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RIO GRANDE SLOPE SEDIMENT PATHWAY

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SEDIMENTATION AND SEDIMENTARY MODELS:
CONTINENTAL SLOPE OF THE NORTHWESTERN GULF OF MEXICO

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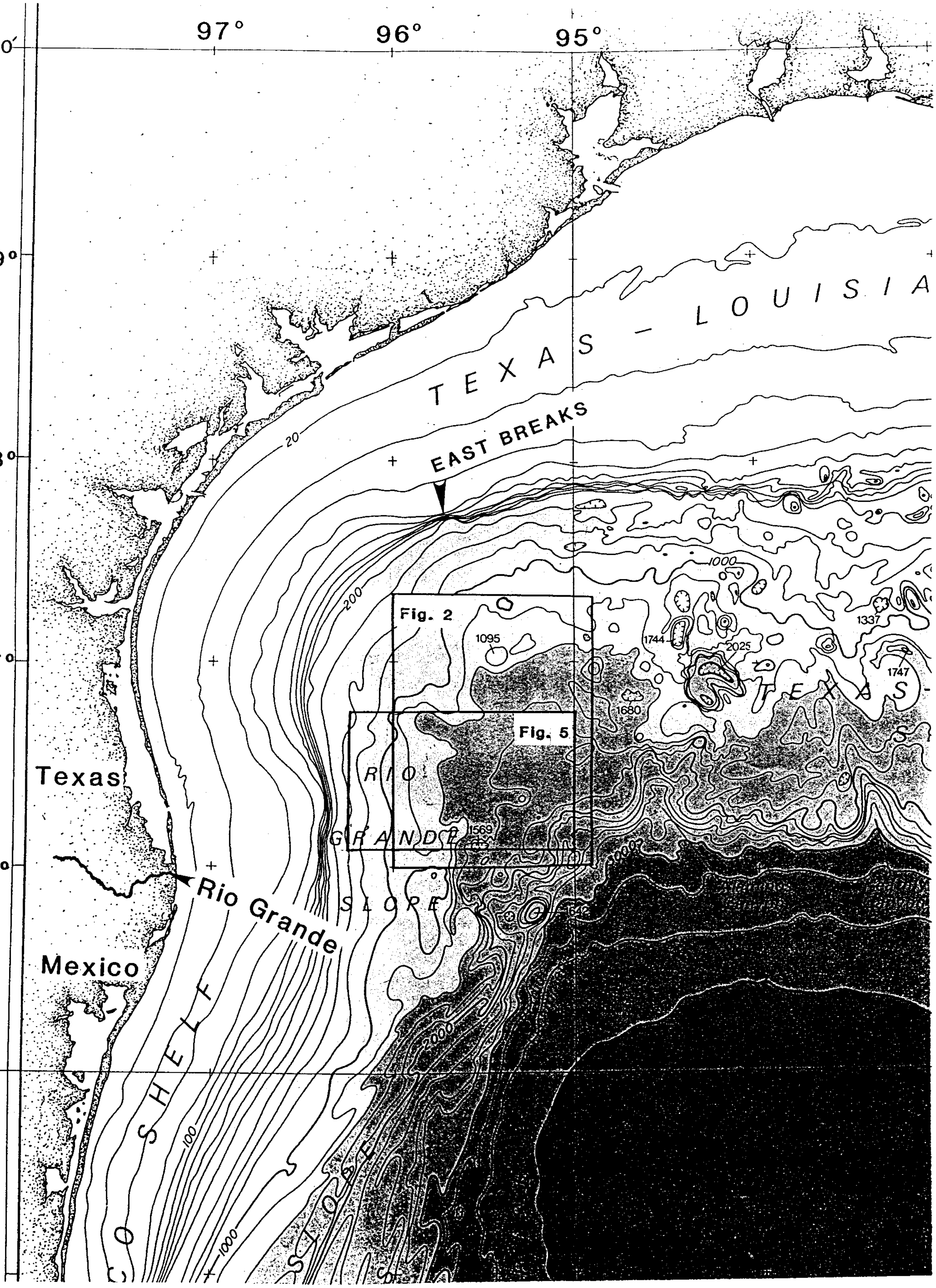


Figure 1 Index map showing location of study area with coverage of Figures 2 and 5. Base map is from Bryant and Bryant (1990).

RIO GRANDE SLOPE SEDIMENT PATHWAY

Introduction

This report covers work completed, to date (March 1993), on a major downslope sediment transport system on the continental slope of the Rio Grande delta (sometimes referred to as the Rio Grande Fan - RGF). This work represents completion of analysis of the surficial sedimentary data presently in hand. These data include high resolution (3.5 kHz and small [75 and 150 cu.in.] air guns) seismic profiles and piston cores collected in 1981, 1990 & 1991. Core information and brief discussions of cruises and cores were included in a progress report of July 1992. Information from 11 cores is used in this report.

Mapping includes acoustic reflection echo-types (especially the extent of the prolonged echo type that typically characterizes coarse-grained sediment), channels (especially within the prolonged echo pattern), and underlying salt. Our data is rather extensive between water depths of 1200 and 1800 meters. At greater depth, the pathway simplifies to a submarine canyon, but much additional work is needed in the 1200 m to shelfbreak (~200 m) depth range. Bathymetric data is available from Bryant et al. for 95° - 96°W, from NOS Alaminos Canyon and Port Isabel sheets, and from the Atlas of NOAA's Multibeam Sounding Data in the Gulf of Mexico Exclusive Economic Zone (1992).

Sediment Pathway - Distributional Characteristics

As with all other known downslope sediment transport systems in the western Gulf of Mexico, the primary control of the location of the sediment pathway is the location of a sediment source, specifically, a low-stand, shelf-edge delta. In this case, the delta is the late Wisconsinian low-stand lobe of the Rio Grande (Fig. 1). The overall delta is about 70 n.mi. (130 km) wide at the coast. The cross-shelf dimension is about 50 n.mi. (93 km), and the cross-slope length to the Perdido Escarpment (1800-3000 m) is about 70 n.mi. (130 km). Suter and Berryhill (1985) mapped the latest low-stand deltaic deposits at the shelf edge which are up to 160 m thick, 20 n.mi. (37 km) wide and extend 50 n.mi. (93 km) north of the Mexican border. Within the slope portion of the delta, the mapped sediment pathway extends eastward between latitudes 26°10' and 26°40'N. Data coverage is good between longitudes 95°05' and 95°50'W but is sparse between 95°50' and 96°15'W. The pathway's width varies considerably from about 5 to almost 30 n.mi. (9 - 55 km).

