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Letter Section

Late Quaternary Deltaic Lowstand Wedges on the Rhône Continental Shelf, France

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Abstract

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Shallow seismic profiles on the Rhône continental shelf have shown the existence of stacked progradational lowstand wedges on the outer shelf accumulated during late Quaternary glacioeustatic lowstands. The wedges are bounded by sharp to erosional sequence boundaries and onlap onto the middle shelf. The thickness of individual wedges attains 50 meters at the shelf edge, where they are sheared by slumping. The wedges exhibit well-developed progradational clinoforms, episodically interrupted by internal unconformities on which there is a downward shift of the succeeding clinoforms. These represent small-scale (in the order of a few meters) falls in sea-level. During the Quaternary eustatic cycles, the durations of the stable highstand conditions appear to have been too brief to permit the regressive highstand tract to prograde to the outer shelf. Therefore, the shelf edge builds up entirely with lowstand wedges.

Introduction

In a recent paper, Posamentier and Vail (1988) described sedimentation patterns on clastic sedimentary shelves affected by cyclic variations in relative sea level. One of the more innovative aspects of their work is the analysis of the deposits associated with low sea-level conditions on the shelf, i.e. "shelf-perched lowstand wedges". These occur as regressive wedges of deltaic coastal sediments which prograde seaward over the outer shelf and upper slope, and onlap updip onto the shelf sequence boundary.

Although recent studies in the Gulf of Mexico by Suter and Berryhill (1985) have described thick deltaic depocenters on the outer shelf deposited during low Quaternary sea-level stands, to date no detailed stratigraphic description of lowstand wedge systems has been published, and their internal structure still remains conjectural. This paper presents the initial results of a detailed study of a complex of Quaternary lowstand wedges that has accumulated on the outer shelf adjacent to the present-day Rhône delta in Southeast France.

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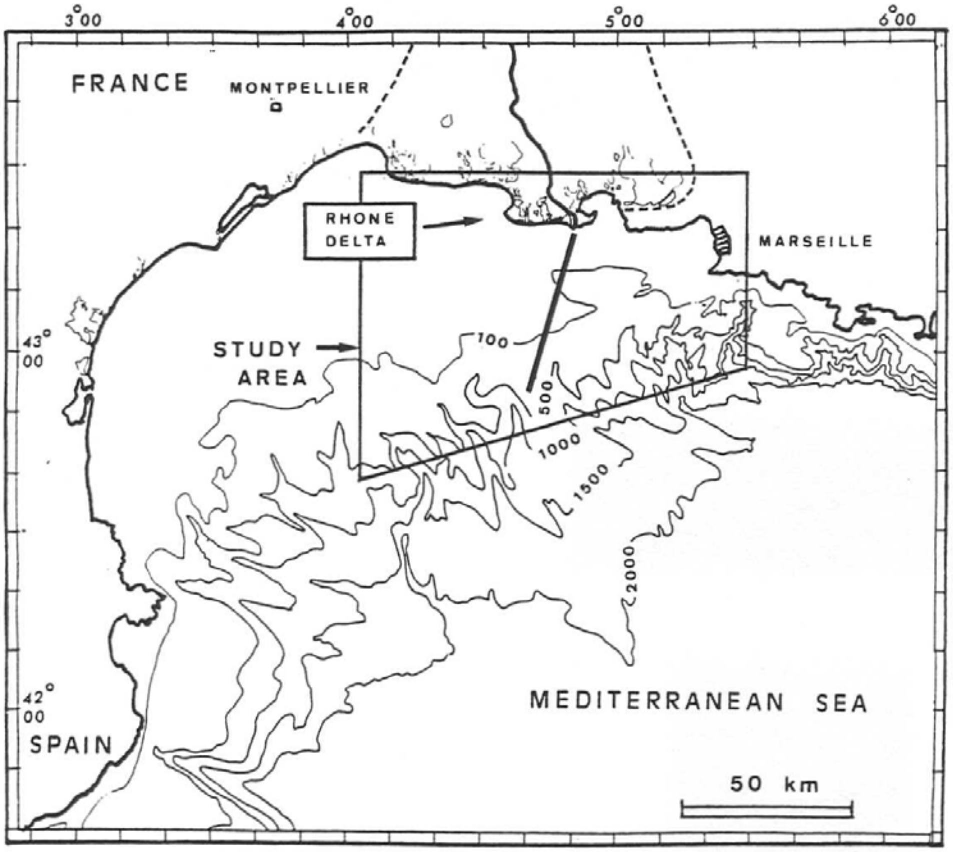

Fig. 1. French Mediterranean continental shelf and location of the high-resolution seismic transect discussed in this paper. Water depths are in meters.

