Correlation of the offshore sequences referred to the Kimmeridge Clay Formation—relevance to the Norwegian sector

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The lithologies referred to the Kimmeridge Clay Formation are acknowledged to include the most important petroleum source rocks known in the North Sea. However, the correlations and historical review presented herein demonstrate that widespread use of the term 'Kimmeridge Clay Formation' is a misleading piece of stratigraphic nomenclature which stems from conflicting definitions of the unit both offshore and onshore. This has led to striking differences in the way the unit is perceived in different basins of the North Sea area.

The base of a unit is regarded as a fundamental criterion in stratigraphy, and yet several quite different definitions for the base of the Kimmeridge Clay Formation exist in the literature. In eastern England the base is placed at a chronostratigraphic marker (the Oxfordian–Kimmeridgian boundary) even when present within a homogeneous claystone sequence. Immediately offshore this entire claystone sequence is included in the Kimmeridge Clay and an older, but more lithostratigraphically significant, horizon (the contact with Corallian limestones) is taken as the base. In total contrast, the base in the northern North Sea is viewed as the contact between bituminous claystones and underlying claystones of more normal character. The basic criteria on which the northern Kimmeridge Clay Formation was defined (anomalously high organic content and associated log responses) were never documented in the offshore type and reference sections of the southern UK North Sea. Similarly, bituminous shale developments are not typical of the Kimmeridge Clay as defined in the Netherlands sector.

Adoption of a local formation nomenclature for the Norwegian sector is urged as a means to more-precise correlation. A scheme proposed by the Norwegian Lithostratigraphic Nomenclature Committee is outlined. This classification is based on the recognition that the economically important organic shales are discrete and readily mappable units, but that they are not always synchronous or continuous between basins. A review of the role of the Kimmeridge Clay Formation in other national sectors is also suggested.

INTRODUCTION

In the recent work of the Norwegian Jurassic Lithostratigraphic Nomenclature Committee (1980–1984) much time was devoted to assessing the place of the Upper Jurassic–lowermost Cretaceous Kimmeridge Clay Formation in the Norwegian Lithostratigraphic scheme. During the course of this work it became clear that the term was no longer easy to apply in the Norwegian sector. The unit previously defined as the Kimmeridge Clay Formation was considered to be too broad, to contain too many facies types, and to be of limited use in correlation or in the understanding of basin evolution. These problems were compounded by imprecise and variable definitions of the unit in previous attempts at offshore lithostratigraphic classification. A decision was therefore taken to replace the existing nomenclature with a number of locally-defined units, and these proposals were published by Vollset and Doré (1984).

Unfortunately, the term ‘Kimmeridge Clay Formation’ is strongly entrenched in the literature and parlance of North Sea explorationists, in all involved national areas, with the possible exception of the Danish sector. Normally this consideration alone would be grounds for extreme caution in modifying the nomenclature. However, it is precisely this entrenchment which leads to misunderstanding and problems of correlation; although the term is widely used, there is no consensus as to its meaning. The problem is essen-
The Kimmeridge Clay is variously thought to comprise the following.

(i) All shales of late Jurassic age, regardless of log character (particularly in the Norway–UK Central Graben).

(ii) A sequence of bituminous shales distinguished by very high gamma-ray readings and anomalously low seismic velocities (widely accepted in areas north of the Mid-North Sea High).

(iii) A sequence of shales defined by the particular class of kerogen found in its organic fraction.

(iv) Shales of Kimmeridgian age. Surprisingly, terms such as 'Kimmeridgian shale' still occur in the literature, where clearly referring to sequences of much broader chronostratigraphic range, or even to non-Kimmeridgian sequences. This probably results from the fact that the Kimmeridge Clay Formation of the English mainland is equated with the Kimmeridgian stage sensu anglico (see the following section).

Brookfield (1973), in referring to onshore British stratigraphy, wrote: 'The lithostratigraphic terminology of the Oxfordian and Kimmeridgian is truly a mess' (p. 137). In this brief account we attempt to show that some of these problems have been transferred to the offshore realm. In examining these problems we will expand upon our proposal to reclassify locally the Upper Jurassic-lowermost Cretaceous shale units, which include the richest source rocks known in the North Sea, and will draw attention to some of the conceptual problems that exist in Norway and in other national sectors.