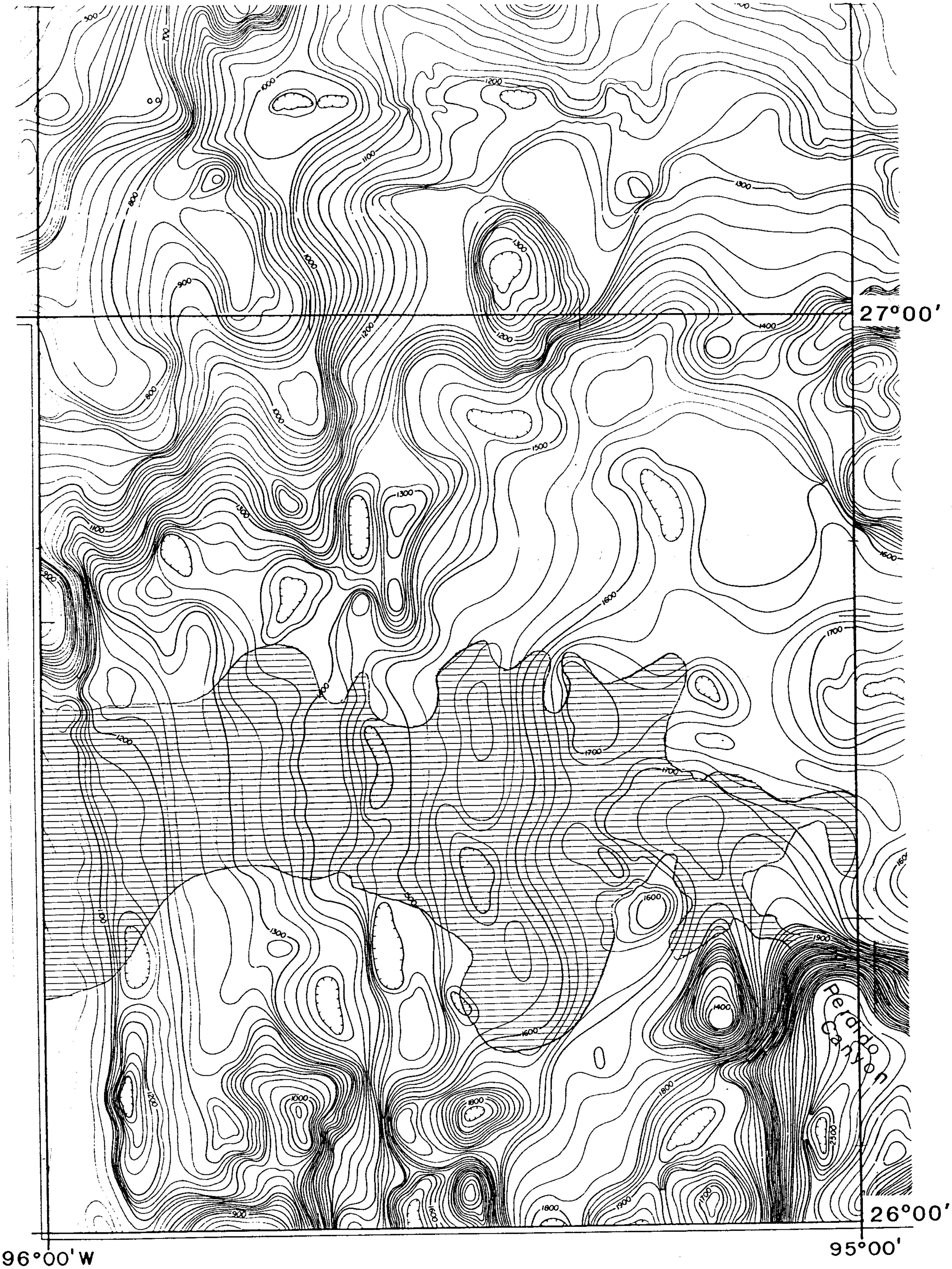


Figure 2 Distribution of downslope sediment pathway relative to bathymetry on the Rio Grande slope. The sediment pathway is outlined from the distribution of prolonged 3.5 kHz echo-type (horizontally lined). Note that the pattern occurs within a region of subdued bathymetric relief. Bathymetry from Bryant et al. (private publication).

The pathway appears on bathymetric maps (Fig. 2) as a swath of subparallel contours of a concave surface that is smooth and simple relative to more irregular, higher relief surfaces to the north and south. The pathway is mapped as the distribution of a prolonged 3.5 kHz bottom echo (Fig. 3), a pattern that has been commonly correlated with relatively coarse grained sediment (e.g., Damuth, 1980; Rothwell et al., 1991). It tends to have rather distinctly higher micro-relief (~25 m) than other echo types. This prolonged echo type is underlain directly or at very shallow depth (e.g., one reflection doublet) by a chaotic seismic facies (Figs. 3 and 4). Two other echo types mapped, semi-prolonged and hemipelagic drape, are underlain in seismic section by strong continuous reflections, commonly diverging for the semi-prolonged and parallel for the drape.

Using GLORIA sonographs, Rothwell et al. (1991) mapped (eastward of 95°42'W) a back-scatter pattern corresponding to the prolonged 3.5 kHz echo pattern as "a northern lobe of the Rio Grande Fan [which] marks an area of channelized cross-slope sediment transport" (1991, p. 310). Their map (1991, Fig. 6) shows the same general pattern as ours (Figs. 2 and 5) but has the pathway boundaries somewhat simpler and broader.

In the lower slope, the pathway clearly becomes the head of Perdido Canyon (Figs. 2, 5 and 6), an indentation of the salt-front that forms the Perdido (and eastward the Sigsbee) Escarpment. Upslope, the pathway broadens between the 1550 and 1450 m isobaths, narrows between the 1450 and 1200 m isobaths and broadens again farther upslope, although our control there is very limited.