Study area

The study area, on the continental shelf off the Rhône delta on the French Mediterranean coast (Fig. 1), is one where the shelf forms a relatively flat platform; in the area concerned it is about 50–60 km wide. The shelf break occurs at a water depth of 100–120 m and delimits a steep (up to 10°) continental slope incised by numerous canyons and affected by large-scale sediment mass movement (Coutellier, 1985). Although the entire region is within the active Alpine tectonic belt, relative sea-level changes due to subsidence or uplift were subdued during the late Pleistocene (Lefebvre, 1980), and the late Quaternary shelf deposits primarily reflect glacioeustatic sea-level changes.

During the past 2 years a grid of shallow seismic profiles has been established on the shelf and upper slope. Several transects have shown the regional stratigraphic relationships within late Quaternary deposits and one of the most representative is discussed in this paper (Fig. 1).

Description of the section

All the sections across the outer shelf within the study area exhibit a superposition of seaward progradational sediment wedges.

A regional transect (Fig. 2) was shot across the entire shelf, from the present-day Rhône delta to the shelf break, a distance of over 50 km. As shown, the outer shelf sediments consist of superposed progradational wedge-shaped units (as many as five are visible). The units

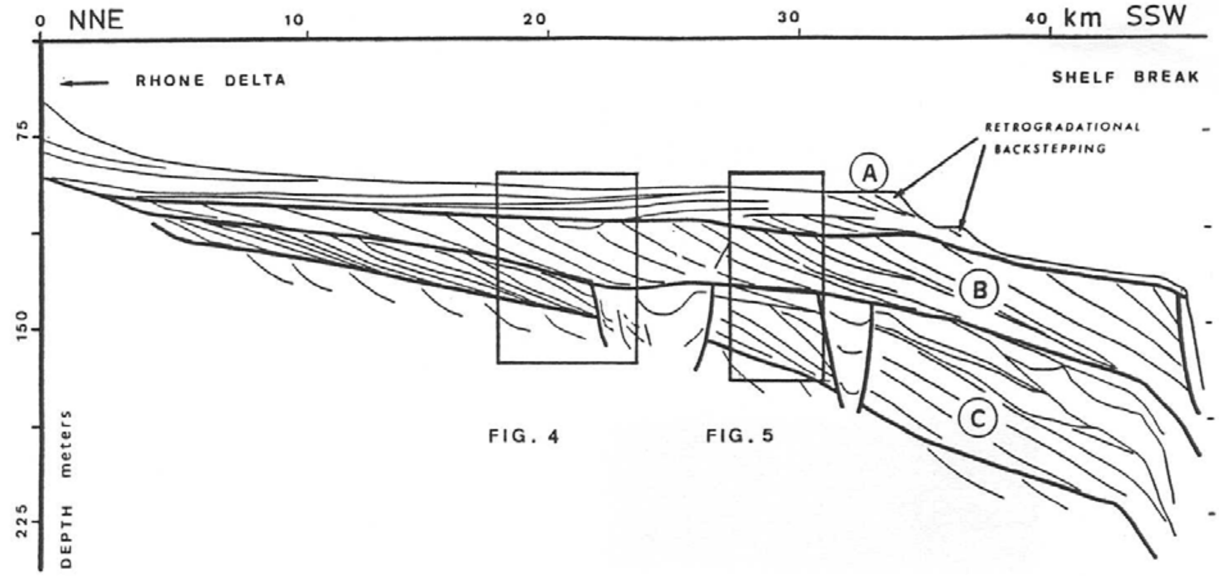

Fig. 2. Regional transect (see Fig. 1 for location) illustrating the internal geometry of the superposed sediment wedges on the outer shelf. Detailed studied units are noted: A, B and C.

are separated from each other by downlap surfaces and all have prograded out to the shelf break. However, the high gradient of the continental slope has impeded sediment progradation on the slope because large-scale slumping and sediment failure shears off the distal extremity of the prograding wedges as soon as they attain the shelf edge. This slumping is a common feature all along the shelf break. The three youngest units (A, B and C in Fig. 2) are described in this paper.

