Neogene Stratigraphic Development of the Arabian (Persian) Gulf

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LONG TERM GOALS

The Arabian Gulf is a shallow (<100 m), epicontinental sea connected to the Gulf of Oman through the Straits of Hormuz. This basin, besides being an important military, economic, and political region, serves as an excellent model for sequence stratigraphic studies of an arid littoral environment. Neogene sediments in the Gulf comprise a northeast-thickening wedge (0.1-2.0 km) of clastics shed from the Zagros uplift in Iran. Our long-term goal is to understand how variations in sediment source, tectonic subsidence, climate, and sea level affected sedimentary processes and stratigraphic development of an arid, shallow-marine environment.

OBJECTIVES

Our objectives include mapping Quaternary channels, deltas, and sequence stratigraphy across the entire basin and correlating these to wells and surface sediment cores. Our previous work in the Arabian Gulf revealed an unconformity dating to the Last Glacial Maximum (LGM) and a sequence of deltas along the northern Iranian margin (Uchupi et al., 1996, 1998). Radiocarbon ages suggested that the basin was subsiding in apparent contradiction to previous interpretations of seafloor topography. In the initial part of the present study, our objectives include mapping the LGM unconformity and the overlying Holocene unit, mapping channels in the LGM surface beneath the soft delta marls, tracing these features into the deeper regions of the basin, and using the topography of the seafloor and the LGM surface to test the hypothesis that the Iranian side of the basin was subsiding more rapidly than the Arabian side to the southwest.

APPROACH

In July-August 1998 aboard the *USNS Bowditch*, we collected sediment cores, CTDs and XBTs, sonobuoy refraction profiles, and high-resolution seismic profiles obtained with the ship's 3.5 kHz echosounding transducer and a towed 48-channel reflection system. This survey covered as much of the Gulf as possible given the restrictions that reefs, oil fields and territorial limits have on operations of NAVOCEANO ships. The approach was to seismically map Neogene stratigraphy and tie this structure to dated surface sediment cores and industry wells where possible. The survey was a joint program between WHOI and NAVOCEANO.

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WORK COMPLETED

In the short time since the present grant was awarded, we have compiled, edited, and mapped the primary seafloor structures in water depths greater than ~30 m (Figure 1b). These data were merged with soundings on navigation charts to produce a digital data base for the Gulf as a whole (Figure 2a). We examined all 3.5 kHz records from both the July and August 1998 legs of the UNSN Bowditch, identified and digitized the LGM surface (Horizon 1), and produced a structural map of the surface (Fig. 1a) and an isopach map of the overlying Holocene unit (Fig. 1b).

RESULTS

The most startling result is the apparent lack of Holocene sediment over most areas of the Gulf deeper than ~30 m (Figure 1a). Sediment cores confirm this result. Sediment cores in regions with 0-2 m of Holocene material identifiable in the acoustic records often penetrate 10-50 cm of Holocene marl into reddish-brown Pleistocene sediment. Holocene accumulation is constrained to the margins of the basin off rivers draining the Zagros Mountains in Iran and to small, thin regions of presumably carbonate deposition in 40-50 m of water off UAE (54°45' W and 55°30' W). Few data were collected close enough to Iran's coast to adequately map the Holocene unit, so the extent of its distribution is under-represented in Figure 1b. The Tigris-Euphrates-Karun Delta in the northwest portion of the Gulf is problematic. Although, the delta is commonly interpreted as a Holocene feature, we could not identify Holocene material acoustically (Figure 1b). Sediment cores closest to this delta recovered a layer of marl <1 m thick above cross-bedded reddish-brown sand. Surface textures of quartz grains suggest aeolian processes deposited the sand. We have not yet dated this material, so the accuracy of our seismic interpretations at the northwest end of the Gulf can not be confirmed.

The shape of the LGM surface in the northern basin (northwest of the sill at ~52° W) differs significantly from that of the central basin to the southeast (Figure 1a). The surface is very flat on transects from southwest to northeast - increasing in depth by 20 m from ~55 m to ~75 m. The SW-NE lateral gradients are much greater in the central basin where depths reach over 100 m. The lateral gradients in the other direction also differ. Depth to the LGM in the northern basin increases systematically from ~40 m off the Hilleh River to ~75 m at the sill (52°W), whereas depth does not appear to systematically vary along the central basin. The origin of these differences is unclear because many processes can affect seafloor depth in epi-continental seas, but our preferred interpretation is that subsidence rate increases much more in a SW-NE direction across the central basin than across the northern basin. In this respect, the central basin appears to follow the pattern predicted by foreland basin models. Radiometric dates on sediment cores from the northern basin indicate subsidence (Uchupi et al., 1998), but the rates may be less than those in the central basin reflecting, perhaps, NW-SE lateral differences in deformation within the Zagros Mountains.

