Delta or coastal plain? With an example of the controversy from the Middle Jurassic of Yorkshire

J. Alexander

SUMMARY: Deltaic and coastal plain deposits can be distinguished from each other in the rock record where enough data are available to interpret the three-dimensional distribution of facies and unconformities over a wide area. This distinction is based on the distribution of facies rather than purely on a marine-to-alluvial transition as has been the case in the past. The distinction between deposits of the two environments is often very difficult or impossible, and if based on limited data may lead to inaccurate and even incorrect models that can cause problems with prediction of reservoir rocks or coal location in the subsurface. Models of the gross facies distribution for tectonically, eustatically and autocyclically controlled coastal plains are seen as the end-members of a continuum between coastline depositional styles.

The Middle Jurassic sedimentary rocks of the Yorkshire Basin are used to illustrate the controversy that can arise from imprecise definitions and the application of incorrect facies models. The Middle Jurassic Ravenscar Group is interpreted here as the deposits of a tectonically and eustatically influenced coastal plain. Repeated fluctuations between shallow-marine and non-marine conditions are interpreted as mainly caused by vertical tectonic movements and sea-level changes rather than by autocyclic processes.

There is considerable controversy over the interpretation of the depositional environment of many sedimentary successions. Much of the controversy arises because of differing interpretations of specific words and probably fundamentally different perceptions. A survey of over 100 geologists and geomorphologists from British and European universities and oil companies shows that the use of the term 'deltaic' varies considerably. This wide variation of definition is particularly disquieting as large volumes of fossil fuels are found in sediments that are attributed to deltaic environments of deposition. Also, deltas and other coastal localities are sites for the deposition of exceptionally thick sediment piles.

It has been the tendency in recent years to apply the term 'deltaic' to any sedimentary succession that involves a transition from a marine to an alluvial environment of deposition. It is clear that in many cases these deposits will not strictly be deltaic in origin although they may contain similar facies or even be made up in part of deltaic deposits.

Barrell (1912, 1914) proposed criteria for the recognition of deltaic deposits in the rock record. These criteria were based on Gilbert's description of deltas with topset, foreset and bottomset beds. Barrell stressed that not all deltas would exhibit this structure. The distinction rested largely on the recognition of large coarsening-upward cycles reflecting progradation and the passage from marine to alluvial conditions at any one site. However, these are not sufficient criteria to distinguish between deltaic and other types of coastal plain deposits.

The main reason for the ubiquitous use of the word 'deltaic' for any sediments containing a marine-to-alluvial transition is the variation in the definition of 'deltaic' used by geologists when applied to the rock record. The survey revealed that there was no commonly accepted definition of either delta or deltaics.

Where a number of deltas coalesce laterally, the resulting area of land can be called a coastal plain although this may also result from other mechanisms. For example, distinction should be made between passive progradation of deltas or coastal plains resulting from sedimentary processes and an area of alluvial conditions created as a result of tectonic uplift or sea-level fall.

In this paper geometrical facies models are presented for the end-members of prograding coastline systems before models applicable to the Middle Jurassic sedimentary rocks of the Yorkshire Basin, NE England, are discussed briefly.

Results of the survey of deltaic definitions

An informal survey of geologists and geomorphologists was undertaken primarily to clarify the author's own ideas on deltaic deposits. This survey was carried out by direct questions and discussion with people at the meeting *Deltas: Sites and Traps for Fossil Fuels*, the British

From WHATELEY, M. K. G. & PICKERING, K. T. (eds), 1989, *Deltas: Sites and Traps for Fossil Fuels*, Geological Society Special Publication No. 41, pp. 11–19.

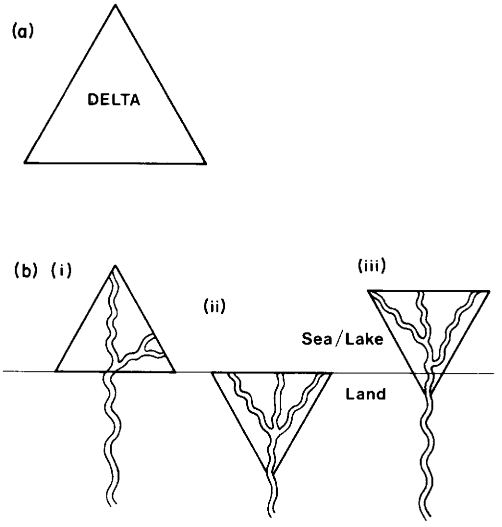

FIG. 1. The delta of Herodotus: (*a*) the fourth letter of the Greek alphabet; (*b*) three possible plan-form geometries that fit into this definition.