Units B and C can be traced over the entire study area and form widespread landward tapering progradational sediment wedges. Unit B clearly terminates updip by onlapping onto the top of unit C on the mid-shelf at a water depth of 90 m. This onlap consistently occurs at the same depth (Fig. 3). Unit C also pinches out in the mid-shelf region; however, it is not possible to clearly identify the exact point of its onlap onto the shelf. Both units exhibit well-defined seaward clinoforms which have prograded out to the physiographic shelf break, where they attain a total thickness of about 50 m. Unit C is also affected locally by synsedimentary slumping and faulting in zones of retrogressive slump

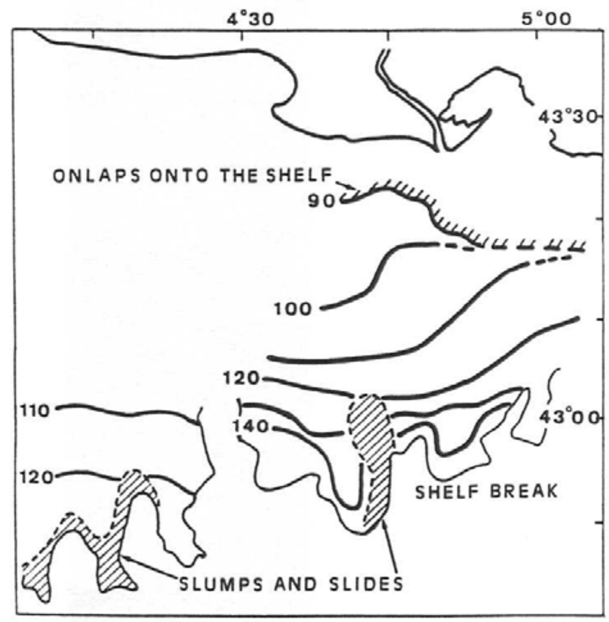

Fig. 3. Contour map of the upper boundary of unit B (contours in meters below present sea level).

systems which can be traced seaward into a canyon-like depression on the shelf margin and upper slope (Fig. 4). These canyons, or large "gullies" in the terminology of Coleman (1981), act as depocenters on the shelf margin.