Our present data suggest that channels eroded in the LGM surface are found, for the most part, only beneath the Holocene deltas off Iranian rivers. Figure 3b shows an example. They appear to develop in Pleistocene delta marls that are probably softer than older, coarser, and more consolidated sediment exposed along the southwest side of the Gulf. The channels are "perched" on the Iranian margin and cannot be traced either as fans or channels onto the floor of the northern basin. The channels terminate where the Horizon 1 surface abruptly steepens down to what appears to be a wave-cut terrace at 75-78 m (Figures 3a, 3c, and 3d). In the northern basin the terrace extends for 50-60 km southwestward across the floor of the basin (Figure 1a) and appears to represent a still-stand in relative sealevel. The terrace can be traced around the southeast nose of the delta (~52°W) and northward into the central basin at a depth of ~85 m. Based on these depths, we estimate differential subsidence of about 0.6

mm/yr. We tentatively date the terrace and the channels to the end of the Younger Dryas at ~11,500 yrs BP. Future radiocarbon dates on sediment cores will help to constrain our chronology.

IMPACT/APPLICATIONS

Channels buried beneath the acoustically transparent marl deltas along the Iranian coast do not appear to be limited to the mouths of present rivers. They occur along the crest of the underlying paleo-delta and terminate abruptly along the steep, wave-eroded slope bordering the northern basin terrace. The channel fans do not extend more than a few hundred meters out onto the floor of the Gulf. Lateral variations in subsidence rate do not agree with simple foreland basin models and appear to be a primary agent controlling patterns of sediment accumulation.

TRANSITIONS

These results - and others that we prepare as we progress with this project - will be transitioned to our colleagues at NAVOCEANO for their use in preparation of data bases in support of fleet operations.

RELATED PRODUCTS

The high-resolution seismic and seafloor mapping results provide an arid environment end-member to the STARTIFORM field studies.

REFERENCES

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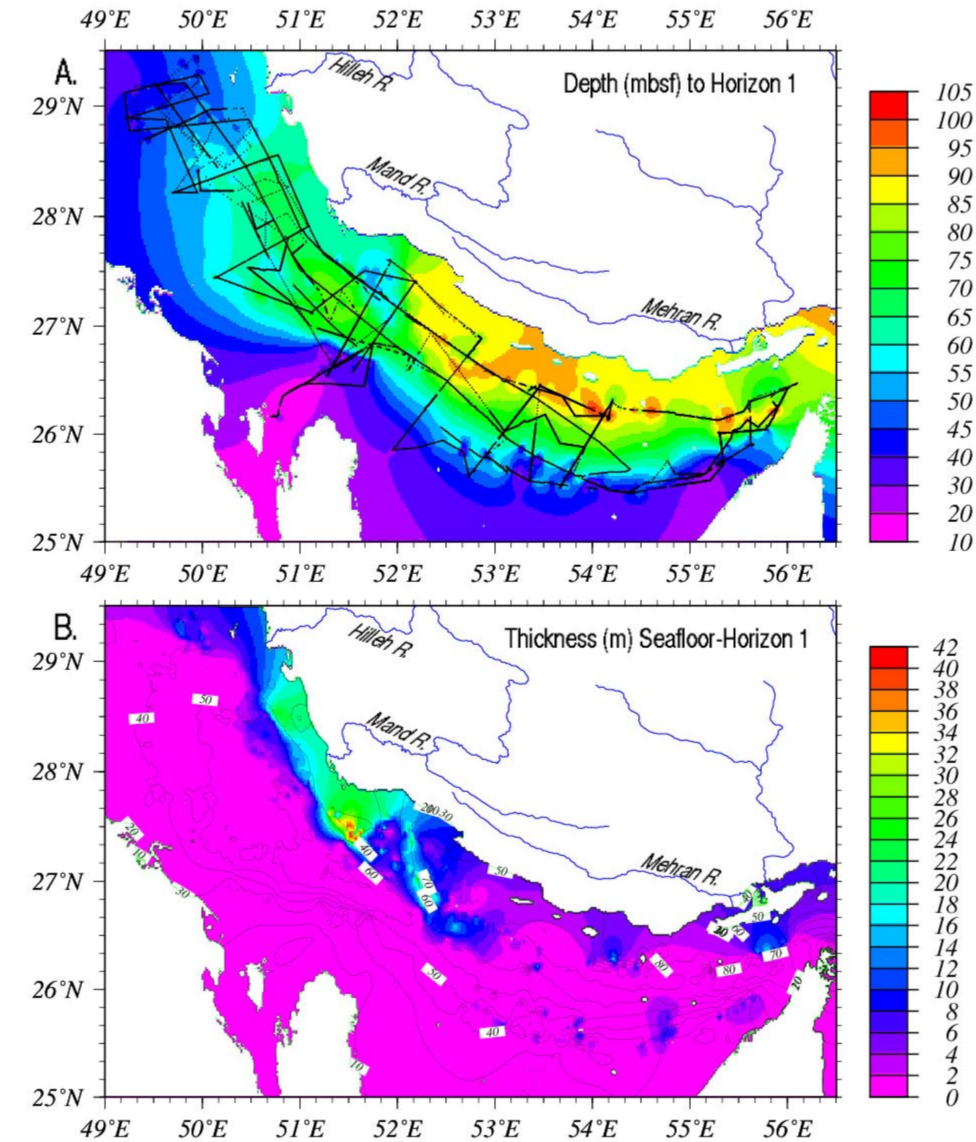

Figure 1. (a) Structure map on Horizon 1 shows the depth below sealevel to the LGM unconformity. Black dotes indicate the distribution of data points from 3.5 kHz data collected on the USNS Bowditch in 1998. (b) Thickness of the interval between seafloor and Horizon 1. This unit is primarily marls deposited in late Holocene deltas seaward of rivers draining the Zagros Mountains in Iran. Contours are depths to seafloor based on only the bathymetry data collected along the tracklines shown in (a).