Salt Controls

In cross section, the sediment surface of the pathway actually has the slight bulge typical of a submarine fan. However at depth, the pathway is clearly a sediment-filled valley or trough. Figures 3 and 4 show the trough formed largely by expansion of chaotic seismic facies beneath the prolonged 3.5kHz echo pattern. The seismic section also shows that the trough lies between salt structures at about 1 second subbottom. The more general extent that salt distribution controls the pathway is illustrated in Figure 5. With only a few very small exceptions, salt underlies the pathway only on the north side approximately between longitudes 95° 37' - 47' W. Here, and also at the other small exceptions, there is no bathymetric relief reflecting the salt. At all other points where salt is marginal to the pathway, the bottom shoals by a few tens to over 100 m over the salt. Greater relief (to over 200 m) to the north and

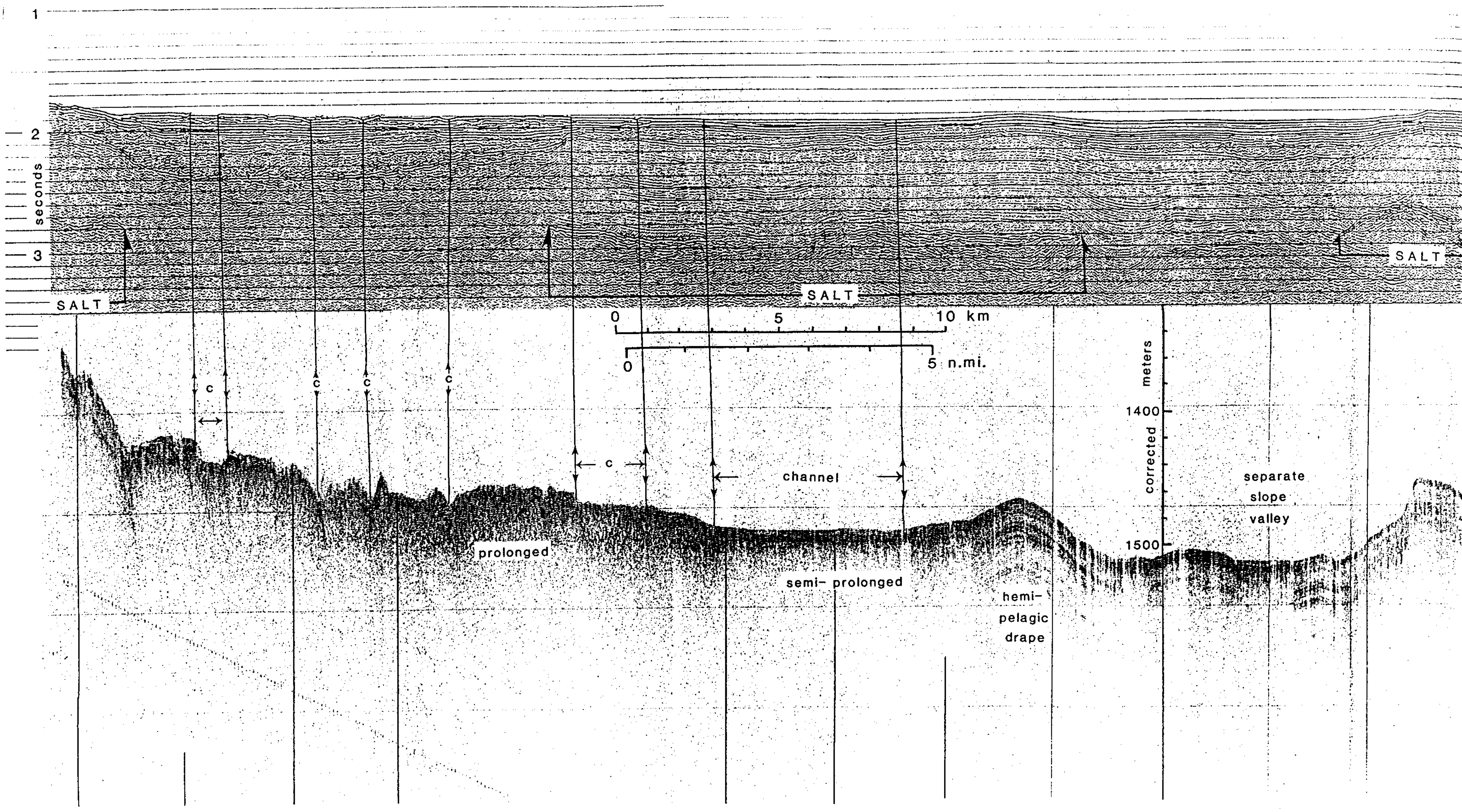


Figure 3 Cross sections of sediment pathway. Top - 75 cu.in. air gun source; note trough of thicker sediment beneath channels and between salt (at 2.7 - 3.0 seconds depth) and similar but smaller trough between salt in the separate slope valley. Bottom - 3.5 kHz showing prolonged, semi-prolonged and hemipelagic drape echo types. Expanded view of air gun section corresponding to the extent of prolonged echoes is shown in Figure 4. Location of profile is shown in Figure 5.

