridge Clay Formation. The type sections of the formation and the stage are cliff outcrops on the south Dorset coast between the Isle of Portland (National Grid Reference SY 680 730) and Kimmeridge Bay (SY 901 790) (Fig. 1). The highest part of the Lower Kimmeridge Clay (the upper part of the Eudoxus Zone and the Autissiodorensis Zone) and the whole of the Tithonian Upper Kimmeridge Clay (Elegans to Fittoni zones) are exposed in continuous cliff sections at Kimmeridge Bay. The Kimmeridgian sections have steadily deteriorated during the past 150 years due to an increase in the amount of sea-defence works, and many of those recorded in the 19th and early 20th centuries [1,2,33,40] have disappeared. The Oxfordian–Kimmeridgian boundary beds at Black Head (SY 7239 8195) and Ringstead Bay (SY 7486 8137) provide good exposures from time to time in the Baylei Zone and lower part of the Cymodoce Zone, but much of the succession above that is poorly exposed and deeply weathered. In contrast to the Dorset sections, the Kimmeridgian outcrops exposed in the cliffs between Le Havre and Cauville (Fig. 1) are unprotected and are continually renewed by marine erosion.

Comparison of the published descriptions of the Dorset and Normandy successions shows broad lithological and faunal similarities [1,13,34,35], and there is agreement on their correlation at the ammonite zonal level [3,25,26]. There is, however, no published chronostratigraphical comparison of the two successions. In recent years, descriptions of the Kimmeridge Clay have combined the lithological, sedimentological, palaeontological and geophysical wire line-log data to produce a chronostratigraphy that is applicable throughout onshore Britain. The Lower Kimmeridge Clay has been divided into 35 chronostratigraphical units (referred to as KC 1 to KC 35) on the basis of combinations of what are believed to be isochronous sedimentary and palaeontological events [18,20]. These units have been grouped into five sequences, each of which is bounded by a third-order stratigraphical sequence surface (Km 1 to Km 6) [38].

Early descriptions of the equivalent sediments in Normandy concentrated on the biostratigraphy [22,31,32]. More recent descriptions [34,35] have enhanced the palaeontological descriptions and combined them with the lithological data. Because of their continual renewal the Normandy sections now provide a better opportunity to improve our knowledge of the detailed biostratigraphy of parts of the Sub-boreal Kimmeridgian than does any English section. The Normandy sections were closer than the Dorset-type section to the Sub-Tethyan faunal province in Kimmeridgian times, and they offer a better opportunity for inter-province correlation.

2. Correlation of the Dorset and Normandy successions

Stratigraphical summaries of the Kimmeridgian successions exposed on the Dorset and Normandy coasts are shown in Figs. 2 and 3, together with their correlations. The Dorset succession and zonation are based on work by numerous authors on the cliff sections [2,4–7,9–13,16,21,33,36,39,40,43], and on continuously cored boreholes [10,18,20]. The Normandy coast succession is based on published descriptions of the lithostratigraphy and biostratigraphy [8,14,22,25–28,31–35], and additional observations made on sections visible in May 2000, November 2001, and June 2002.

The Normandy sections consist of a series of geographically separated exposures on foreshores and in low cliffs which, taken together, provide a continuous succession of about 45 m of strata that range from the Baylei Zone to the middle part of the Eudoxus Zone. A low northerly dip ($< 0.5°$) in the Kimmeridgian rocks causes them to be unconformable overstepped by almost horizontal Cretaceous rocks when traced southwards from near Cauville to Le Havre (Fig. 1). Geographical details of the sections and their access points are given elsewhere [19,34].