Sedimentological Research Group Meeting, 1986, and assorted other occasions. The results obtained from this informal survey fell into three main categories.

(a) A delta is any sedimentary succession that has a transition from marine to non-marine, or any marine–fluvial or lacustrine–fluvial interface.
(b) A delta is a crudely triangular lobe of sediment deposited where a fluvial channel enters a sea, ocean or lake.
(c) A deltaic deposit is the rapidly deposited sediment that progrades into an ocean, sea, lagoon or lake and originates from a single river system. The river supplied sediment more rapidly to its mouth than could be dispersed by basinal processes although the sediment may be reworked *in situ* by wave or tidal activity.

Definition (b) includes some of the most succinct definitions given (Fig. 1*a*) and relates most nearly to the original definition of Herodotus. This prompted the comment: 'Herodotus knew what he was talking about. Something appears to have been lost in the sedimentological translation! Most "things" we geologists call deltas or deltaic deposits probably/certainly are not'. The triangle definition also introduces some variation in the land forms that would be included in this definition (Fig. 1*b*).

50% of those questioned agreed essentially with the third definition, and this is the one that is followed in this paper. Many people emphasized that deltaic deposits were primarily the result of progradation of a single river system. Several people observed that distributary systems were not ubiquitous in deltas although they were common, and that interaction of alluvial, tidal and wave activity allowed a wide range of morphological forms, thus allowing a wide range of facies patterns to come under the same general delta definition. In such cases the landforms near the mouth of single river systems resulting from deposition of the river load, but without the triangular shape, can be called deltas.

It is important to stress the range of scale of deltas from metres to kilometres depending on the system under consideration. The classic Gilbert-type delta is probably developed in relatively rare conditions. It is common for deltaics not to include topset, foreset and bottomset beds as stressed by Barrell (1912, 1914).

Deltaic versus coastal plain models

It is possible to erect four theoretical end-member models for constructive coastline depositional systems (Fig. 2): delta; autocyclically controlled coastal plain; tectonically controlled coastal plain; eustatically controlled coastal plain. These types can be subdivided on the basis of climatic conditions, sediment grade and the extent of tidal and wave activity. Major problems arise when defining the boundary conditions between these classes and when interpreting the nature of deposits where the predominant control changed through time or several controls were of equal importance, as appears to have been the case in the Middle Jurassic Yorkshire Basin as discussed below. Coastal plain and delta complexes as defined here have many sedimentary processes in common and consequently have similar facies, although the facies architecture is different.

Distinguishing features of the models and discussion

Deltaic deposits

The definition of 'deltaic' used in this paper follows (c) above. Significant features of this model are as follows: (i) they are the deposits of a single alluvial system forming near the mouth of that system; (ii) the deposits prograde by autocyclic processes into a marine or lacustrine basin, and this progradation leads to a vertical marine-to-alluvial transition and a distinct shore-