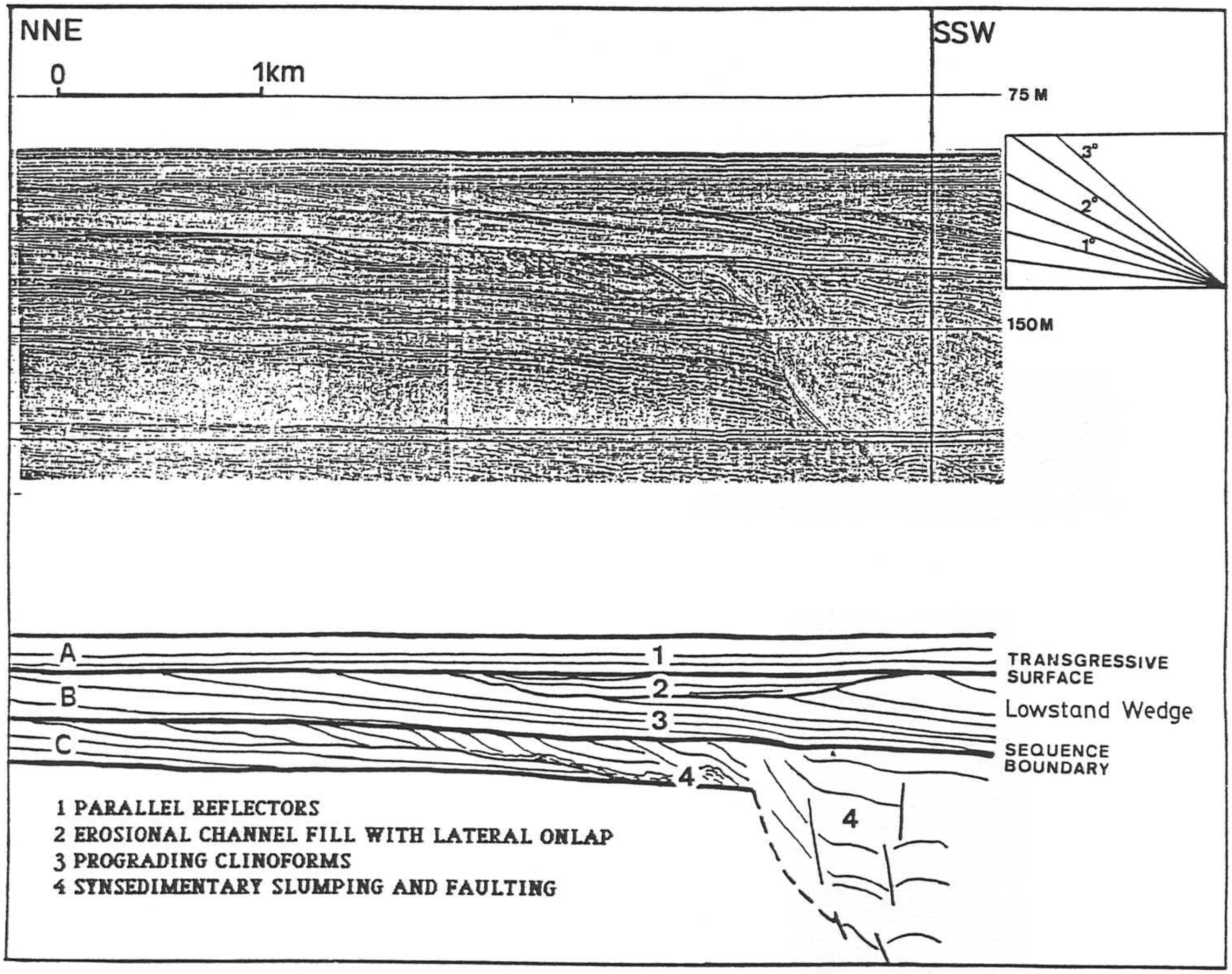

Fig. 4. Part of the seismic transect in Fig. 2 and line drawing illustrating the internal structure of units A, B and C. Note the synsedimentary faulting and slumping in unit C, and the erosional channel feature incising the top of unit B.

The internal organisation of the progradational units is complex and the clinoforms are regularly interrupted by oblique surfaces which mark a downward shift and onlap of succeeding clinoforms (Fig. 5). These surfaces are commonly erosional and can truncate the preceding clinoform surfaces. They subdivide a progradational wedge into a number of successive lozenge-shaped subunits which, as will be discussed later, can be interpreted as responses to variations in relative sea level.

The upper and lower surfaces which bound the progradational units B and C are generally abrupt and erode the underlying clinoforms. These surfaces are locally incised by erosional channels which are up to 0.5 km wide and 10–15 m deep and filled with oblique or horizontal reflectors which onlap onto the channel margins (Fig. 4). The upper unit (A) exhibits two prominent terrace-like features (Fig. 2) which consist of superposed retrogradational structures. Landward, the sediment surface slopes upward and joins the present regressive Rhône delta front which consists of beach sand and shoreface silty sands and prodeltaic muds (Aloisi, 1986).