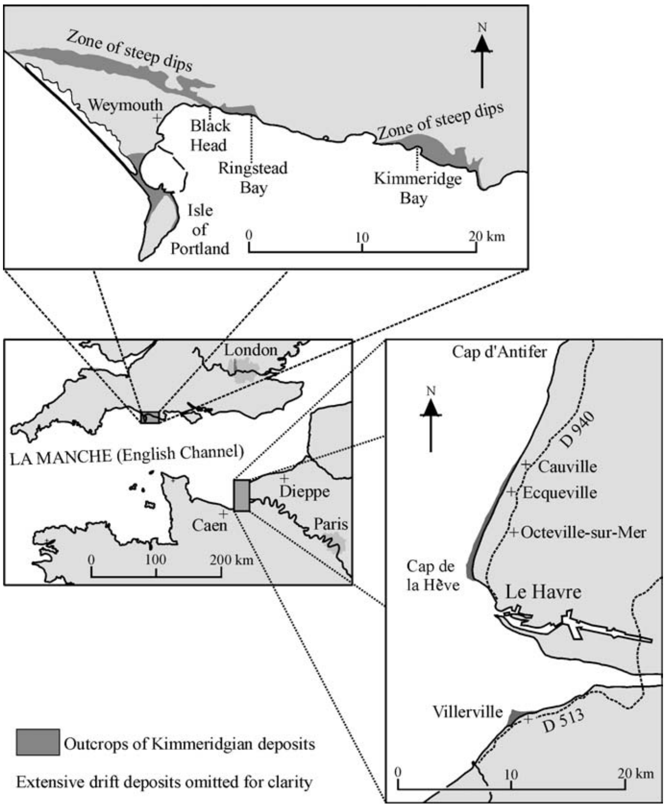

Fig. 1. Geological sketch map showing the positions of the sections referred to in the text.

Fig. 1. Carte géologique thématique montrant la position des coupes citées dans le texte.

The Early Kimmeridgian marked a time of world-wide sea-level rise that was part of a second-order eustatic cycle that began in the Middle Jurassic [23]. Kimmeridgian sedimentation in Dorset and Normandy reflects a complex interaction of eustacy and tectonism [37]. In the Lower Kimmeridgian, the basin geometry was such that relative falls in sea level created widespread unconformities. In post-Mutabilis Zone times, following a widespread transgression in early Eudoxus times, unconformities were confined to the margins of the depositional basin [37], to areas such as the Boulonnais [30,42].

2.1. Baylei and Cymodoce zones

Sedimentological comparison with similar Early Kimmeridgian successions, such as that of the Boulonnais, suggests that the Baylei–Cymodoce Zone sediments of the Normandy coast were deposited in a homoclinal mid-ramp setting in which storm-wave reworking was significant [30,42], and that the equivalent beds on the Dorset coast were deposited in an outer-ramp setting below or at storm-wave base. Cyclostratigraphical analysis of the Kimmeridgian succession in Dorset has shown that the duration of the preserved Baylei–Cymodoce sediments is only about 10% that of the more complete Eudoxus and Autissiodorensis zones [41]. The Normandy succession is probably similarly condensed, and both successions contain numerous major and minor sedimentary breaks [17,20,24,32,34]. These are especially obvious in the calcareous lithologies of the Normandy coast where they give rise to numerous hardground surfaces. The comparable succession on the Dorset coast consists predominantly of mudstones in which erosion and omission surfaces are lithologically less pronounced. The preserved successions in both areas are so fragmentary that their sequence stratigraphy