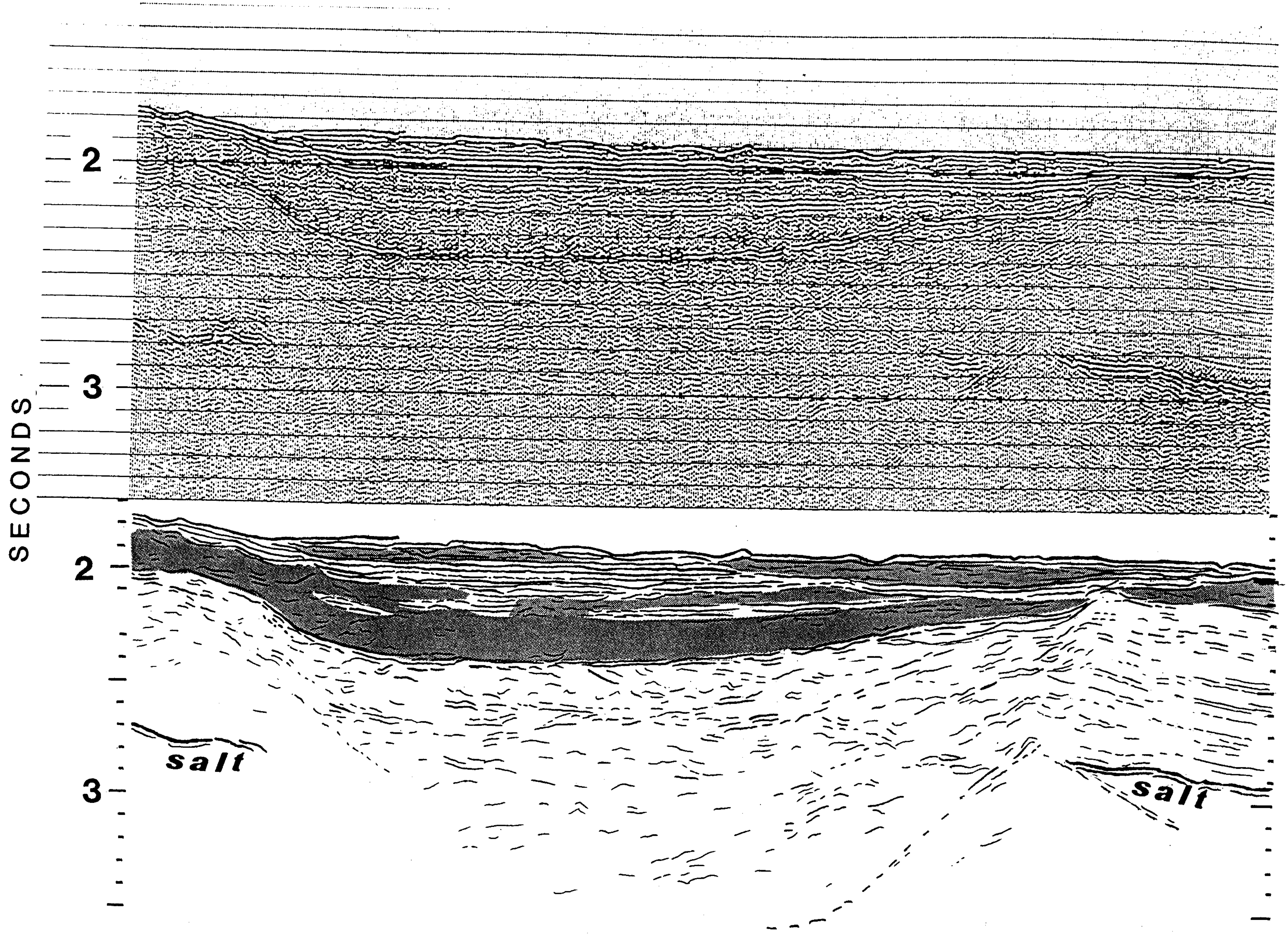
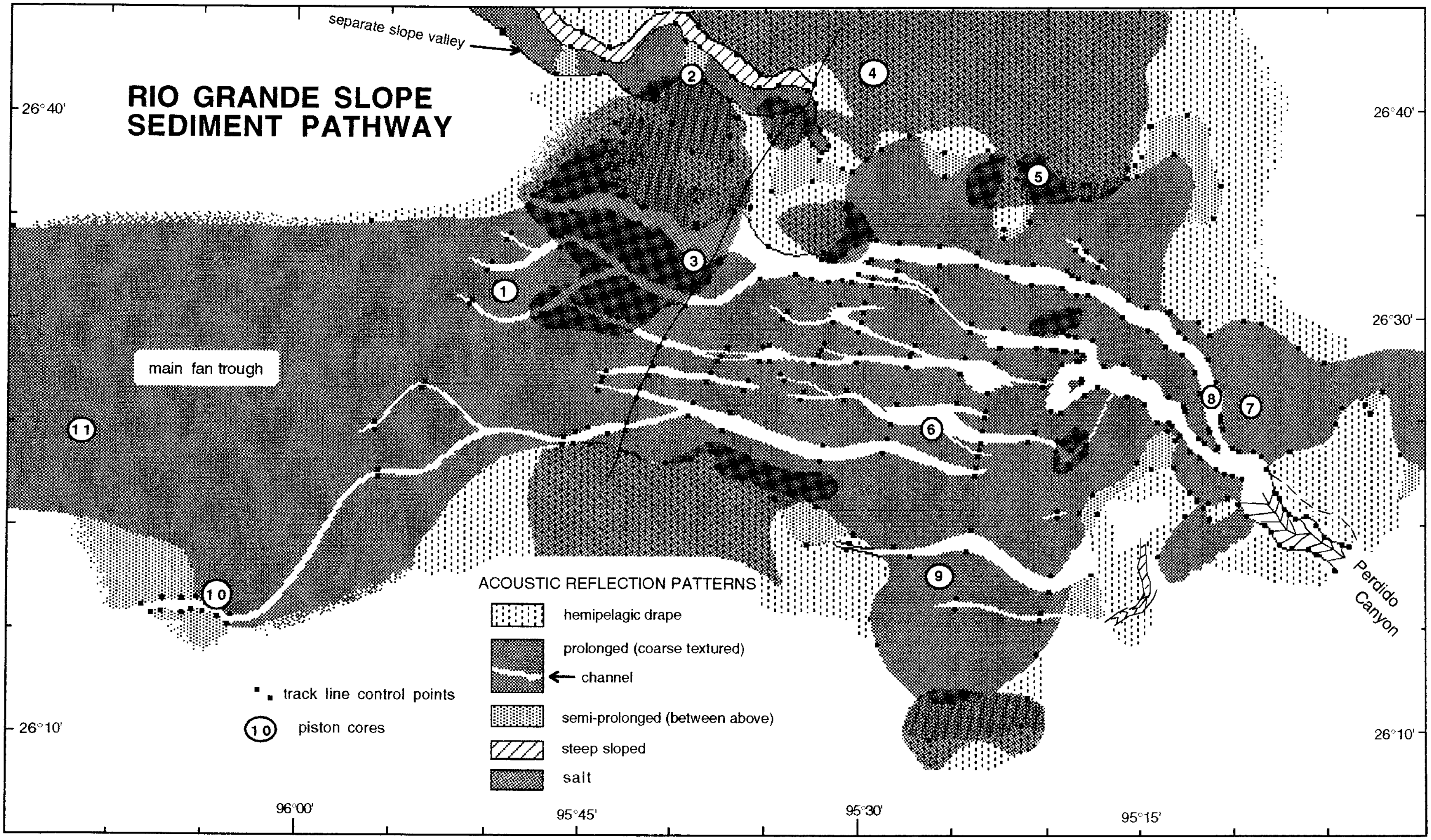


Figure 4 Seismic section of trough typically associated with prolonged echoes and channels on 3.5 kHz profiles. The trough is consistently located within a salt-free zone. Top – uninterpreted section. Bottom – line drawing of same section with chaotic facies shaded down to about 2.4 seconds. Much of the deeper part is probably chaotic, but the data is too limited to outline boundaries.