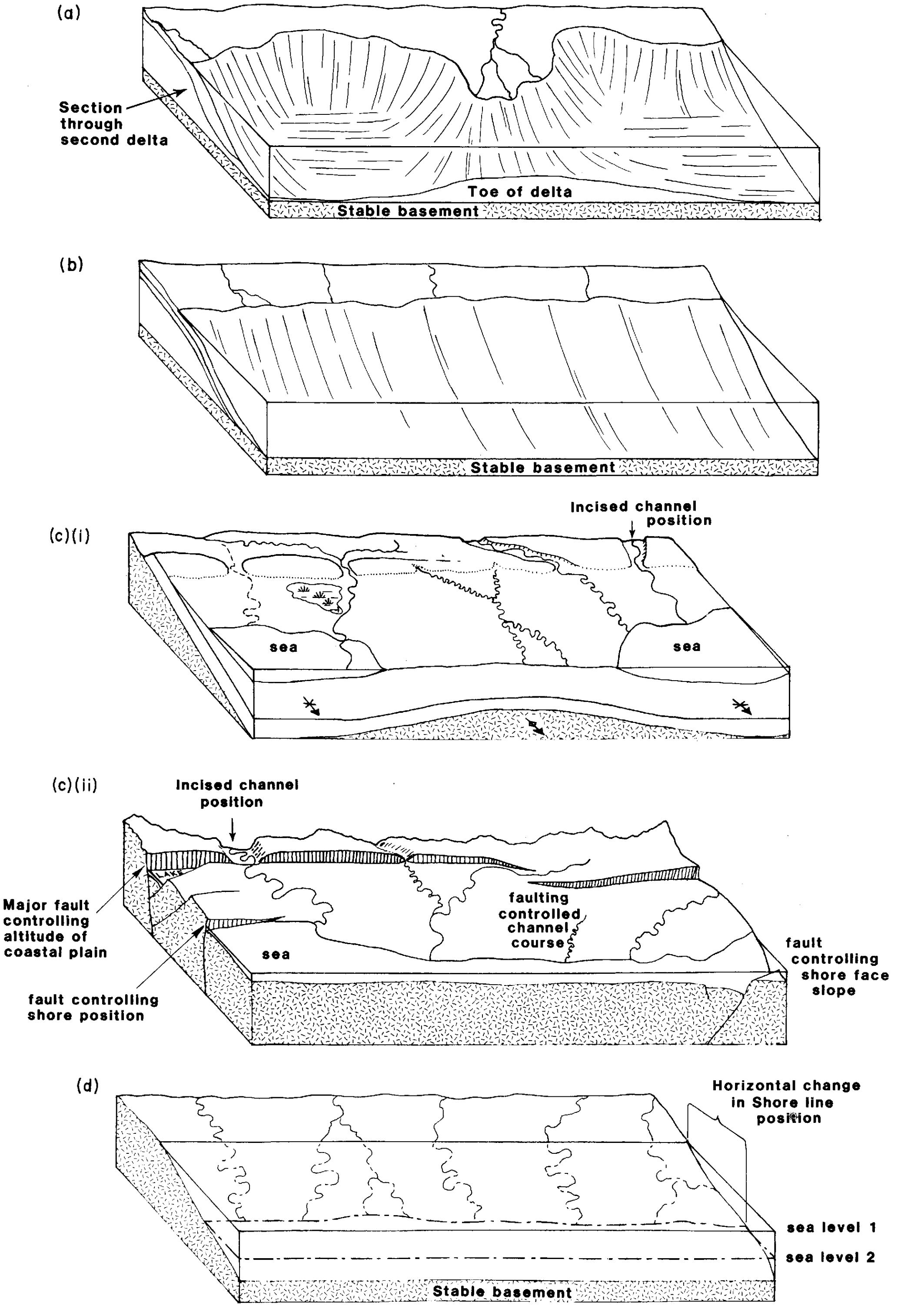

FIG. 2. Block diagrams representing the large-scale facies distribution in the four end-member models of aggrading coastlines: (*a*) deltaic model, (*b*) autocyclically controlled coastal plain, (*c*) tectonically controlled coastal plain ((i) coastal plain controlled by folding; (ii) coastal plain controlled by faulting) and (*d*) eustatically controlled coastal plain.

line perturbation; (iii) a coarsening-upward sequence may be developed as a result of lobe progradation, and this sequence may subsequently be removed by distributary channel erosion; (iv) distributary channel systems may have been present, producing a reduction in channel sandstone body size down-palaeocurrent; (v) a fanning pattern of channel-belt deposits is developed as a result of the point-sourced alluvial system, and this fanning sandstone body architecture develops even if distributary systems were not present; (vi) lobe switching is an inherent process in many forms of deltas and may lead to repeated lobe progradation over the same site to produce a rhythmical succession.

Deposition on the upper delta plain (area of alluvial deposition away from major marine influence) may result in facies patterns that are very similar to those formed on coastal plains.

Autocyclically controlled coastal plain

This depositional model results from progradation of a prism of terrestrially derived sediment into a marine or lacustrine basin. In general, an autocyclically controlled coastal plain comprises a number of deltas that have coalesced laterally and/or prograded at the same time. This configuration of laterally interfingering alluvial systems results in a sedimentary body with a more regular rectangular distribution of facies than is seen in isolated deltas. In most cases it would be impossible to distinguish the deposits of individual alluvial systems in the rock record unless (i) there is considerable difference in the load characteristics of the rivers, (ii) there is considerable spacing between river systems of similar size, as in the Cenozoic Gulf Coast sediments (Galloway 1981) and/or (iii) there is a persistent topographic control of channel positions resulting in vertical stacking of channel sandstone bodies owing to differential compaction of the substrata, minor tectonic deformation or upstream control of the site of river entry into the depositional basin. Even in this case, there would still be considerable problems in distinguishing the overbank deposits for the different systems.