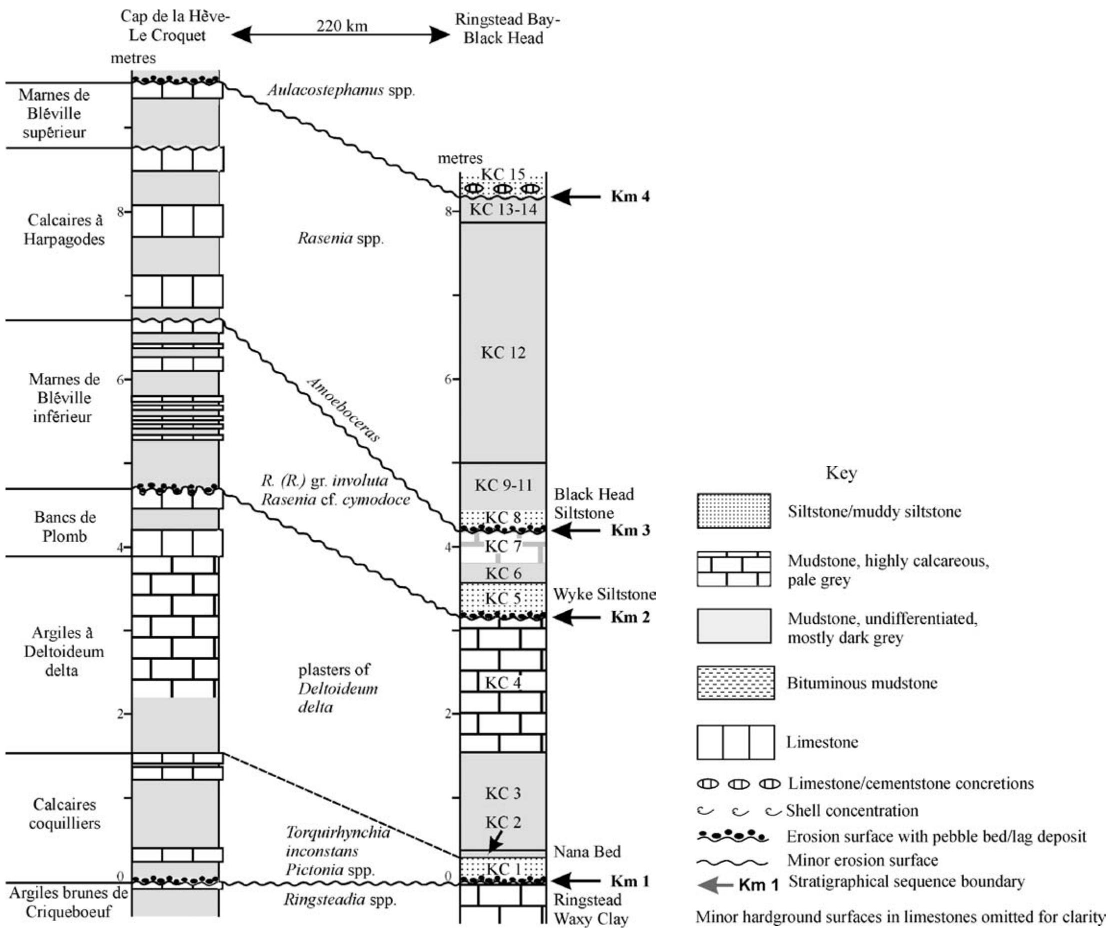

Fig. 2. Correlation of the Baylei and Cymodoce zones successions: 'Formation des Calcaires coquilliers' to 'Formation des Marnes de Bléville' (after [34]) and English chronostratigraphical units KC 1 to KC 14.

Fig. 2. Corrélation entre les successions des zones à Baylei (des Calcaires coquilliers aux Bancs de plomb) et à Cymodoces (Marnes de Bléville) (d'après [34]) et des unités chronostratigraphiques anglaises (KC 1 à KC 14).

cannot be interpreted with confidence, and they cannot be correlated in detail.

The correlation of the Dorset and Normandy successions at the zonal level, based in part on published accounts [3,32,34], is summarised in Fig. 2. On the Normandy coast, the total thickness of the Baylei and Cymodoce zones has been estimated to vary between about 9 and 12 m [22,32]. The comparable thickness at Ringstead Bay is about 8 m, but it varies between 7 and 20 m within a few kilometres [13].