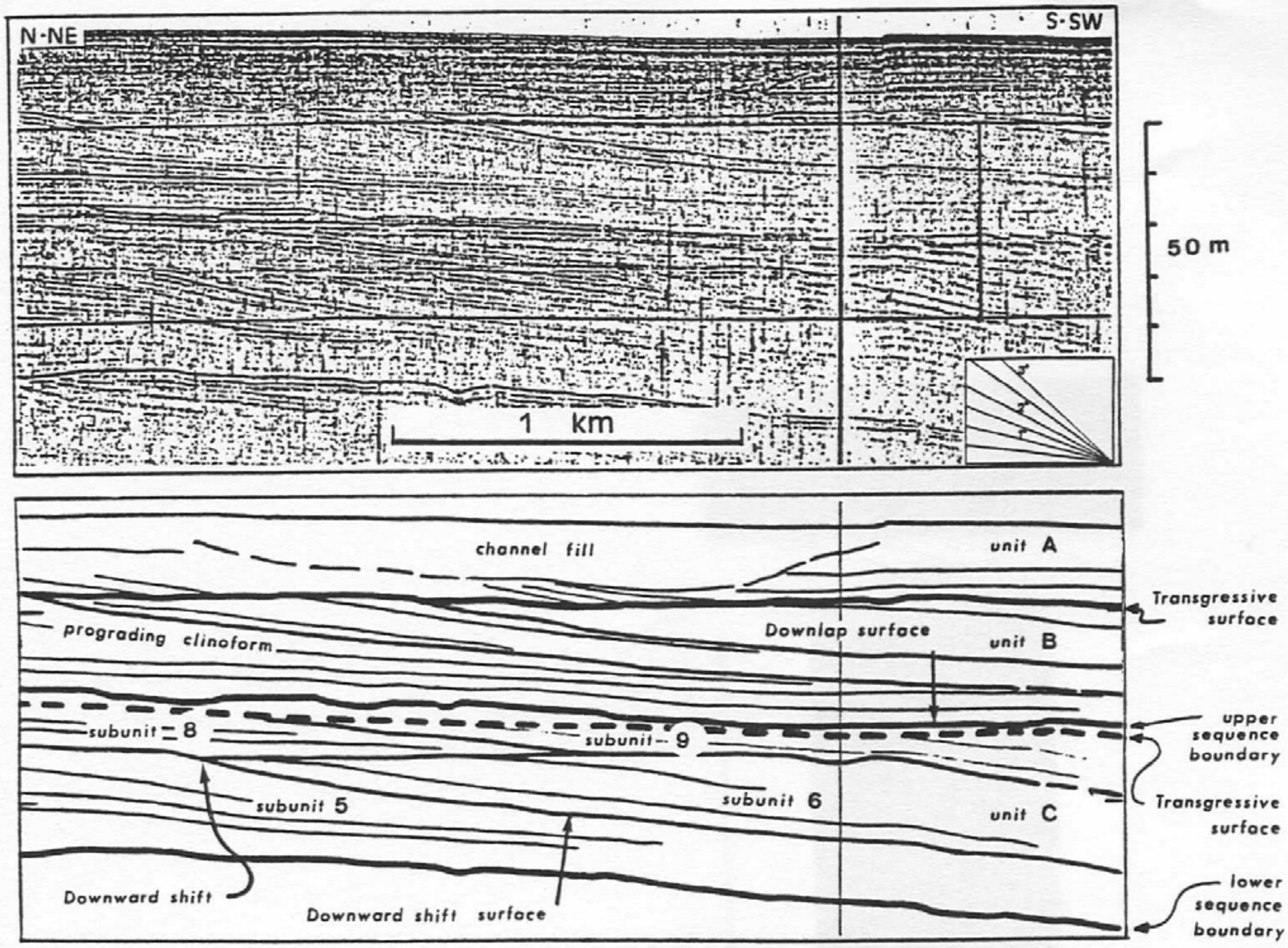

Fig. 5. Part of the seismic transect in Fig. 2 and line drawing illustrating downward shifts within units B and C.

Discussion

The regionally widespread and continuous clinoforms in units B and C strongly suggest coastal deltaic progradation, with facies probably similar to those of the modern Rhône delta, i.e., wave-dominated beach and shoreface deposits. If this is the case, the constant depth of onlap of wedge B onto the shelf (90 m below present sea level) indicates that the wedge accumulated when relative sea level was 90 m (or slightly less, due to isostatic readjustment) lower than at present. Unit C is very similar and also appears to onlap onto the mid-shelf. Therefore, unless late Quaternary subsidence was in the order of 90 m (which appears very improbable), both units B and C represent progradational lowstand wedges as defined by Posamentier and Vail (1988).

If units B and C are lowstand wedges, the toplap surfaces which cap the clinoforms would represent the transgressive surface (Fig. 6). These appear to be erosional and are probably wave-cut ravinement surfaces. In view of the lack of sigmoidal upbuilding of the clinoforms and the thin or absent transgressive tract between units B and C, this transgression seems to have been very rapid and accompanied by a low sediment supply.

Unit A represents a transgressive tract, as shown by the parasequence-scale retrogressive stacking of small progradational bodies above unit B. These bodies closely resemble the trans-

