3D SEISMIC STRATIGRAPHY AND EVOLUTION OF UPPER PLEISTOCENE
DEEPWATER DEPOSITIONAL SYSTEMS, ALAMINOS CANYON,
NORTHWESTERN DEEP GULF OF MEXICO

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ABSTRACT: The Pleistocene Alaminos Fan in the northwestern deep Gulf of Mexico is a large submarine fan located at the base of the continental slope. High-resolution, near-seafloor 3D seismic data were interpreted to study the evolution of two Pleistocene shallow sequences. Results indicate that there can be considerable variability in the evolution of deepwater systems in the same overall setting, and the significance that seafloor topography and gradient changes can make in the overall development of different architectural elements. Seismic facies indicate that the sequence consists primarily of mass-transport deposits (MTDs), channel-fill sediments, and sheet deposits in the lower sequence, whereas the upper sequence consists of a single channel.

The older sequence consists of two distinctly different deepwater systems. To the east, a prominent channel system overlies basal MTDs. The channel system consists of one upfan channel that bifurcates downfan to at least six discrete channels flanked by levees. The evolution of the downdip distributary channel system is the result of deposition in the unconfined setting. To the west, an updip channel fed sheet deposits that developed in the back limb of a fold in a confined setting. The sheet, in turn, is overlain by a channel–levee system. This vertical change is likely the results of the fill-and-spill of sediments in the area.

In the near-floor sequence, a single deepwater channel is flanked by low-amplitude levee reflections. Quantifying the dimensions of this younger channel shows that it evolved from a wider, straight channel at the base of the sequence to a relatively narrow sinuous channel with increasing sinuosity upward.

KEY WORDS: Seismic stratigraphy, deepwater fan, deepwater channels, sheet deposits, evolution, mass-transport deposit

INTRODUCTION

The continental slope of the northern deep Gulf of Mexico has a complex, irregular bathymetry that has greatly affected the distribution of Cenozoic deepwater depositional systems. The middle and lower slope is characterized by a series of bathymetric highs and lows created from shallow allochthonous salt or intraslope basins with thick Cenozoic sediments, which were the sites of salt withdrawal (Fig. 1). These intraslope basins have created a series of confined deepwater depositional systems. The basinward edge of the lower slope is the Sigsbee Escarpment, a major structural feature that was created from the amalgamation of several shallow allochthonous salt features (Fig. 1). In four areas along the Escarpment, Pleistocene channels have bypassed through the confined lower slope and expanded at the base of slope into the unconfined abyssal plain, creating large channelized submarine fans. From west to east, these are the Alaminos Canyon Fan (Morton and Weimer, 2000), Keathley Fan (Lee et al., 1989), Bryant Fan (Lee et al., 1996), and Mississippi Fan (Weimer and Dixon, 1994).

The lower slope in the Alaminos Canyon area consists of a series of amalgamated allochthonous salt bodies that originated from separate salt features (Fiduk et al., 1996). A prominent embayment is present in the salt front forming the “canyon,” which is actually an area in between salt tongues and is not stratigraphic in its origin. During the Pleistocene, this reentrant has served as a conduit for deepwater channels where they emanate from the lower slope onto the abyssal plain.

Using regional 2D seismic data, Morton and Weimer (2000) defined five Pleistocene depositional sequences and mapped a
series of channel–levee systems that originated from the “canyon” and farther to the east. A recently acquired 3D seismic data set across the same general area has allowed us to study the evolution of these channels in greater detail. Water depths in this area range from 2100 meters in the north to 3200 meters in the south. The relatively shallow depth of the channels in the subsurface allows us to perform a systematic evaluation of the vertical and lateral evolution of deepwater depositional elements from a confined to an unconfined setting. During the late Pleistocene, the bathymetry of study area was somewhat irregular. To the east, the gradient change was gentle toward the deep basin; to the west, the backlimb of a deepwater fold created an irregular gradient where a subtle basin was filled via the fill-and-spill process.