<u>Figure 5</u> Map showing sediment pathway as defined by a prolonged 3.5 kHz echo pattern. Location is shown in Fig. 1. Core number key: 1- IG38-6, 2 - IG38-8, 3 - IG38-9, 4 - IG38-10, 5 - IG38-11, 6 - 90L566-6, 7 - 91L580-5, 8 - 91L580-6, 9 - 91L580-7, 10 - 91L580-8, 11 - 91L580-9. Note Appendix A for core data. SSW-NNE line is the location of the profile shown in Figures. 3 and 4.


RIO GRANDE SLOPE
SEDIMENT PATHWAY
separate slope valley
main fan trough
Perdido Canyon
1
2
3
4
5
6
7
8
9
10
11
26°40'
26°30'
26°10'
96°00'
95°45'
95°30'
95°15'
ACOUSTIC REFLECTION PATTERNS
hemipelagic drape
prolonged (coarse textured)
channel
semi-prolonged (between above)
steep sloped
salt
track line control points
piston cores

south of the pathway (Fig. 2) reflects abundant sheet and diapiric salt structures.

The salt that underlies a small part of the pathway and constrains the northern boundary between longitudes 95°32-15' W has been interpreted by Hardin (1989) as a stock canopy which extends under most of the mapped area. Our data indicate that the salt is not present under most of the pathway, and canopy sheets lie only to the north. Chaotic structures beginning at 1.7 to 1.9 seconds subbottom suggest that salt has been evacuated from this level, possibly by the loading of deposition within the pathway. This is approximately the average depth of salt equilibrium (i.e., where sediments are compacted to the density of salt according to Hardin, 1989, and Nelson, 1989); so salt would not be expected to evacuate from here. Evacuation might occur, however, if the overlying sediment column was heavier than usual, resulting in a steeper compaction curve. If the sediments within the pathway had a high sand content, they would, indeed, be more dense than would a mud column. This scenario is suggested as a working hypothesis.

Channels

Figure 5 shows the distribution of channels within the pathway; and Figure 7 shows several examples of 3.5 kHz profiles through channels. Widths and areas of channel cross sections given are those observed. Real horizontal dimensions may be somewhat smaller due to non-orthogonal track line crossings. However, most track lines are less than 10° from perpendicular to the trend of the channels (~99°).

Perdido Canyon has depths of over 100 m and cross sections over 100,000 m^2 (note Fig. 6), but channels within the pathway are much smaller. Channel depths range downward from 40 m to detection limits of 2 or 3 m, with frequency increasing as depth decreases. Apparent widths range from 3 km to <300 m with two modes, 1 - 3 km and <500 m. Channel size decreases very generally upslope. The two largest channels merge as they enter Perdido Canyon. The northernmost channel remains the largest and most continuous upslope to about 1300 m water depth where it becomes the northern margin of the pathway. The channel pattern mapped indicates greater complexity and less straight continuity than indicated by Rothwell et al. (1991). Comparison of mapped channels suggests that sonographs reflect one or both steep margins of the channels we have mapped. Rothwell et al. (1991) also seemed to have largely missed the large channel near the northern side of the pathway, perhaps due to its considerable breadth and somewhat subdued banks (note Fig. 3). Channels

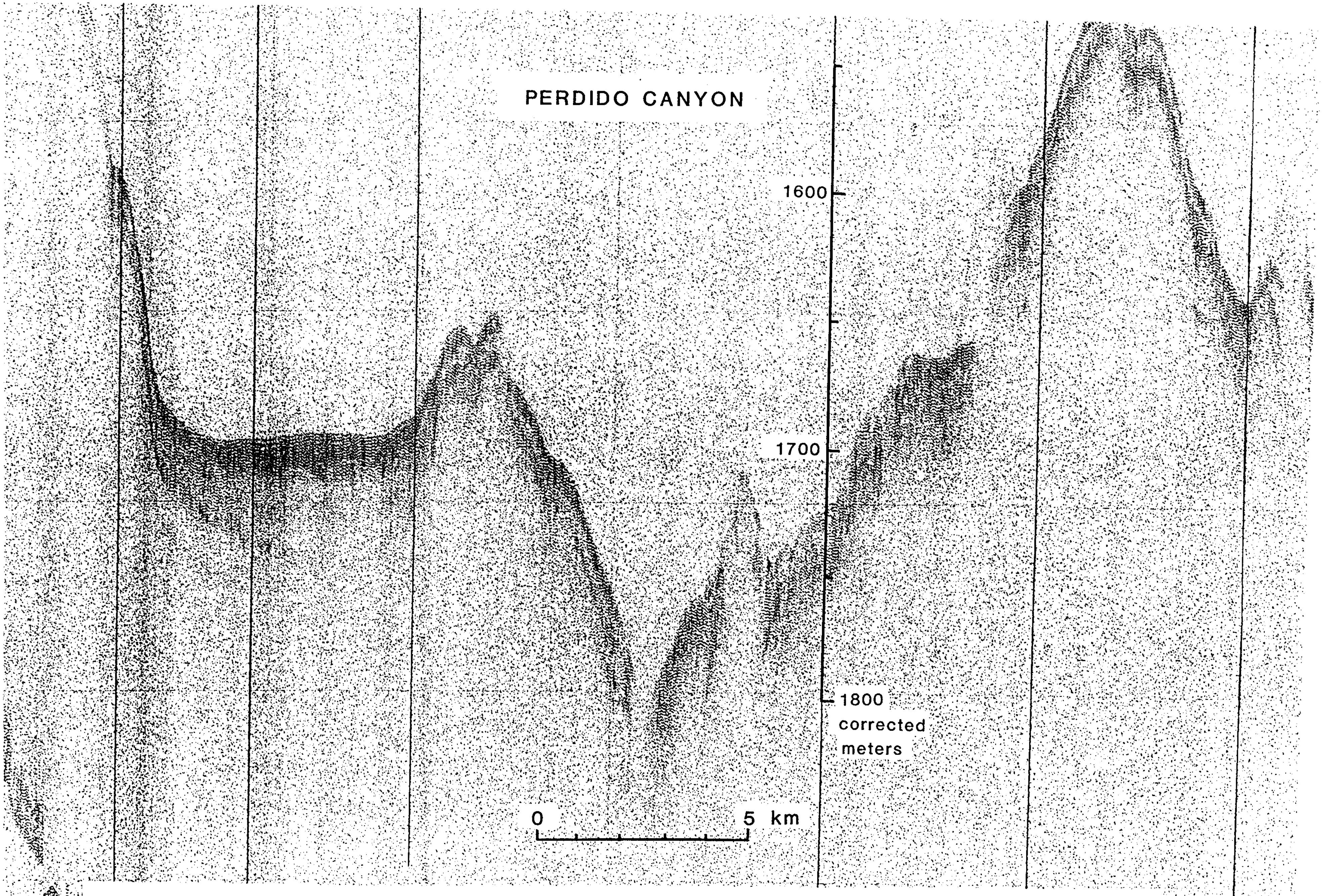


Figure 6 Head of Perdido Canyon near the top of the Perdido Escarpment (near 95°08' W).