THE ‘SPREAD’ OF THE KIMMERIDGE CLAY FORMATION FROM ITS TYPE AREA

Onshore England

The name ‘Kimmeridge Clay’ has been in use since the dawn of British stratigraphy in the early 19th Century (e.g. Fitton, 1836). The type area for the Kimmeridge Clay Formation is Dorset on the south coast of England (e.g. Arkell, 1947), where the unit consists of dark claystones with numerous limestone/dolomite stringers and phosphatic horizons. The lowermost part of the unit is developed in a calcareous, shelly facies but higher in the sequence bituminous clays and oil shales are frequent. The Kimmeridge Clay of the English mainland is essentially synonymous with the Kimmeridgian stage sensu anglico (e.g. Arkell, 1933; Cox and Gallois, 1981; Cope, 1980, fig. 14), or Kimmeridgian–early Middle Volgian in Boreal terminology.

Over much of its northeastern outcrop in England (Fig. 1) the Kimmeridge Clay overlies more claystones of Late Oxfordian age, the Amphthill Clay. The latter unit in turn overlies, and is in part equivalent to, limestones and calcareous sandstones of the Corallian Formation. The relationship between the Kimmeridge Clay and Amphthill Clay is generally obscure due to lack of exposure, and is mainly documented in early literature, summarized by Arkell (1933). It is alluded to here because the contact between these two units is of significance offshore.

The Amphthill Clay extends as far south as Oxfordshire. In the southern part of its outcrop there is a non-sequence between the Amphthill and Kimmeridge Clays, commonly expressed by a phosphate nodule band (Arkell, 1933). Elsewhere, however such as on Humberside, there is very little or no hiatus. Key sections at South Ferriby (Kelly and Rawson, 1983, p. 66) and Worlaby (Richardson, 1979, p. 13) show the Amphthill Clay–Kimmeridge Clay transition to be one of continuous deposition, with no perceptible lithological difference above and below the ‘contact’. In fact, the facies of the basal Kimmeridge Clay and the underlying Amphthill Clay—dark, calcareous, shelly, non-bituminous claystone—are everywhere remarkably similar. In boreholes the ‘contact’ has almost invariably been determined on palaeontological grounds alone (e.g. Arkell, 1983, p. 418; Wright, 1980, p. 74). The base of the Kimmeridge Clay Formation occurs at the base of the lowermost (baylei) zone of the Kimmeridgian stage, but this marker has little significance in lithostratigraphic terms. Brookfield (1973, p. 141) writes: ‘Despite contrary opinions ... there is no major lithological or faunal break between the Oxfordian and Kimmeridgian stages in Britain’.

The Kimmeridge and Amphthill Clays thin northwards towards the Market Weighton High (Fig. 1). North of the high in the Yorkshire Basin boreholes have proved a thick Kimmeridge Clay sequence and limited exposures indicate, for the uppermost zones at least, strong similarities to the Dorset type area (Cope, 1974). The Kimmeridge Clay was long considered to rest directly on Corallian beds in this area, but recent boreholes have proven the existence of intervening Amphthill Clay. Once again, however, this identification appears to be based solely on late Oxfordian datings and not on any lithostratigraphic criterion (I.G.S., 1974).

Southern North Sea, UK sector

The first application of the name Kimmeridge Clay Formation to the offshore realm was by Rhys (1974) in the recommendations of a joint Oil Industry–I.G.S. committee on North Sea nomenclature. The formation was defined as the uppermost unit of the Humber Group, a primarily claystone sequence of Oxfordian–Kimmeridgian age found in the Southern North Sea Basin. Extension of the name offshore was intended to express correspondence with the deposits documented in Norfolk, Lincolnshire and Yorkshire, and hence with the Dorset type area. The type well for the offshore Kimmeridge Clay was 47/15-1 (Phillips) with 47/9–1 (Gulf) as a reference section. Both wells are approximately 65 km east of the Humber estuary. Well 48/22–2 (Burmah) also serves to illustrate the Kimmeridge Clay Formation and lies about 65 km ENE of the Wash (Fig. 1).

The Humber Group as defined by Rhys (1974) also includes the Corallian and the underlying Oxford Clay Formation. In the type well the Kimmeridge Clay Formation is only 34 m thick, and is shown to rest directly on the Corallian. The comparatively minor thickness of Kimmeridge Clay may indicate contemporary thinning towards an offshore extension of the Market Weighton High (Fig. 1). However, it is also clear from the wells that there is a major unconformity between the Kimmeridge Clay and overlying Volgian–Lower Cretaceous sediments (Rhys, 1974, figs. 6 and 7). It seems likely that, as on Humberside...