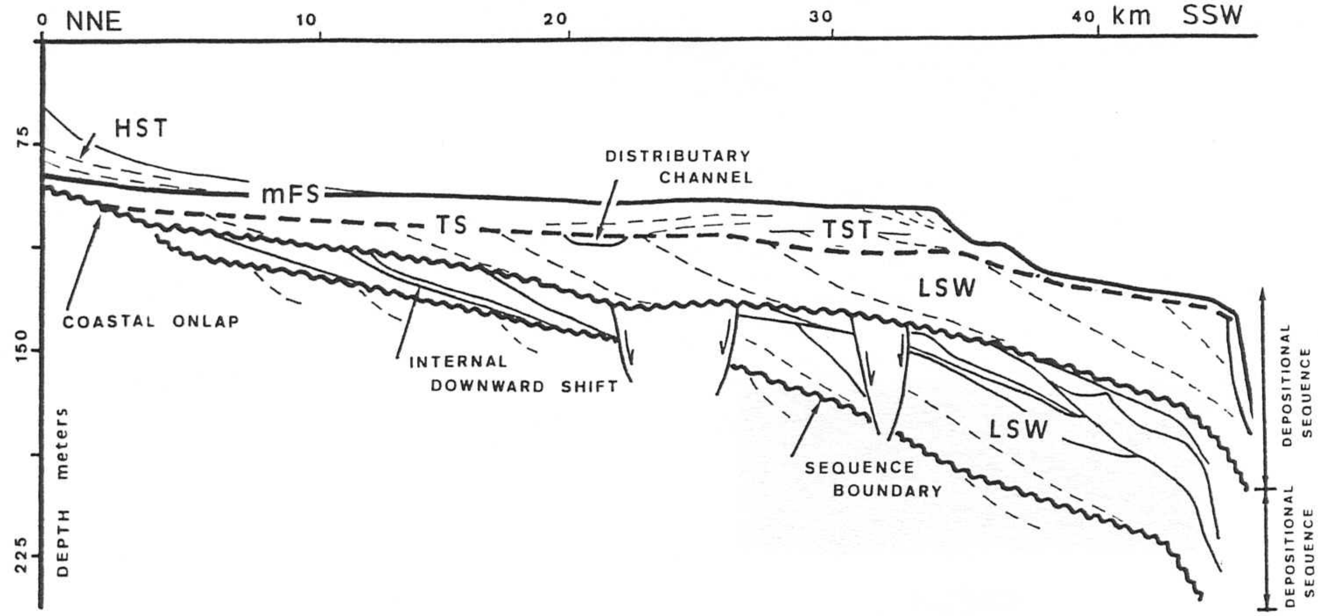

Fig. 6. Sequence stratigraphic interpretation, illustrating two separate depositional sequences and the depositional system tracts as defined by Posamentier and Vail (1988). *HST* - highstand system tract; *mFS* - maximum flooding surface; *TST* - transgressive system tract; *TS*- transgressive surface; *LSW* - lowstand wedge.

gressive parasequence stacking patterns illustrated by Van Wagoner et al. (1988).

In sequence stratigraphic terms, units C and B+A represent sequences deposited during two successive (?) eustatic cycles (Fig. 6). The apparent lack of highstand deposits could indicate that stable highstand conditions did not last sufficiently long for the Rhône delta to prograde to the outer shelf. The highstand tract is therefore only developed on the inner shelf.

The oblique surfaces which punctuate the progradational wedges and are accompanied by a downward shift of clinoforms indicate the occurrence of episodic small-scale falls in sea-level ($\leqslant 5$ m). These falls could be due to short-term climatic fluctuations. In addition to these allocyclic events, delta lobe switching could also form unconformable surfaces; however, the distinct downward shift of onlap leads us to believe that in most cases the discontinuities are formed by small-scale eustatic falls in sea level. This implies that they could be regionally correlatable. In outcrop section, these downward shift surfaces would be marked by an abrupt shallowing of facies within an overall upward shallowing trend, as illustrated by Mutti and Sgavetti (1987), Posamentier and Vail (1988) and Plint (1988). These surfaces downlap and converge onto the basal surface of the lowstand wedge, which would be the sequence boundary *sensu stricto*. The resulting structure, a lowstand wedge, would be very complex, as illustrated in Fig. 7.

Both the internal downward shift surfaces and the sequence boundary are erosional. This results from the sudden increase in storm wave energy on the seafloor which in turn results from the rapid lowering of sea level (see Plint, 1988). This implies that even though the lowstand wedges are progradational over the shelf, in outcrop and in cores their bases would be sharp.