Importantly, this paper presents a case study from a small portion in the Alaminos Canyon protraction area that builds on previous work and illustrates the 3D seismic stratigraphic interpretation of the near seafloor in a base-of-slope setting. The purpose of the paper is to: (1) characterize the evolution of deepwater depositional systems within a sequence stratigraphic framework at the transitional area from a confined setting to an unconfined setting, (2) describe the systematic evolution of channels and sheet deposits in two different sequences, (3) quantify some of the channel attributes in the youngest sequence, and (4) document how subtle difference in the gradient of the base-of-slope area affects the architecture and sedimentary evolution of the area.

REGIONAL SETTING AND DATA BASE

The Alaminos Canyon protraction area is a major exploration province in the northwestern deep Gulf of Mexico. During the past ten years, six discoveries have been made in the study area, and three began production in 2010 (Great White, Silvertip, and Tobago) (Figs. 2, 3). The traps for these fields consist of large box folds of the Perdido Foldbelt, a southwest-trending feature (Trudgill et al., 1999; Camerlo and Benson, 2006) (Fig. 4). The upper Paleocene and lower Eocene strata (downdip equivalent to the shallow-marine Wilcox Formation) form the major reservoirs. The reservoirs are found in distributary channel-fill to sheet-like deepwater channel-fill strata deposited in the unconfined abyssal plain (Zarra, 2007). The foldbelt developed primarily during the early Oligocene, creating a series of bathymetric highs and lows. These folds remained high through the Pleistocene, affecting the distribution and lithofacies of the lower sequences of the Alaminos Fan (Fig. 4).

The 3D data set used in this study includes the upper 500 ms of a 3D seismic survey covering 1000 square miles (2600 square kilometers) (Figs. 2, 4). Bin size is 25 m x 25 m. No wireline logs from the exploration wells penetrated the two sequences, so the lithology from the wireline logs could not be correlated to the seismic data.

SEQUENCE STRATIGRAPHY AND DEPOSITIONAL ELEMENTS

Morton and Weimer (2000) defined five Pleistocene depositional sequences in the study area, informally numbered as 1–5 (oldest to youngest). The ages of the sequences are not known in detail. The sequences were defined by first identifying the condensed sections and erosional sequence boundaries. The condensed sections have good lateral continuity across the study...
Fig. 2.—Map showing the regional setting of the Alaminos Fan, its bathymetry (contour interval is 100 m), and undifferentiated allochthonous salt in the lower slope (blue). Fold axes of Perdido Foldbelt are show by dashed lines and numbered 1 to 5. Black dots show location of exploration wells. Black box outlines the location of the Alaminos Protraction area in the northern Gulf of Mexico. Modified from Morton and Weimer (2000).

Fig. 3.—Map showing location of the channel valleys of the four channel–levee systems identified by Morton and Weimer (2000). Channels are numbered according to their occurrence in sequences (1, 2, 4, 5). The 2D seismic grid used for the study is shown by gray lines. Black box outlines the location of the 3D data set. Coalesced salt tongues of the Sigsbee Escarpment are shown in gray.
area associated with relative highstands in sea level. These horizons can have extensive regional onlap from the overlying sequence. Locally, these condensed sections are eroded by the overlying sequence; this erosional surface is the deepwater expression of the sequence boundary. Sequence boundaries were recognized by erosional truncation of the underlying sequence and the onlap of reflections of the overlying sequence. Commonly, chaotic to hummocky reflections overlie more parallel reflections (levee–overbank) across this erosional surface. Where the erosional sequence boundary is traced laterally, it merges with the top of the condensed section (Fig. 4). Thus, the top of each condensed section is the correlative conformity at the base of each sequence.

Five distinct depositional elements with distinct seismic facies are present: channel fill, levee, overbank, mass-transport deposits, and sheets (Fig. 5). Channel-fill sediments exhibit high-amplitude reflections with fair to moderate continuity. Deposits are limited laterally, but are extensive in the downfan direction. Levees have low to moderate reflections with good lateral continuity. They are wedge-shaped in cross section, and adjacent to the channel margin. Overbank deposits constitute most of the sediments in this deepwater area. They consist of parallel to subparallel reflections with low to fair amplitude and good to fair continuity. Sheet deposits are continuous, high-amplitude parallel reflections and are present in paleobathymetric lows. Mass-transport deposits primarily overlie erosional sequence boundaries. These deposits consist of low-amplitude, chaotic reflections with poor continuity. The top of these reflections is commonly a laterally continuous, high-amplitude reflection, and these reflections are then overlain by a channel complex. The laterally continuous reflection is interpreted as a localized condensed section that formed associated with decreased rates of sedimentation within the sequence.