Tectonically controlled coastal plain

In this model the change from marine to non-marine depositional conditions is controlled by synsedimentary tectonic deformation. This is seen on a small scale in several neotectonic areas, notably in Greece (Jackson *et al.* 1982) and along the shore of Hebgen Lake, SW Montana (Alexander & Leeder 1987). In both these modern examples the horizontal distance of near-instantaneous shoreline movement, resulting from single seismic events, was small owing to the high relief of the areas concerned. This effect is most pronounced in areas of low coastal relief where only small amounts of vertical movement will cause the shoreline to move by a considerable distance across the gently sloping surface (Leeder & Gawthorpe 1987).

In the deposits of tectonically controlled coastal plains, evidence of synsedimentary tectonic activity will be preserved in the rock record. This evidence will be in the following form.

(1) Little, if any, evidence of a prograding wedge, although this may occur locally; there may be sudden switches between marine and non-marine conditions.
(2) Variability in formation thickness relating to folds or faults in the sedimentary succession, with such thickness variations frequently being associated with facies variations.
(3) Facies variations relating to persistent topographic features rather than vertically changing facies due to progradation or random distributions. In particular, examples include stacked sandstone bodies formed as a result of topographic control of the drainage pattern. Changes in the extent of marine influence along strike, associated with tectonic features, may be common, as observed in the area around Long Nab in the Middle Jurassic of the Yorkshire Basin. This effect can be seen to a lesser extent in other models.
(4) A non-random pattern of soft-sediment deformation superimposed on an inherent random pattern. Of particular diagnostic value are beds deformed by load and founder structures that can be traced over a considerable lateral extent (Mayall 1983; Alexander & Williams, in prep.) and concentrations of deformation structures near synsedimentary tectonic features (Alexander 1987; Leeder 1987).
(5) Abrupt vertical changes of marine influence, notably localized flood deposits containing marine microfossils.

Eustatically controlled coastal plain

This facies model is very similar to the tectonically controlled coastal plain model. In the eustatically controlled plain, vertical changes from marine to non-marine conditions result from fluctuations of sea level. These changes may be rapid or slow and superimposed on other local changes. Intuitively, it seems that hybrid models with a eustatic influence would be more common than examples where major changes in coastline position were controlled solely by sea-level change. However, many examples of major changes in shoreline position are recorded as a result of the major sea-level changes that occurred in the Quaternary associated with fluctuating climatic and glacial conditions (Curray 1960; Nelson & Bray 1970).

Distinguishing eustatic control from other effects in the rock record is currently very difficult since there appear to be few features that are unique to this case. Eustatic changes may be more widespread than tectonic effects, but this may not always be the case.

Conclusions for different coastline models

In the same climatic conditions, the facies distribution in a cross-section perpendicular to the shoreline through deltaic and autocyclically controlled coastal plain deposits will be similar, although the facies distribution parallel to the coastline will be significantly different. Similarly, tectonically and eustatically controlled coastal plains may have similar facies architecture but the mechanisms responsible for the pattern will be significantly different. This difference can be seen in the nature of channel-belt sandstone body stacking patterns and in the distribution of soft-sediment deformation. Individual deltas may not conform, *sensu stricto*, with the delta model throughout their history and may temporarily display facies relationships more consistent with other coastal plain models. In cases where there are insufficient data to make a distinction between the environments, a more general term such as 'paralic' or 'marine–alluvial transition' should be used in preference to a model that has a large probability of being inaccurate, thus avoiding basing any hydrocarbon or coal exploration on an incorrect facies distribution model.

These models are only end-members in a continuum and it is thought that hybrid coastline depositional systems will be the rule rather than the exception, as is the case with the Middle Jurassic of Yorkshire.

Introduction to the Ravenscar Group

The Middle Jurassic Ravenscar Group is well exposed in the cliffs between Yons Nab and Staithes (Fig. 3). These very well exposed outcrops are frequently used to demonstrate the nature and pattern of alluvial and deltaic facies to students, professional geologists and reservoir engineers working on time-equivalent rocks in the North Sea oil province. Care should be taken to acknowledge the differences between these two areas. In both these areas, local regression occurred in the Middle Jurassic despite rising sea levels.

The Ravenscar Group consists of alternating 'marine' and 'non-marine' formations, and demonstrates lateral and vertical variations in sandstone architectural style (Alexander 1986*a*). The pattern of formation thickness and facies variation is shown schematically in Fig. 4.