The Baylei Zone exposures in Dorset and Normandy have yielded few age-diagnostic fossils other than *Pictonia*. In Dorset, *P. densicostata* Buckman is restricted to the zone (KC 1 to KC 4). In Normandy, a younger assemblage with *P. baylei* Salfeld and *P. thurmanni* (Contejean) occurs in the 'Formation des Calcaires coquilliers' [34], suggesting that the sedimentary break at the base of the Kimmeridgian lasted longer in Normandy than it did in Dorset [25]. The distinctive brachiopod *Torquirhynchia inconstans* (J. Sowerby), which has been recorded only from the basal bed KC 1, occurs sparingly in the 'Formation des Calcaires coquilliers'. Lithological similarities between the Dorset and Normandy successions include lumachelles composed of *Nanogyra nana* (J. Sowerby) in KC 2 (the Nana Bed) and the

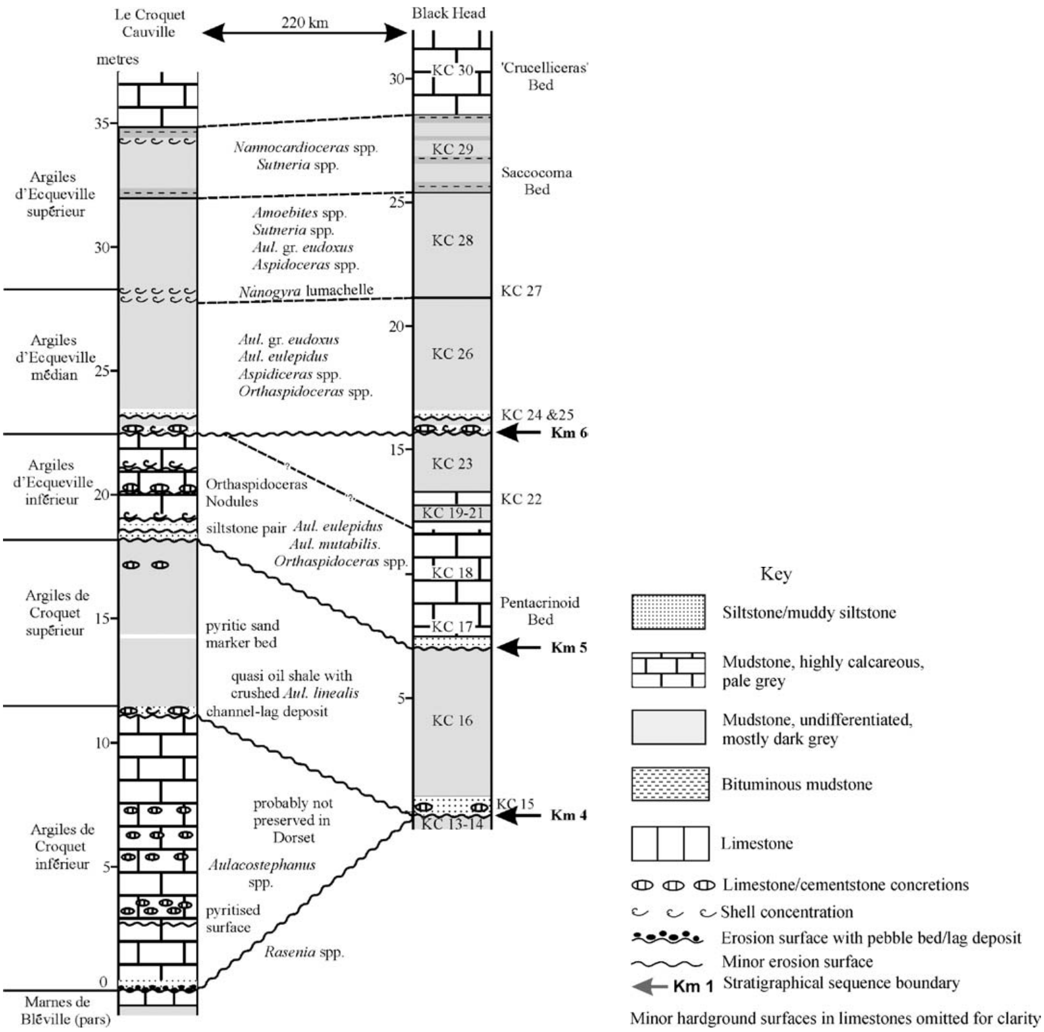

Fig. 3. Correlation of the Mutabilis and Eudoxus Zone successions: 'Formation des Argiles d'Octeville' (after [34]) and English chronostratigraphical units KC 15 to KC 30.