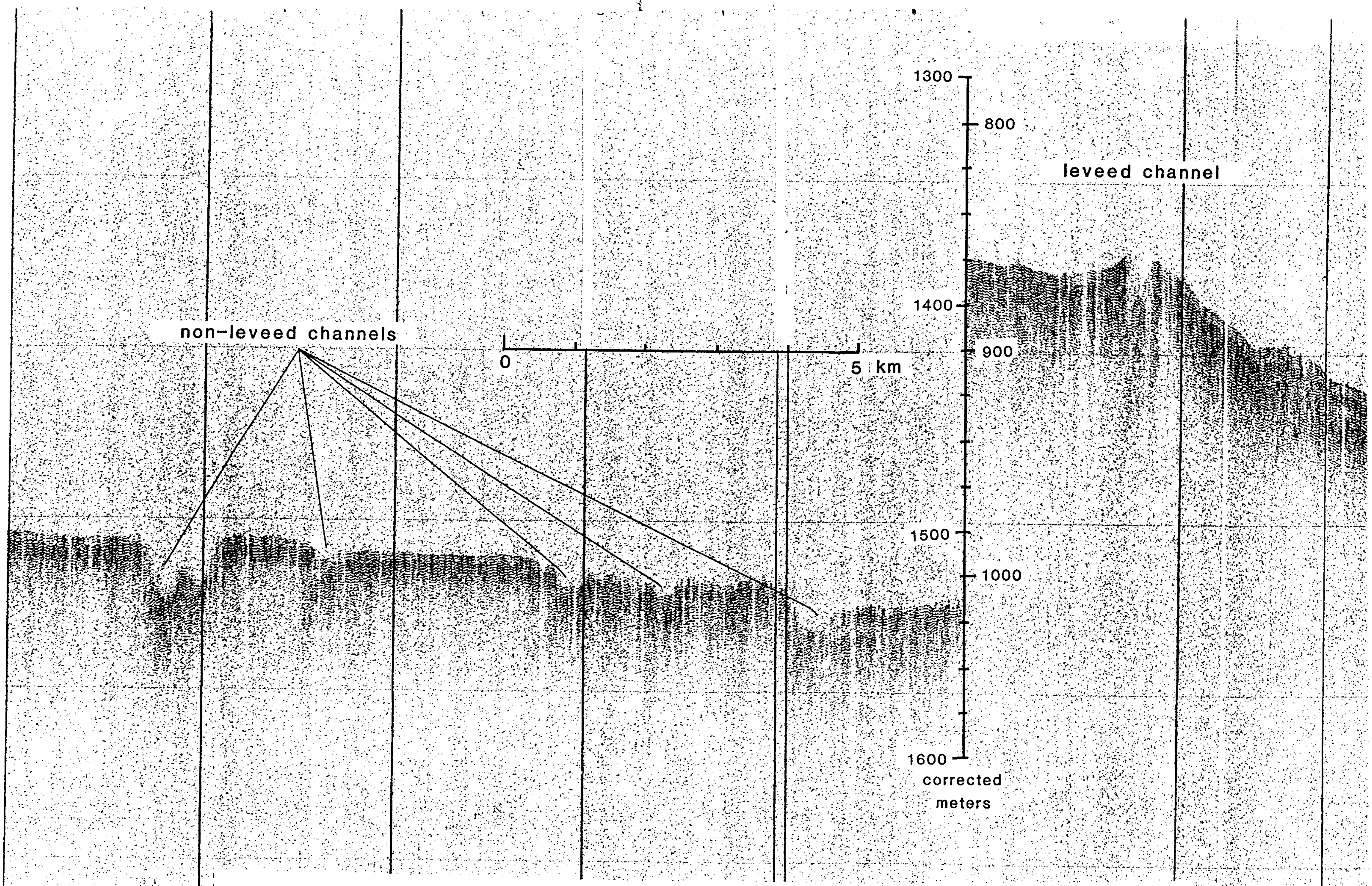


Figure 7 3.5 kHz profiles of channels within the Rio Grande pathway. Non-leveed channels (left) are at about 95°36' W, near the center of Figure 5. Leveed channel (right) is near core 10 (Fig. 5) are somewhat better developed in the vicinity of 95°35' W where salt constrains the pathway to its narrowest. Somewhat farther downslope at about 95°25' W the pathway broadens and channels become shallower and more discontinuous.

The overall pattern has the appearance of a braided stream. Braided streams typically occur where there is a decrease in slope and consequent aggradation. Figure 2 shows a slight decrease in slope after a relatively steep gradient between 1060 and 1160 m. With admittedly limited control upslope, it appears that channels begin to become abundant below this depth. Another slope steepening occurs from 1580 to 1660 m, and channels appear to reorganize across this depth zone (Figs. 2 and 5).

Sediments

A summary of core data is given in Appendix A. The locations and numbers of 11 cores are shown in Figure 5. The presence of sand in 9 of 11 cores shows that this Rio Grande slope sediment transport system is sand bearing. There are suggestions that it is sand-rich. In two cores there are 70 t0 150 cm of massive, clean sands. However, in seven of the nine sand-bearing cores, the sand occurs only in trace amounts. Except for one core taken in a clearly hemipelagic setting (4 - IG38-10), the traces of sand are at about the same stratigraphic level (within 30 cm of (below) the Holocene / Pleistocene boundary, where identifiable) and within about 30 cm of the core bottoms (at subbottom depths of 155, 175, 192, 195, 230, 235, and 318 cm). In the two cores with abundant sands, their tops are about the same depths as the trace sands - 190 and 223 cm. It seems reasonable to extrapolate that more massive sands (like those in cores 2 and 3) just below the depths of penetration, commonly caused the corer to stop penetrating. Different results with different corers provide some support for this hypothesis. Of cores (with sands) from the prolonged echo pattern, two of four taken with a 1,400 lb corer contained the massive sands, while four of four cores taken with a 400 lb corer had only trace sands. However, a core (V3-121) reported from the literature by Rothwell et al. (1991), contains only bioturbated mud for 800 cm below irregular sand lenses from 95 to 175 cm, and is rather like core 4 from the bathymetric high.