Of the five sequences identified by Morton and Weimer (2000), this study focuses on the two youngest sequences, numbers 4 and 5. Two distinct sites of deposition are present in the study area basinward of the escarpment in these two sequences (Figs. 2, 4). East of fold 1, the channels extend into the unconfined abyssal plain, where the sea floor has a gentle gradient. Between fold crests 1a and b, the channels cross a bathymetric low area that created a confined setting, somewhat similar to the intraslope basins to the north in the continental slope. The architecture of the coeval deepwater deposits differs from the unconfined to confined setting.

SEISMIC ATTRIBUTES

The morphology, architecture, and internal sedimentary facies of the deepwater systems were imaged in 3D seismic data by extracting seismic attributes based on the interpreted horizons. A number of seismic attributes were utilized: average energy, average reflection, maximum-absolute amplitude, maximum-peak amplitude, mean amplitude, total amplitude, edge detection (continuity or coherence), and root-mean-square (RMS). A comparison of these initial attributes indicates the RMS attribute is the best candidate to characterize this deepwater system (Fig. 6A, B).

Two additional attributes, spectral decomposition and stratal slices (Hammon, 2009), were used to further analyze the stratigraphic architecture. Spectral decomposition analysis and stratal slices by using opacity (Fig. 6A, B) show a result similar to that from RMS. Using spectral decomposition, the morphology of the channel-fill reflections can be imaged well at lower frequency (30 Hz) because of the marked differences in amplitude values between the channel-fill and levee–overbank reflections. In stratal slices, channels were interpreted from flattened vol-
Fig. 5.—Seismic profiles showing the details of the sequences in portions of the study area. See Figure 4 for location of profiles. SB = sequence boundary, MTD = mass-transport deposit. A) Profile across western portion of area is in the backlimb of the fold. Sequences 2 and 3 are characterized by mass-transport deposits at their base overlain by low-amplitude reflections. Sequence 4 is characterized by continuous parallel reflections that thin and onlap at the edges of the basins (sheet deposits). Sequence 5 has low-amplitude overbank reflections. B) Profile across eastern portion of study area. Sequence 4 is characterized by high-amplitude reflections of channel-fill sediments that change their position throughout the evolution of the sequence. Low-amplitude levee and overbank reflections bound the entire area. Sequence 5 consists of a single channel with moderate-amplitude reflection. Most of the sequence consists of low-amplitude levee and overbank deposits.
ume slices produced using Domain Transformation, a technique that simultaneously flattens an entire interval of a seismic volume (Hammon, 2009). The transformation process resamples a seismic volume to a fully flattened state, known as the stratal domain. In the stratal domain, each horizontal slice (known as a stratal slice) is a representation of a paleo–depositional surface such that depositional elements present in a volume are rendered easily interpretable. The domain transformation process is guided and constrained by previously interpreted surfaces. In this study, the constraining surfaces are deepwater sequence boundaries.

**3D SEISMIC STRATIGRAPHY**

**Sequence 4**

The distribution of the architectural elements of sequence 4 are intriguing because the eastern side is characterized by a channelized system deposited in a largely unconfined bathymetric setting, whereas the western area consists of sheet-like deposits in the backlimb of a fold in a confined bathymetric setting. To illustrate the details and variability in the two areas, a series of sequential vertical profiles are shown in Figures 7 and 10 to illustrate the downfan evolution of the eastern and western systems. These profiles are discussed in some detail below to emphasize the extensive depositional variability from upfan to downfan. In addition, seismic attribute maps (RMS and stratal slices) are shown here to illustrate the morphologic features and evolution of the deepwater channels and sheet deposit (Figs. 8, 9, 11, 12).