Fig. 3. Corrélation entre les successions des zones à Mutabilis et à Eudoxus : Argiles d'Octeville (d'après [34]) et les unités chronostratigraphiques anglaises KC 15 à KC 30 (voir le texte pour la limite des zones).

'Argiles à Deltoideum' delta, and beds of dark grey mudstone crowded with the large oyster *Deltoideum delta* (Wm Smith) in KC 3 and the 'Formation des Argiles à Deltoideum' delta.

The 'Formation des Bancs de plomb' is correlated here on lithostratigraphical grounds with the highly calcareous mudstone KC 4 of the Dorset succession. The formation is capped by a complex phosphatised and glauconitised hardground surface that marks a widespread erosion surface in northern France [17,24]. It is the probable correlative of sequence boundary Km 2 in England which similarly marks a widespread sedimentary break that was followed by a rapid transgression.

The 'Marnes de Bléville' ('inférieures' and 'supérieures') and the intervening 'Calcaires à Harpagodes' represent a condensed succession of limestones and mudstones with several sedimentary breaks represented by mineralised and burrowed surfaces. The presence of *Rasenia* throughout this part of the succession indicates correlation with KC 5 to KC 14. Four assemblage horizons (I to IV) have been identified in the Cymodoce Zone in England [4]. The oldest, characterised by *Rasenia* cf. *cymodoce* (d'Orbigny), is confined to the Wyke Siltstone (KC 5) [5]. On the Normandy coast, *R. cymodoce* has been recorded as a single impression from the 'Bancs de Plomb' (Hantzpergue in [34]). Horizon II, characterised by *Rasenia (R.) involuta* Spath, has been recorded from KC 6–7 in England and from the 'Marnes de Bléville inférieures'.

The base of the 'Calcaires à Harpagodes' is marked by an erosion surface overlain by a silty mudstone [34]. The *Rasenia* assemblages above this level suggest correlation of the erosion surface with sequence boundary Km 3 and the silty mudstone with the Black Head Siltstone (KC 8). The presence of *Amoeboceras* at this stratigraphical level in Dorset [13] and Normandy [32] might provide a further link. Horizon III, characterised by *Rasenia (Zonovia)* gr. *evoluta* Spath, occurs in KC 12 and is represented by *R. pseudoeumela* (Tornquist) in the 'Calcaires à Harpagodes'. Horizon IV, characterised by *R. (Semirasenia) askepta)* Ziegler and *Rasenia (Raseniodes)* cf. *lepidula* (Oppel), occurs in KC 13–14 and the 'Marnes de Bléville supérieures'.

The basal bed of the 'Argiles d'Octeville' [15] is a silty mudstone with common shell brash and phosphatic pebbles that include casts of *Rasenia* derived from the underlying beds [34]. It rests on a burrowed and bored hardground surface at the top of the 'Marnes de Bléville' that marks a widespread erosion surface that correlates with sequence boundary Km 4. It precedes a rapid expansion of the geographical extent of the Sub-boreal Province and a breakdown of barriers that had inhibited faunal migration in the Late Oxfordian and Early Kimmeridgian. In northern France it marked the submersion of the 'Sequanian-facies barrier' and the opening of the Anglo-Norman depositional basin to Tethyan influences [17].