There has been considerable debate over the extent of marine influence in the alluvial formations of the Ravenscar Group and discussion as to the most applicable sedimentary models (Leeder & Nami 1979; Hancock & Fisher 1981; Livera & Leeder 1981; Fisher & Hancock 1985; Alexander 1986*a*,*b*). The continuing disagree-

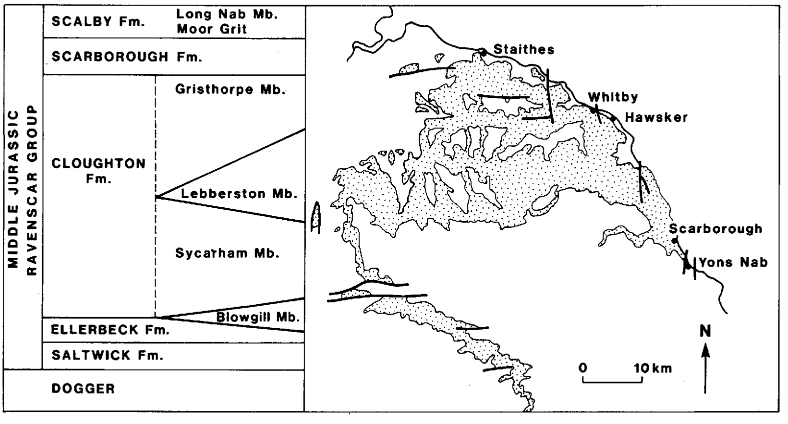

FIG. 3. Location map of the Yorkshire Middle Jurassic and the nomenclature used in this paper. (After Hemingway & Knox 1973.)

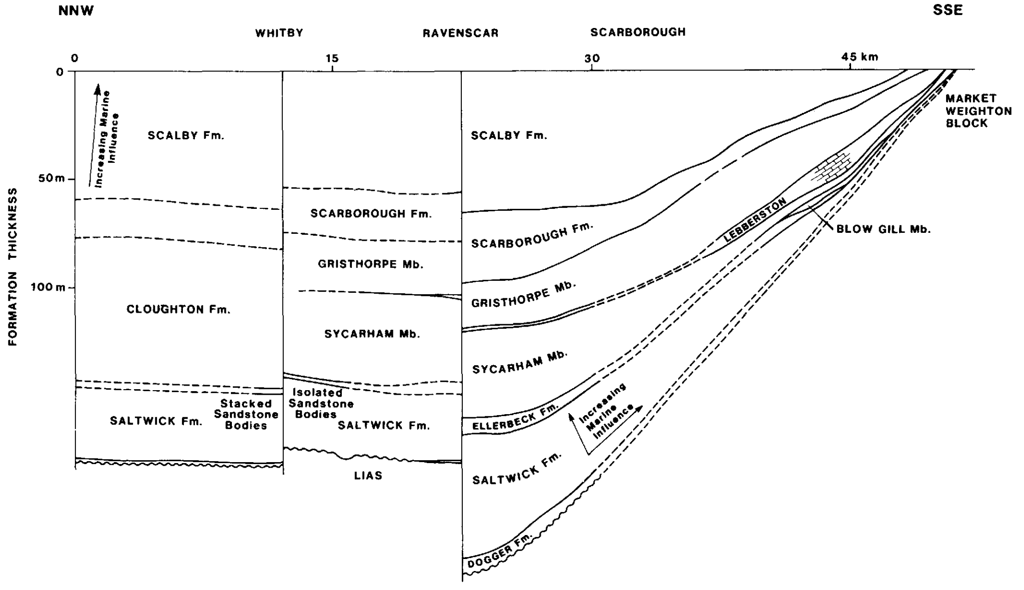

FIG. 4. Schematic diagram of the major thickness variations in the Middle Jurassic across the Yorkshire Basin. The Dogger, Ellerbeck and Scarborough Formations and the Lebberston Member are marine.

ment has been caused, in part, by people working on limited data and on variations in the criteria thought to indicate deltaic conditions, as well as by scale problems. A brief discussion is presented below to justify the use of an alluvial-dominated tectonically and eustatically influenced coastal plain model for these rocks.

The onset of non-marine conditions in the Yorkshire Basin was sudden, with the main break in sedimentation occurring between the open marine Liassic and the shallow-marine Dogger Formation (Figs 3 and 5). This break in sedimentation and change in depositional environment is represented by an unconformity with a slight angular discordance, and demonstrates a period of uplift and folding prior to the Middle Jurassic that appears to have continued, albeit at a slowed rate, throughout that time. The Dogger Formation contains clasts of phosphatized Liassic shale and locally derived conglomerates. At many sites the top of the Dogger Formation contains rootcasts and evidence of pedogenesis, indicating superposition of subaerial conditions on marine sediments. Locally, the Dogger Formation is overlain by a thin coal.