**Eastern Area.**

The channel system has distinct downfan changes in three areas. In the two upfan profiles, channel fill tends to be strongly aggradational with little lateral migration (Figs. 7A, B). The middle five profiles indicate that the channelized zone has begun to expand laterally, with extensive cross-cutting within the channels (Figs. 7C–G). The three downfan profiles illustrate that the channel has become more distributary, with distinct separate channels (Figs. 7H–J).

Upfan, two distinct zones of aggradational high-amplitude reflections are present vertically (labeled a and b in Figure 7A) that are offset by about 1.5 km migrate from west to east (Fig. 7A).
Five kilometers downfan, the same two vertical zones of high-amplitude reflections are present (labeled a and b in Figure 7B); however, the amount of lateral migration is less than in the upfan profile.

Significant changes in the channel architecture and morphology begin to develop five kilometers downfan, as the width of the high-amplitude channel-fill sediments has increased to about 8 km, indicating that the channel fill begins to become more distributary (Fig. 7C). Two general vertical zones of high-amplitude reflections are still present (labeled a and b in Figure 7C). With the increase in the width of the channel-fill zone, more details of the sedimentary processes can be observed. In the lower zone (a), the dipping high-amplitude reflections indicate both a western and an eastern direction of channel migration. In the upper zone (b), the channel migrated to the west initially, and then to the east at the end of the channel fill.

An additional five kilometers downfan, the width of the channel fill in the lower zone (a) remains about 8 km, whereas the width of the upper zone is less than 2 km (Fig. 7D). Continued lateral migration and erosion is present in the lower zone; the upper zone remains a fairly stationary, aggradational channel fill. In Figure 7E, the same two vertical zones of high-amplitude, channel-fill reflections are present (a, b). The lower zone is up to 10 km in width; the initial channel fill migrates from the east to west, and then migrates back to the east. In the uppermost zone (b), five discrete high-amplitude zones of aggradational reflections are present with no lateral offset (labeled I–V in Figure 7E).

In Figure 7F, the overall zone of channel fill continues to increase in width to 15 km. In lower zone (a), the high-amplitude reflections migrate from west to east; in the upper zone (b), channel fill seems to migrate from east to west. One notable observation is that unlike the upper zone upfan 5 km, there are not any discrete, individual channel fills. Instead, the channel has eroded into one another, creating a more continuous zone of high amplitude.

A distinct change in the channel-fill architecture begins to evolve in the four downfan profiles. The distinct lower and upper zones present upfan have changed downfan to where discrete individual channel-fill sediments are flanked by levees, and become more distributary downfan. Four discrete zones of high-amplitude channel-fill reflections are present (labeled I–IV in Figure 7G, H) separated by zones of low-amplitude regions associated with the levees. The channel-fill reflections show distinct migration to the east. The updip bifurcation and distinct individual zones of channel fill are evident. Each discrete zone of high-amplitude channel fill is in turn overlain by the low-amplitude facies of the levees that are coeval to younger channel fill. Farther downfan, the channels become increasingly distributary and isolated (Fig. 7I, J).

The updip-to-downdip changes of the channel systems are shown in four vertical levels in Figure 8. The stratal slices show that the morphologies and geometries of the channel-fill deposits vary between stages; these variations are also illustrated in the vertical profiles. The lowermost channels are erosional and fairly linear (Fig. 8E), and become more distributary-like in the next level
Fig. 7 (above and on following two pages).—A–J).—Ten updip to downdip seismic profiles across the eastern portion of the study area. See text for details of interpretation. See Figure 8 for location of profiles.
The distributary pattern corresponds to a series of channels that have cut into one another and filled with sediment. The crosscutting relationships create good continuity and connectivity in the channel-fill sediments. Upward, the channels become more individual and discrete, with less cutting and eroding into one another (Fig. 8C). The shallowest level of channels is slightly more sinuous and increasingly more isolated (Fig. 8B).

The RMS amplitude maps show a pattern similar to the stratal slices (Fig. 9). At the base of sequence 4, a series of chaotic, low-amplitude reflections of a mass-transport deposit overlie an erosional boundary (Figs. 7F, 9A). The overlying channel systems initially develop as a wide zone of higher amplitudes (60, 150 ms), changing upward to a more distributary system with discrete separate channels (220, 300, 400 ms).