The erosional channels which incise the upper surface of the wedges probably represent distributary channels associated with the prograding deltaic wedge. The successive step-like sea-level falls which affected the wedge as it prograded would have lowered the base level and caused the channel to become more incised. The base of the channel would therefore be genetically linked to the downward shift surface rather

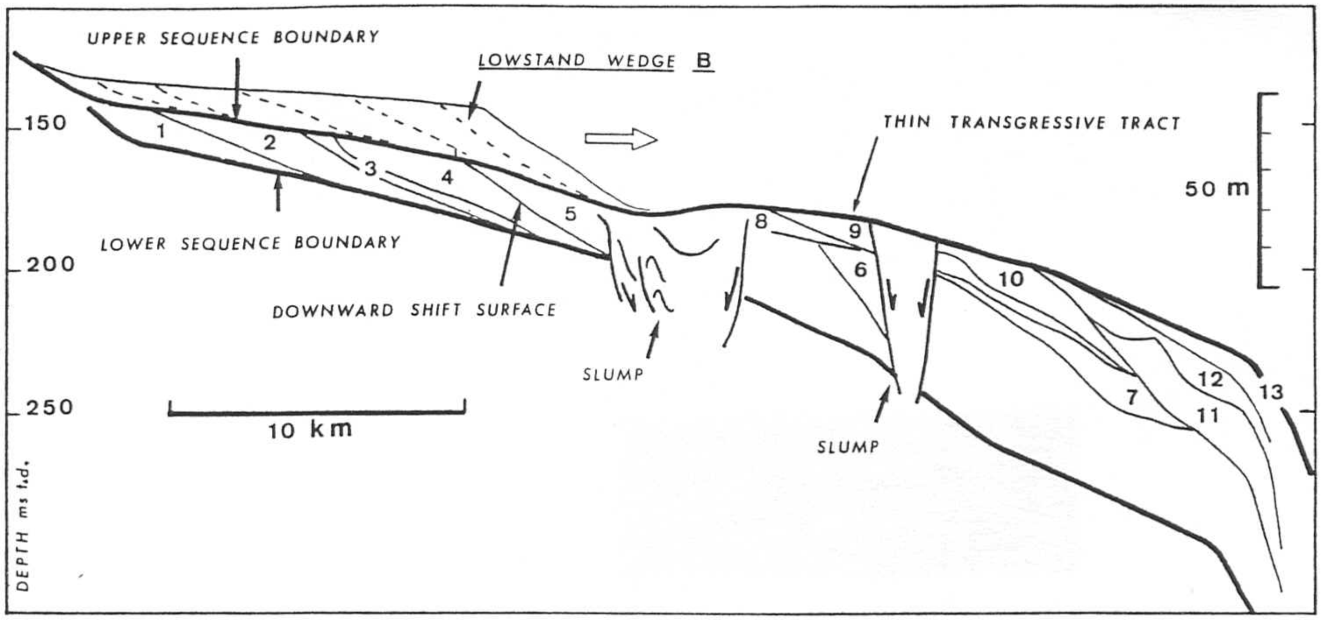

Fig. 7. Internal structure of lowstand wedge unit C illustrating the downward shift surfaces and the complex pattern of lozenge-shaped subunits. Note the sea-level rise after deposition of subunit 7 which resulted in an aggradational stacking of the subunits comprising the lowstand wedge.

than to the sequence boundary, as in the case of a true fluvial incised valley.

To the left of the section in Fig. 6, i.e. on the inner shelf, the distal extremity of the present-day highstand Rhône delta shoreface is visible downlapping onto the transgressive deposits. This delta has prograded about 15 km over the shelf during the last 6500 yrs, i.e. since the onset of the reduced rate of sea-level rise at the end of the Holocene (Oomkens, 1970).

Conclusions

Although more work is necessary to fully document the internal architecture of the shelf-perched lowstand wedge deposits, the following conclusions may be proposed:

(1) Quaternary glacioeustatic cycles resulted in the stacking of progradational lowstand deltaic wedges on the outer shelf; these wedges are bounded by regional unconformities. They may be affected by shelf edge slumping and thus provide sediment to the slope and basin.

(2) On the outer Rhône shelf the wedges are separated by thin transgressive deposits, and highstand deposits appear to be absent. This implies that on shelves affected by short-lived periods of highstand, the outer shelf would be built up mainly with lowstand wedges.

(3) The wedges are bounded by erosional sequence boundaries which onlap onto the shelf. Their internal structure is one of seaward prograding clinoforms interrupted by internal small-scale unconformities which mark episodic relative sea-level falls.

(4) The upper surface of the wedges is locally eroded by distributary channels which can be incised by subsequent sea-level falls as well as by wave ravinement during transgression.

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