The base of the Saltwick Formation, the first non-marine formation in the basin (Fig. 3), is also a plain of non-deposition or erosion. This is particularly well displayed where there has been incision of Saltwick channels into the Dogger Formation and underlying shales, as seen for example between Whitby and Robin Hood's Bay, indicating a lowering of river base level rather than simple progradation.

There is considerable evidence throughout the Ravenscar Group that the depositional surface

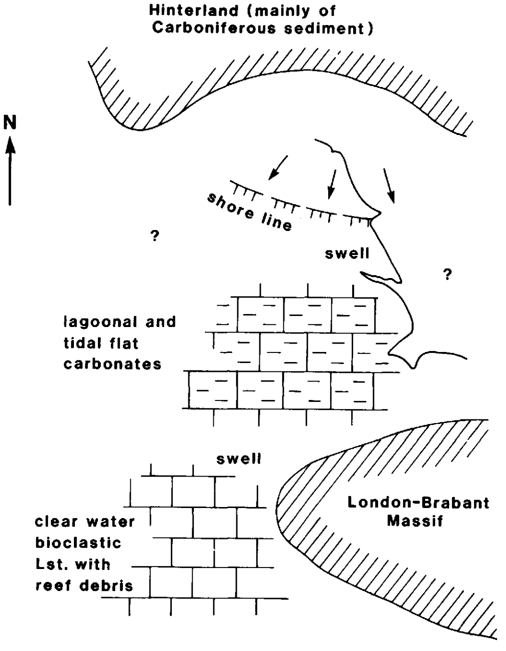

FIG. 5. A generalized palaeogeographic reconstruction. (After Livera 1981.)

was never far removed from marine influence. This evidence includes intercalation of marine formations and members, early diagenetic features and microfossils characteristic of brackish marine conditions within sediments with a dominantly alluvial character.

At the transition from the Lebberston Member to the Gristhorpe Member (Fig. 3), the Yons Nab Beds represent a rapid progradation of a wave–tide–fluvial influenced shoreline (Livera 1981). This is the only part of the succession where shoreline deposits are recognized. In the Saltwick and Scalby Formations there is evidence for a gradual upward increase in marine influence, shown by the occurrence of brackish marine microfossils and changes in palaeosol characteristics. This increased marine influence is interpreted as the result of a slow rise in sea level and subsidence of the area owing to sediment consolidation (Alexander 1986*a*).

One of the main differences between the Ravenscar Group and many other successions is that, in this case, the alluvial formations are relatively much thicker than the marine formations. In other successions described as deltaic, such as the Yordales of northern England, the converse is true. In the Ravenscar Group there is only locally preserved evidence of progradation into standing water (Livera 1981).

Palaeogeography of NE England during the Middle Jurassic

During the deposition of the Ravenscar Group, the Yorkshire Basin slowly and periodically subsided relative to the Pennine and Mid-North Sea Highs to the N (Kent 1974; Hemingway & Riddler 1982) and the Market Weighton Block to the S (Bott *et al.* 1978). The main sediment supply was from the N with rivers apparently converging into the Yorkshire Basin from the Pennine and Mid-North Sea Highs, and a shallow shelf sea lay to the S over the Market Weighton Block. S of the Market Weighton Block, the Bajocian is represented by a variety of shallow-marine lagoonal clastic and carbonate sediments of the Inferior Oolite Series. There was therefore a restricted marine connection to this area throughout the Middle Jurassic.

The area generally had a gentle southerly slope that allowed the position of the shoreline to change drastically in response to relatively minor tectonic movements and/or changes in sea level. One of the effects of this gentle slope is seen near the base of the Saltwick Formation where there is evidence of an increase in marine influence to the S through a small increase in the appearance of brackish marine microfossils and a slight change in the types of plant fossils (Harris 1953). There is no evidence, however, of 'deltaic' deposits in the Sole Pit Trough (Kent 1980) and little clastic input to the carbonate shelf to the S.

Coastal plain model for the Ravenscar Group

The interpretation of an alluvial-dominated tectonically and eustatically controlled coastal plain model is the result of considering a large volume of data collected over the last two decades (Knox 1969; Nami 1976; Livera 1981; Alexander 1986*a*). The main factors that lead to this model are as follows.