**Western Area.**

In the backlimb of the fold, sequence 4 consists, at its base, of largely nonchannelized sheet-like reflections that onlap the flanks of the folds (labeled a in Figure 10A). These deposits are overlain by lower-amplitude reflections with variable continuity and reflection geometry (labeled b in Figure 10A). The lower unit (a)
Fig. 7 (continued).—
is partially eroded by the overlying unit (b) near the crest of the eastern fold (Fig. 10A). About 5 km downfan (southwest), the thickness of the lower unit (a) decreased due to erosion by the overlying unit (b). Two MTDs and channel-fill sediments are present in unit b. An additional 5 km downfan, the crest of the fold has less bathymetric expression, and the basin begins to widen and have less gradient change (Fig. 10C). The sheet is partially eroded to the east by the overlying unit b. The upper part of the sequence consists of a series of low-amplitude reflections with variable continuity. Another 5 km downfan (Fig. 10D), the sheet has begun to disappear as the eastern edge is eroded by the overlying unit. Erosion along the base of this unit has a stairstep appearance, overlain by dipping reflections (rotated blocks). In Figure 10E (5 km downfan), the sheet deposits are apparently not present, and slides directly overlie the lower interval to the west.

The stratal slices emphasize the vertical differences in geometries of the deposits (Fig. 8). Distinct ponded sheet deposits are present in the lower two images (blue and green, respectively, in Figure 8D, E), which are fed by updip channels (not shown in Figure 10). In the upper two images (Fig. 8B, C), a channel, partially imaged on the seismic profiles (Fig. 10C), can be seen to bypass through the area.

RMS amplitude maps illustrate a vertical evolution similar to that of the stratal slices (Fig. 9). The higher amplitude (yellow) to the west is present in the image 20 ms above the SB 4 horizon (Figure 10). At 60 ms above the SB 4, the outline of the sheet is still visible, although decreasing markedly in amplitude. The four overlying images (150, 200, 220, 300, 400 ms) all show low amplitudes indicating the shallower interval present in the sequence seen on the seismic profiles.
In sequence 5 (near-floor sequence), seismic images show a single deepwater channel that trends to the southeast. The updip to downdip changes on vertical profiles are illustrated in Figure 7. The updip channel consists of a zone of high-amplitude reflections with little lateral migration (Fig. 7A). The channel width is about 2 km. This channel directly overlies the channel fill of the underlying sequence. Downdip 5 km, the high-amplitude channel-fill reflections are about 2.5 km wide at their bases; the channel fill migrates to the west, and the channel-fill zone becomes narrower upward (Fig. 7B). Another 5 km downfan, the seismic profile crosses the sinuous bend of the channel such that the channel-fill reflections are imaged twice (Fig. 7C). Bathymetric elevated levee reflections are present on both sides of the channel fill.

From this point downfan, the amplitudes of the channel-fill reflections decrease with little lateral migration. The amplitudes of the channel-fill reflections are considerably lower than in the underlying sequence, possibly indicating finer-grained sediments filling the channel. The four downfan profiles all show a zone of channel ranging from 2 to 3 km in width, and a decrease in the amplitude and a decrease in the lateral continuity of the channel-fill reflections (Figs. 7D–H).

The stratal slices through this channel also indicate a slight upward change in channel geometry (Fig. 11). The lower stratal slice shows a fairly straight channel with only one significant updip sinuous bend. Shallower in the section, there is a discrete increase in the sinuosity of the channel in three discrete areas. A
similar vertical change is shown in four RMS amplitude maps (Fig. 12). Between 330, 280, 230 ms extractions, there is a slight increase in sinuosity (Figure 12). By 180 and 100 ms, the channel has increased in its sinuosity of the channel. An RMS extraction map of the seafloor shows sediment drape within the channel. This shale drape is indicative of low rates of sedimentation and is a condensed section characterized from the high-amplitude reflection (Fig. 12G).

QUANTIFICATION OF DEPOSITIONAL ELEMENTS

Quantifying the evolution of different depositional elements can provide important parameters for predicting geometries of sand bodies and reservoir modeling. For the youngest sequence (# 5), we measured vertical changes in the channel width and its sinuosity based on seismic attribute maps. Channels in sequence 4 could not be easily quantified due to the complex distribution of channel-fill sediments.