The somewhat anomalous occurrence of thin sands within the hemipelagite of core 4 (IG38-10) suggests that turbidites were big enough and sandy enough to extend thin overbank deposits to nearby bathymetric highs. If this is the correct explanation for these sands, it certainly supports the sand-rich hypothesis.

Cores 7 and 8 (L580-5 and -6 respectively) are from an overbank area and an adjacent channel respectively. Both cores have trace sands near the core bottoms, within 25 cm of (below) the Holocene / Pleistocene contact. Core 7 also has a thin clean sand at a depth of only 28 cm. The interpolated age for this sand is less than 3,000 yrs. In the core from the channel, there is only about 30 cm of homogeneous mud at this horizon. It is suggested that the turbidity current that dropped the sand at the overbank location was competent enough to bypass rather than deposit within the channel, with only a slowing tail depositing the mud. Small mud turbidite deposits may account for the Holocene section being about 60 cm thicker within the channel. This location is only about 11 km (6 n.mi.) above the head of Perdido Canyon where bypassing or erosion would be expected.

Core 9 (L580-7) appears to have two to five mud turbidites within the Holocene section. This produces the highest apparent accumulation rate within the core suite; but even if the obvious mud turbidites are subtracted from the section, the hemipelagite accumulation rate is exceeded only by the two shallowest cores. Core 9 is located in a southern lobe of the pathway that might be somewhat of a cul-de-sac that traps more mud than the rest of the system. Channels do occur within this lobe, but they may not be part of the main channel system (Fig. 5).

As is common elsewhere on the slope, Holocene (hemipelagic) accumulation rates tend to increase upslope. A parallel decrease in carbonate content (Appendix A) suggests that increased accumulation of terrigenous clastics toward their source accounts for dilution of biogenic carbonate.

Although extensive sands were not sampled within the pathway, the nature of the channels suggests a sand distribution pattern. If the analogy to a braided stream is valid, the portion of the pathway where channels are most developed should be a broad region of aggradation of bed load (sand). Furthermore, on a more local scale, channels often show an increase, then a decrease in size (depth and cross sectional area) before disappearing. Where a channel diminishes and terminates should be a specific locus of bed load deposition. The connection of the pathway to Perdido Canyon also suggests that there should be significant sand deposits at the base of slope.

Figure 8 shows that the mapped pathway overlaps with the downslope extension of the low-stand Rio Grande shelf edge delta mapped by Suter and Berryhill (1985). Thus the delta is clearly the source of

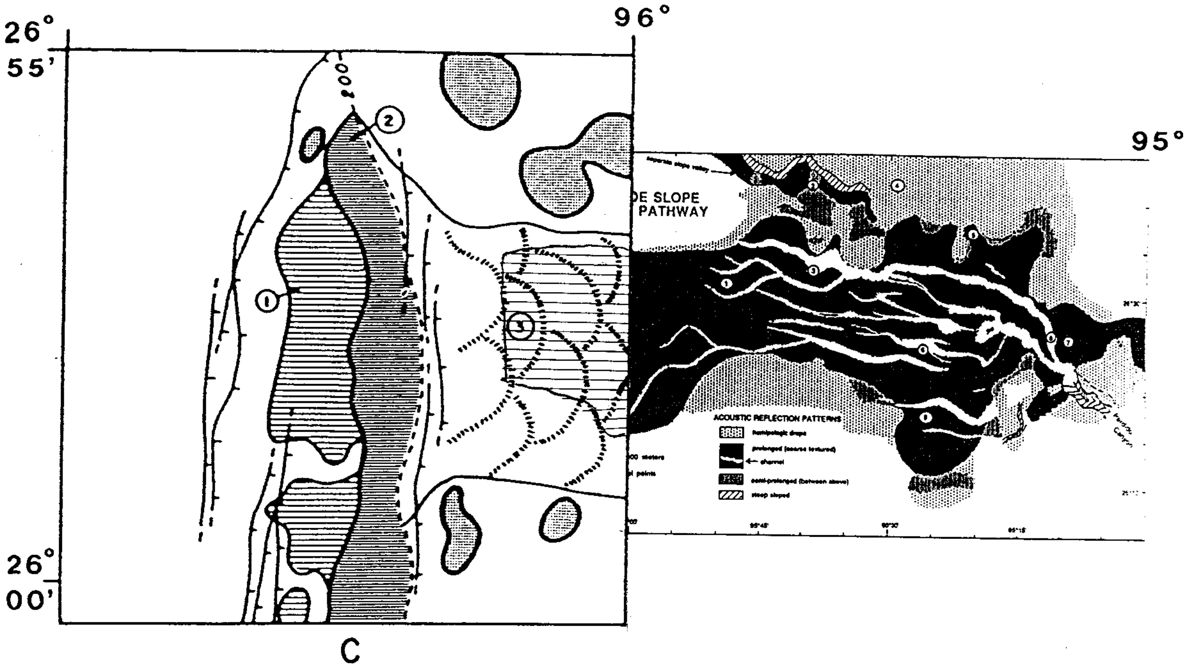


Figure 8 Relationship between downslope sediment pathway and low-stand shelf-edge delta. Left part of the figure: "Aerial perspective of late Wisconsinan Rio Grande shelf-margin delta. ... Slumps and slides: (1) general extent of older lumped sediments (chaotic facies) buried beneath younger undeformed prograded sediments ... , (2) general extent of surficial slides, and (3) series of overlapping large slumps and slides down the delta front. Associated deformational features of regional extent are growth faults (hachures on downthrown sides) and crudely circular diapiric structures on continental slope" (Suter and Berryhill, 1985; Figure 8c). Overlap (lightest horizontal lines) between (3) above and channeled prolonged-echo facies (right part of figure) shows that the lowstand delta is the source of sediment in the pathway and suggests slump - turbidity current transformations within the pathway.

sediments. Suter and Berryhill describe the region of map overlap as a "series of overlapping large slumps and slides" (Fig. 8c, 1985). Again, although our coverage of this area is very limited, the apparent lack of channels agrees with the observations of Suter and Berryhill. Their discription of the upper slope portionof the system suggests that slump - turbidity current transformations played a major role in sedimentation within the pathway.