(1) A sudden onset of marine conditions at the base of the Saltwick Formation. The initial onset of alluvial conditions is interpreted to have resulted from local tectonic uplift rather than progradation of an alluvial system by autocyclic processes from the N or a sea-level change.

(2) The palaeogeography with inferred 'highs' to the N and S of the basin (Hemingway & Riddler 1982).

(3) The limited connection of the basin to open marine conditions, with a carbonate shelf to the S, so that small amounts of vertical movement would result in abrupt changes in depositional conditions. The slow subsidence of the Yorkshire Basin produced a clastic sediment trap that prevented dispersal farther S and so allowed the development of the carbonates to the S.

(4) No evidence of fanning or dividing of channel sandstone bodies southward has been found. Convergence of flow in the northern part of the basin has been suggested from provenance studies (Hemingway 1974; Hallam 1975).

(5) Tectonic influence on the Middle Jurassic Yorkshire Basin coastal plain is demonstrated by abrupt thickness changes across structural features (Fig. 4) and dramatic lateral variations in alluvial architecture (Alexander 1986*a*, *b*).

(6) The rising sea level throughout the Middle Jurassic is interpreted to be the cause of the gradual vertical increase in marine influence through the Scalby and Saltwick Formations.

Conclusions

Many depositional styles are possible on a constructive coastline. These can be classified by a four-end-member system into delta, autocyclically controlled coastal plain, tectonically controlled coastal plain and eustatically controlled coastal plain. Generally, a hybrid model will be most applicable. In the example from the Middle Jurassic of Yorkshire, a tectonically and eustatically influenced coastal plain model was found to fit the data best, rather than a delta environment as defined at the beginning of this paper.

ACKNOWLEDGMENTS: Heartfelt thanks are due to all those people who, in good spirit, answered my questions on definitions and generally put up with my persistent interruptions of civilized conversations at the bars of various conferences. I would like to thank Mike Leeder for his much-valued supervision during my 3 years in Leeds, British Petroleum for their financial support of my PhD, the French Institute of Petroleum for collaboration in the summer of 1986, and J. F. Freeman Ltd for donating the money to pay my wages at University College, Cardiff. Thanks are also due to Julie Jones, Liz Jolly and Mike Fisher for comments on the manuscript.

References

ALEXANDER, J. 1986*a*. *Sedimentary and tectonic controls of alluvial facies distribution: Middle Jurassic, Yorkshire and the North Sea Basins and the Holocene, SW Montana, USA*. Unpublished PhD thesis, University of Leeds.

—— 1986*b*. Idealised flow models to predict alluvial sandstone distribution in the Middle Jurassic Yorkshire Basin. *Marine and Petroleum Geology* **3**, 298–305.

—— 1987. Syn-sedimentary and burial related deformation in the Middle Jurassic non-marine formations of the Yorkshire Basin. *In*: JONES, M. & PRESTON, R. M. F. (eds) *Deformation of Sediments and Sedimentary Rocks*. Geological Society of London Special Publication **29**, 315–324.

—— & LEEDER, M. R. 1987. Active tectonic control of alluvial architecture. *In*: ETHRIDGE, F. G., FLORES, R. M. & HARVEY, M. D. (eds) *Recent Developments in Fluvial Sedimentology*. Society of Economic Paleontologists and Mineralogists Special Publication **39**, 243–252.

—— & WILLIAMS, G. D. *Seismically induced soft-sediment deformation in Triassic marginal lacustrine deposits*. In preparation.

BARRELL, J. 1912. Criteria for the recognition of ancient delta deposits. *Bulletin of the Geological Society of America* **23**, 377–446.

—— 1914. The Upper Devonian delta of the Appalachian geosyncline. *American Journal of Science* **37**, 225–253.

BOTT, M. H. P., ROBINSON, J. & KOHNSTAMM, M. A. 1978. Granite beneath Market Weighton, east Yorkshire. *Journal of the Geological Society, London* **135**, 535–543.

CURRAY, J. R. 1960. Sediments and history of Holocene transgression, continental shelf, north west Gulf of Mexico. *In*: SHEPARD, F. P., PHTEGER, F. B. & VAN ANDEN, T. H. (eds) *Recent Sediments, North West Gulf of Mexico*. American Association of Petroleum Geologists, 221–226.

FISHER, M. J. & HANCOCK, N. J. 1985. The Scalby Formation (Middle Jurassic, Ravenscar Group) of Yorkshire: reassessment of age and depositional environment. *Proceedings of the Yorkshire Geological Society* **45**, 293–298.