The channel-fill sediments in sequence 5 are about 40 km in length in the study area, and are fairly easy to quantify because of their simple geometries and relative shallowness. The channel width is a measurement of the high-amplitude reflections as identified on the seismic-attributes maps (Fig. 12). Channel widths were the average of measurements every 10 km from updip to downdip; results indicate that the width of the channel fill decreased from 2600 m upward to 1100 m (Fig. 13).

Sinuosity is the channel length divided by a straight-line valley length. Sinuosity of the channel in sequence 5 was measured from the RMS maps (Fig. 12). The results indicate that the sinuosity increased upward from 1.02 to 1.26 (Fig. 14). The upward decrease in channel width and increasing sinuosity was probably caused by a number of factors, including an increase in the mud content of the gravity flows, a decrease in the volume of the flows, and/or a slight decrease in the gradient.

This case study allows us to study, in detail, the upfan evolution of two late Pleistocene channel systems, specifically where the channels emanate from the lower slope onto the base of slope. The lack of an extensive seismic data set downfan limits the number of conclusions about overall channel evolution. Nonetheless, the variability in evolution of the systems, both within and between sequences, needs further explication.

First, in sequence 4, channels extend from the base of slope in two directions into the basin, separated by about 20 km upfan. The evolution of the two systems is markedly different, most likely due to slight differences in the inherited topography of the sea floor and its gradient (Fig. 15). On the eastern side, the channel extended downfan across a large area with subtle decrease in gradient. There is a distinct style of evolution where upfan channel systems are largely aggradational, with some
Fig. 10.—Six updip to downdip seismic profiles across the western portion of the study area. See text for details of interpretation. See Figure 11 for location of profiles.
Fig. 11.—3D perspective of channel images from sequence 5 generated from stratal slices. View is looking north. A) All stratal slices displayed; B, C) individual stratal slices shown in descending depth. Different colors shown the channels at different TWTT. Gray lines show location of the profiles shown in Figure 10.
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Fig. 12.—Three seismic-attribute and interpreted depositional maps for Sequence 5. RMS attribute maps (left; A–G) are shown in ascending order from below the sea floor. Interpreted depositional maps are shown on the right.
lateral migration. As the channel extended downfan in smoother
topography, channels began to bifurcate into discrete indi-
vidual channels flanked by levees and whose course can be
traced in the 2-D and 3-D seismic images. In the intervening
area, the process of channel bifurcation is recognized by a series
of high-amplitude channel-fill reflections that cut into one an-
other with no flanking levee deposits. This process of erosion
of channels creates extremely complex internal channel-fill ar-
chitecture. This process is important because it shows that downfan
channel bifurcation is not a simple process of marked upfan
avulsion and development of a new channel path. Rather, this
pattern shows that upfan channels cut into one another and
migrate laterally while downfan channels bifurcate through
avulsion.

The western channel system in sequence 4 extends downfan
into an area with variable sea-floor topography and gradient due
to the bathymetric expression of the westernmost folds of the
Oligocene Perdido Foldbelt (Figs. 4, 5). This backlimb area was a
partially confined basin where the channel systems reach a
decrease in gradient and a sheet-like deposit forms. Eventually,
sheet deposition ceases and a channel system evolves across the
top and continues farther downfan. The vertical and lateral
sequence is similar to that of fill-and-spill processes of sedimen-
tary fill within a confined slope basin, described by many authors
in the literature (e.g., Prather et al., 1998). In essence, the fold
created enough confinement and decrease in gradient that the
sheet deposits developed associated with the deceleration of
flows from the updip channel. However, as the gradient in the
area was smoothed, the channels began to bypass downdip
south of the study area. Thus, for this base-of-slope system,
subtle changes in bathymetry had profound effects on the kind
of systems that evolved.

Fig. 13.—Graph showing the evolution of channel width in near-
seaflloor sequence (Sequence 5).

Fig. 14.—Graph showing the evolution of sinuosity in channel 5
near-seaflloor sequence (Sequence 5).