2.2. Mutabilis and Eudoxus zones

In contrast to the Early Kimmeridgian, the lithologies and the faunas of the Mutabilis and Eudoxus zones successions of Dorset and Normandy can be matched in detail. All the lithologies in the 'Formation des Argiles d'Octeville' occur in Dorset, and they do so in a similar order. Both successions contain erosion surfaces that mark third-order sequence boundaries. In the Kimmeridge clay, thin lithological and faunal marker beds in the intervening sequences are laterally persistent over large areas and enable the succession to be divided into chronostratigraphical units. For example, units KC 17 to KC 23 (between Km 5 and Km 6) are present almost everywhere throughout the onshore outcrop and subcrop between Dorset and Yorkshire (an area of about 35 000 km^2). This lateral persistence suggests that the Kimmeridgian was a tectonically quiet period in England with uniform depositional environments over wide areas at any particular time. In contrast, the correlative erosion surfaces in the Normandy coast succession give rise to pronounced lateral variations. The best documented of these, that at the base of the 'Argiles d'Ecqueville' (Km 5 equivalent), cuts out the whole of the 6-m-thick 'Argiles du Croquet supérieures' in a distance of only 350 m at Le Croquet Plage [19]. This suggests that there were marked local differences in seabed topography in that area at that time, presumably due to penecontemporaneous tectonic activity.

Four sequence boundaries have been recognised in the 'Argiles d'Octeville' in the present work, each marked by a major erosion surface. Additional minor erosion surfaces are common within the lower part of the succession (Fig. 3). The lowest part of the formation, the 'Argiles du Croquet inférieures', is the least well exposed and its fauna the least well documented. It consists of up to 11 m of calcareous mudstone with calcareous concretions and at least two burrowed erosion surfaces overlain by pyritised concentrations of shells and shell debris. Large crushed *Aulacostephanus* indicative of the Mutabilis Zone are common at several levels, and the shell-rich beds contain common oysters and rhynchonellid brachiopods.

The base of the 'Argiles du Croquet supérieures' is marked by an erosion surface overlain by a shelly, pebbly channel-lag deposit with secondary calcareous concretions. This is overlain by fissile, bituminous mudstones that are locally crowded with crushed *Aulacostephanoides linealis* (Quenstedt) [34], a combination of lithology and fauna that can be matched with parts of KC 16, the oldest organic-rich lithology in the English Kimmeridgian succession. The identification of KC 16 close above the erosion surface suggests that the sedimentary break is the correlative of that at the base of KC 15 (sequence boundary Km 5), and that in England erosion at this level has removed any representative of the 'Argiles du Croquet inférieures' (Fig. 3).

The 'Argiles de Croquet supérieures' are overlain disconformably by the 'Argiles d'Ecqueville inférieures', a highly condensed 4-m-thick succession of calcareous mudstones and siltstones. In the cliffs at le Croquet Plage the erosion surface at the base of the 'Argiles d'Ecqueville' progressively cuts out marker beds in the 'Argiles de Croquet supérieures' in a southerly direction and comes to rest on the 'Argiles de Croquet inférieures' [19]. The most prominent of the marker beds is a thin (10-mm-thick) bed of bioturbated pyritic sand that is presumed to be a storm-generated deposit.

The 'Argiles d'Ecqueville inférieures' contains at least five erosion surfaces and several omission surfaces marked by bioturbation, mineralisation (mostly pyrite) and concentrations of shell debris. *Orthaspidoceras* is abundant at several levels including one in which complete specimens are well preserved in calcareous concretions. *Aulacostephanus* including *Aul. mutabilis* (Sowerby) and *Aulacostephanoides eulepidus* (Schneid) are also present [34]. The fauna and lithologies indicate correlation with KC 18 to KC 23, albeit with several sedimentary gaps. The distinctive Supracorallina Bed of the English succession [1] has not been recorded in Normandy, but the abundance of *Orthaspidoceras* can be matched with a similar abundance at this stratigraphical level on the Dorset coast [39].