GALLOWAY, W. E. 1981. *Depositional Architecture of Cenozoic Gulf Coastal Plain Fluvial Systems*. Society of Economic Paleontogists and Mineralogists Special Publication **31**, 127–155.

HALLAM, A. 1975. *Jurassic Environments*. Cambridge University Press, Cambridge, 269 pp.

HANCOCK, N. J. & FISHER, M. J. 1981. Middle Jurassic North Sea deltas with particular reference to Yorkshire. *In*: ILLING, L. V. & HOBSON, G. D. (eds) *Petroleum Geology of the Continental Shelf of N.W. Europe*. Institute of Petroleum, London, 186–195.

HARRIS, T. M. 1953. The geology of the Yorkshire Jurassic Flora. *Proceedings of the Yorkshire Geological Society* **29**, 63–71.

HEMINGWAY, J. E. 1974. The Jurassic. *In*: RAYNER, D. & HEMINGWAY, J. E. (eds) *The Geology and Mineral Resources of Yorkshire*. Yorkshire Geological Society, 161–223.

—— & KNOX, R. W. O'B. 1973. Lithostratigraphical nomenclature of the Middle Jurassic strata of the Yorkshire Basin of north-east England. *Proceedings of the Yorkshire Geological Society* **39**, 527–537.

—— & RIDDLER, G. P. 1982. Basin inversion in North Yorkshire. *Transactions of the Institute of Mineralogy and Metallurgy* **91**, 175–186.

JACKSON, J. A., GAGNEPAIN, J., HOUSEMAN, G., KING, G. C. P., PAPADIMITRIOU, P., SOUFLERIS, C. & VIRIEUX, J. 1982. Seismicity, normal faulting and the geomorphological development of the Gulf of Corinth (Greece): The Corinth earthquakes of February and March 1981. *Earth and Planetary Science Letters* **57**, 377–397.

KENT, P. E. 1974. Structural history. *In*: RAYNER, D. & HEMINGWAY, J. E. (eds) *The Geology and Mineral Resources of Yorkshire*. Yorkshire Geological Society, 13–28.

—— 1980. Subsidence and uplift in East Yorkshire and Lincolnshire: a double inversion. *Proceedings of the Yorkshire Geological Society* **42**, 505–524.

KNOX, R. W. O'B. 1969. *Sedimentary Studies of the Eller Beck Beds and Lower Deltaic Series in Northeast Yorkshire*. Unpublished PhD thesis, University of Newcastle.

LEEDER, M. R. 1987. Sediment deformation structures and the palaeotectonic analysis of extensional sedimentary basins, with special reference to the Carboniferous of N. England. *In*: JONES, M. & PRESTON, R. M. F. (eds) *Deformation of Sediments and Sedimentary Rocks*. Geological Society of London Special Publication **29**.

—— & GAWTHORPE, R. 1987. Sedimentary models for extensional tilt block/half-graben basins. *In*: HANCOCK, P. (ed.) *Extensional Tectonics*. Geological Society of London Special Publication.

—— & NAMI, M. 1979. Sedimentary models for the non-marine Scalby Formation (Middle Jurassic) and evidence for Late Bajocian/Bathonian uplift of the Yorkshire Basin. *Proceedings of the Yorkshire Geological Society* **42**, 461–482.

LIVERA, S. A. 1981. *Sedimentology of Bajocian Rocks from the Ravenscar Group of Yorkshire*. Unpublished PhD thesis, University of Leeds.

—— & LEEDER, M. R. 1981. The Middle Jurassic Ravenscar Group ('Deltaic Series') of Yorkshire: recent sedimentological studies as demonstrated during a field meeting 2–3 May 1980. *Proceedings of the Geological Association* **92**, 241–250.

MAYALL, M. 1983. Earthquake induced synsedimentary deformation in late Triassic (Rhaetian) lagoonal sequence, South West Britain. *Geology Magazine* **120**, 613–622.

NAMI, M. 1976. *Sedimentology of the Scalby Formation (Upper Deltaic Series) in Yorkshire*. Unpublished PhD thesis, University of Leeds.

NELSON, H. F. & BRAY, E. E. 1970. Stratigraphy and history of Holocene sediments in the Sabine–High Island area, Gulf of Mexico. *In*: MORGAN, J. P. (ed.) *Deltaic Sedimentation Modern and Ancient*. Society of Economic Paleontologists and Mineralogists Special Publication **15**, 48–77.

JAN ALEXANDER, Department of Geology, University College, PO Box 78, Cardiff CF1 1XL, UK.