Separate Slope Valley

At the northern limit of the study area there is a small slope valley that is similar to the larger Rio Grande pathway in several respects. It is somewhat more tightly constrained by salt structures. Those on the north side are shallower and more diapiric and cause the north side of the valley to be a more distinctive escarpment than boundaries of the Rio Grande pathway. It comes very close to merging with the Rio Grande pathway but clearly does not have a surface connection. There is a similar expansion of chaotic facies in an inter-salt trough beneath the surface feature, but these also pinch out just before the valley reaches the Rio Grande pathway.

The feature is of special note, because the sandiest core of our suite from this region is from this valley. This appears to be a turbidite system that is ponded in mid-slope, not directly by a salt structure, but, perhaps, by uplift caused by near merging of salt structures. We have no data on the upslope portion of this system. Its upslope origin is a particularly interesting question, because there is no known shelf-edge low-stand delta between the Rio Grande and the delta at the head of the East Breaks slide complex which is clearly separate system to the north.

Summary and Conclusions

The Rio Grande slope sediment pathway is a conduit for shelf sediments of the low-stand shelf-edge delta of the Rio Grande from the shelf to Perdido Canyon on the lower slope and beyond to an unkown ultimate continental rise or abyssal plain depositional site. Deposition occurs within the pathway from a mass transport system in the upper part and sand bearing turbidity currents in the lower part. The turbidites are associated with a complex, braided, mostly non-leveed channel system. Strata (especially seismically chaotic units) thicken within the pathway but to a lesser degree than within intraslope basins in the central slope to the east. Localized foci of deposition may be related to pathway widening and slope decreases in general and channel die-out in particular.

Smooth overall bathymetry relative to adjacent areas reflects that the pathway is mostly salt-free but laterally salt-constrained. Salt within it appears to be sheets with no associated bathymetric uplift. The Rio Grande depocenter in general, and the pathway in particular may have caused salt to migrate laterally along strike to the north and south away from the pathway as well as downslope to the Perdido Escarpment. Thus the pathway may represent the major basinward axis of deposition of the Rio Grande.

A small but sand-rich system just to the north of the Rio Grande pathway stops in mid-slope somewhat like the East Breaks slide complex. However, unlike the East Breaks slide, the separate slope valley appears to be a sand-turbidite system. Also unlike both the East Breaks and Rio Grande systems, the separate valley has no known shelf-edge delta source. However, the upper slope and source area of this system is largely unexplored.

REFERENCES

Bryant, W. R. and J. R. Bryant (1990) Bathymetric Chart, The Gulf of Mexico Basin. The Geology of North America (GNA-J), The Geological Society of America, Boulder, Vol. J, Plate 1.

Damuth, J. E. (1980) Use of high-frequency (3.5 kHz) echograms in the study of nearbottom processes in the deep-sea: a review. Marine Geology, v. 28, p. 51-75.

Hardin, N. S., (1989) Salt distribution and emplacement processes, northwest Gulf lower slope: a suture between two provinces. in Gulf of Mexico Salt Tectonics, Associated Processes and Exploration Potential, GCSSEPM Foundation Tenth Annual Research Conference, Program and Abstracts, p. 54-59.

Nelson, T. H., (1989) Style of salt diapirs as a function of the stage of evolution and the nature of the encasing sediments. in Gulf of Mexico Salt Tectonics, Associated Processes and Exploration Potential, GCSSEPM Foundation Tenth Annual Research Conference, Program and Abstracts, p. 109-110.

NOAA (1992) Atlas of NOAA's Multibeam Sounding Data in the Gulf of Mexico Exclusive Economic Zone, Volume 1, NOAA / NOS / Coast & geodetic Survey, Rockvelle, MD.

Rothwell, R. G., N. H. Kenyon and B. A. McGregor (1991) Sedimentary features of the south Texas continental slope as revealed by side-scan sonar and high-resolution seismic data. A.A.P.G. Bul., v. 75, p. 298-312.

Suter, J. R. and H. L. Berryhill, Jr. (1985) Late Quaternary shelf-margin deltas, northwest Gulf of Mexico. A.A.P.G. Bull., v. 69, p. 77-91.

APPENDIX A

CORE DATA SUMMARY

core field # (Fig.5 #)	lat./ long.	water depth (m)	core length (cm)	Holocene thickness (cm)	cm/ky @ 63% porosity	hemi-pelagic $CaCO_3$(%)	sand content & other comments
IG38-6 (1)	26°30.5'N 95°47.6'W	1324	182	>175	>8.4	16.3	bottoms in hard sand at 180 cm which stopped corer and bent core barrel; inter-channel
IG38-8 (2)	26°41.3'N 95°39.1'W	1472	387	>175	>8.6	15.4	sandiest core in suite (45%); sand intervals (>90%): 190-208 & 226-387; separate slope valley
IG38-9 (3)	26°32.5'N 95°38.3'W	1463	442	150	7.4	20.4	16% sand; 222-294 cm; margin of deep, northernmost channel
IG38-10 (4)	26°42.7'N 95°26.0'W	1538	912	53	2.4 Hol. 8.7 Pl.	23.9	bathymetric high but still has 5 thin sand beds (194-350 cm); Y8 ash @ 880 cm = 84,000 B.P.
IG38-11 (5)	26°36.4'N 95°20.1'W	1772	248	200	9.6	24.2	two thin sands @ 197 & 220 cm; reentrant in northern margin of pathway
L566-6 (6)	26°24.9'N 95°25.10'W	1579	254	205	11.0	20.4	silty sandy mud 210-254 cm; mid pathway channel
L580-5 (7)	26°25.05'N 95°09.24'W	1732	157	130	6.8	26.6	trace of sand at base (155-57) plus 4 cm clean sand at 30 cm; lower pathway overbank
L580-6 (8)	26°25.52'N 95°11.24'W	1747	234	192	9.2	23.1	trace of sand at base (220-24 cm); lower pathway channel
L580-7 (9)	26°17.40'N 95°26.29'W	1571	346	306	15.4 11.5 w/o mud turbidites	15.6	sandy 315-344 cm; ~5 mud turbidites (~80 cm); southern 'side-lobe' of pathway
L580-8 (10)	26°15.9'N 95°04.40'W	843	289	239	12.0	12.8	channel levee; upper pathway
L580-9 (11)	26°24.6'N 96°11.14'W	649	318	? >260	>13.8	13.6	non-channelled, upper pathway