The base of the 'Argiles d'Ecqueville médianes' is marked by an erosion surface (the correlative of Km 6) that is well exposed in the cliffs ($x = 1210.50$, $y = 438.30$) southwest of Ecqueville (La Brière in museum collections). Throughout the English outcrop and subcrop and on the Normandy coast, the erosion surface is overlain by a calcareous siltstone with secondary concretions and a rich and diverse shelly fauna (KC 24). Close above this, a second siltstone (KC 25) marks another erosion surface that is followed by a second transgressive pulse. Taken together, these pulses mark a rapid transgression that can be recognised throughout much of the Sub-boreal province [17,24,29]. It gave rise to the spread of diverse ammonite assemblages that include species of *Amoeboceras* (*Nannocardioceras*), *Aspidoceras* and *Sutneria*, and *Aulacostephanus* of the *eudoxus* group. Detailed collecting in England adjacent to the sequence boundary indicates that the junction of the Mutabilis and Eudoxus zones lies at the base of one or other of the siltstones [6,13]. More collecting will be needed in Normandy before the boundary can be precisely placed.

The Eudoxus Zone successions on the Normandy and Dorset coasts can be matched in lithological and faunal detail. In both areas, dark grey mudstones with *Aulacostephanus eudoxus* (d'Orbigny), *Aulacostephanoides eulepidus*, *Aul. mutabilis*, *Aspidoceras* spp. and *Sutneria eumela* (KC 26) are overlain by a lumachelle composed almost entirely of the small oyster *Nanogyra virgula* (Defrance) (KC 27). This is overlain by shelly, dark grey mudstones (KC 28) and interbedded mudstones and oils shales (KC 29) with common *Amoeboceras* (*Amoebites*) spp., *Amoeboceras* (*Nannocardioceras*) *anglicum* (Salfeld), *Aspidoceras longispinum* (Sowerby), *Aulacostephanus* spp., *Sutneria eumela* (d'Orbigny) and large forms of *Nanogyra virgula*.

The youngest Kimmeridgian strata currently exposed on the Normandy coast are deeply weathered pale grey highly calcareous mudstones in low cliffs north of Ecqueville ($x = 1211.50$, $y = 438.70$) and south of Cauville ($x = 1212.10$, $y = 439.10$) (Le Tronquay in museum collections). The lithologies and fauna, including species of *Amoeboceras*, *Aspidoceras*, *Aulacostephanus* and *Sutneria*, are those of KC 30 of the English succession. The distinctive *Tolvericeras*-rich marker bed in KC 30 (the Crussolliceras Bed of English authors) has not been recorded in Normandy. When allowance is made for the northerly dip of the Jurassic rocks and the rate of overstep of the Cretaceous rocks, it seems likely that higher beds in the 'Argiles d'Ecqueville' will crop out on the foreshore west of Cauville from time to time in an area that is usually covered by thick beach deposits.

3. Summary and conclusions

The early parts (Baylei and Cymodoce zones) of the Kimmeridgian successions at outcrop on the Dorset and Normandy coasts are highly condensed and lithologically dissimilar. Both successions contain prominent sedimentary breaks that coincide with major changes in the ammonite assemblages. This enables correlations to be made between them at the zonal and third-order sequence stratigraphical level. The later part of the Kimmeridgian (Mutabilis and Eudoxus zones) is lithologically and faunally closely similar in both areas. Differences in the abundances of some faunal elements reflect the closer proximity of the Normandy sections to the Sub-Tethyan Province. There is currently no good permanent exposure through the full thickness of the Mutabilis Zone in England, and the Normandy sections are therefore especially important for future study. Detailed collecting of the ammonite successions in the lower part of the zone ('Argiles du Croquet inférieures') and adjacent to the Mutabilis–Eudoxus zonal boundary would be especially useful. In England, flood occurrences of particular Kimmeridgian fossils, including pentacrinoids (in KC 18), *Nicaniella* (in KC 22), *Saccocoma* (in KC 29) and *Tolvericeras* (in KC 30) have been shown to provide isochronous marker beds over large areas [18,20]. They have yet to be recorded in Normandy.

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