Fig. 15.—Map showing the base of sequence 4 surface (in twtt), which is a good proxy for paleo-bathymetry at the initial time of
deposition. Note the shallower and higher gradients to the northwest indicate the slope, and the crest of the Perdido fold #2 (Fig.
2). The large bowl-shaped area between the slope and foldcrest indicates where the sheet and channel-fill deposits developed.
The more open area indicates the gentle gradient of the eastern fan. The northern updip open area with relatively high gradient
(hot color) is where the updip confined channel developed, and the smoother abyssal plain (cold color) is where the downdip
unconfined channel or channel complex developed.
Second, the eastern channel in Sequence 5 is considerably simpler in its evolution and architecture than the channel in the underlying sequence. The channel in sequence 5 is fairly straight and narrow. Upfan, this channel is in approximately the same position on the slope and water depths as is the channel in the underlying sequence. Clearly, base-of-slope channels can have variability in their evolution, where some bifurcate extensively and others remain as single channels. Perhaps the bathymetry controlled the initial location of the channel, preventing extensive downfan bifurcation in the area (the channel may have bifurcated extensively downfan to the south of the data set).

Third, the amplitudes of the channel-fill reflections in sequence 5 are considerably lower than those in the underlying sequence. Assuming that the rock properties of the channel-fill sediments are similar for the two sequences, the lower amplitude in the shallower channel fill may indicate lower overall sand content. If true, this may indicate a number of controls on the grain size of the channel-fill sediments.

Fourth, the variation of the styles of evolution for base-of-the slope channels has been noted in Pleistocene deepwater channels in other areas of the northern deep Gulf of Mexico (Weimer, 1991; Morton and Weimer, 2004). Some channels extend from the base of slope and remain narrow and sinuous in their course, whereas others bifurcate extensively downfan. The controls on the variation in channel evolution are likely related to subtle changes in gradients, and changing volumes, grain size, and frequency of flows.

Finally, the role of MTDs in the development of the channel system is also variable. Prominent MTDs are present in the outer part of the eastern system in at the base of sequence 4, where the topography created from the deposits apparently controlled the initial location of the overlying channel fill (Fig. 7F). There are no other MTDs in the south of the area described. Within the sequence 4 to the west, several distinct slide deposits are present that overlie the sheet (Fig. 10C). This suggests that slides can form at any place and at any time within the deepwater sequence. Possibly the large MTD at the base of 4 to the east developed as a series of the initial flows delivered sediment to the basin.

CONCLUSIONS

1. The Pleistocene Alaminos submarine fan in the northwestern deep Gulf of Mexico can be divided into five depositional sequences. Each of the sequences is characterized by sediments deposited in channel, levee–overbank, mass-transport, and sheet settings.

2. A 3D seismic data set was used to study the evolution of the two younger sequences in the fan. The lower near-seafloor sequence (4) has two distinctly different depositional systems in the area. To the east, a channel system developed in an unconfined setting. To the west, sheet deposits overlie by channel-fill systems developed in a confined setting between two fold crests in the Perdido Foldbelt. The differences in the systems are likely due to the different inherited basin gradients.

3. The eastern system evolves as a distinct channel system where one updip channel bifurcates downfan into at least six discrete channels that are flanked by levee sediments. The area where the channels initially begin to bifurcate through avulsion is characterized by a series of channels that crosscut each another, with no intervening levees. The western system, in contrast, is fed by an updip channel, and a sheet deposit developed at the terminus. Eventually, the gradient is smoother and the channel system bypasses through the basin.

4. The channel in the youngest sequence (5) is present in the eastern portion of the area. The channel is single and sinuous, and its fill sediments have lower amplitude than those in the underlying sequence, suggesting a possibly finer-grained channel fill.

5. A quantification of channel-fill attributes in sequence 5 indicates that the width of the channel decreased upward from 2600 m to 1100 m, and its sinuosity increased upward from 1.02 to 1.26. These changes in the evolution of the channel are most likely to have been caused by an increase in the mud content of the flows, and possibly a decrease in the volume of the flows through the evolution to the channel. This is likely to have been partially controlled by late Pleistocene eustasy.

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