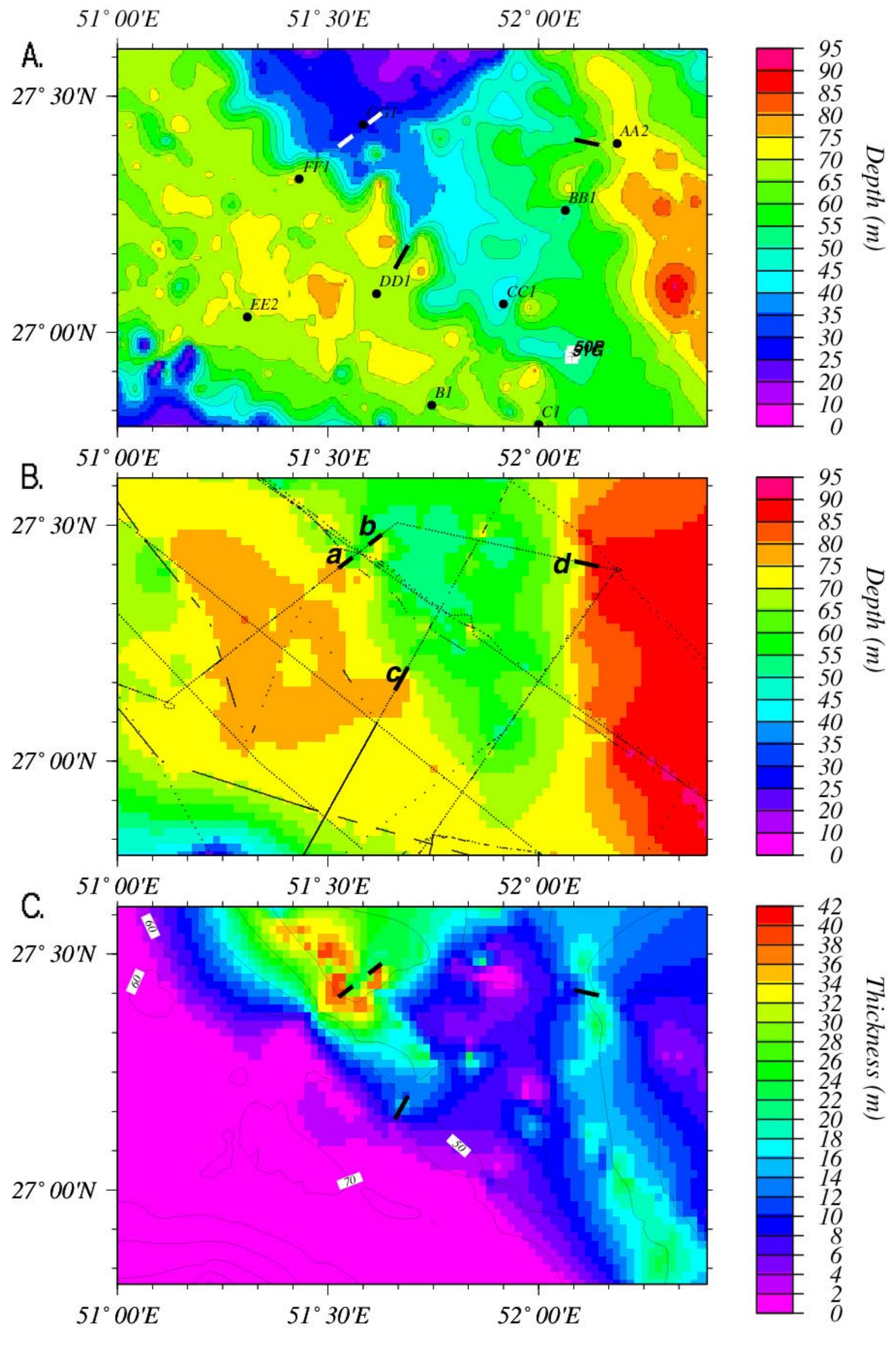

Figure 2. Detail of Gulf shows the southeast tip of the Iranian river deltas. (a) Bathymetry based on soundings digitized from navigation charts. Black dots indicate locations of sediment cores. (b) Depth to Horizon 1 (same as Figure 1a). Black lines indicate data base used for contouring (b) and (c). Letters indicate locations of profiles in Figure 3. (c) Thickness of the interval between seafloor and Horizon 1 (same as Figure 1b).

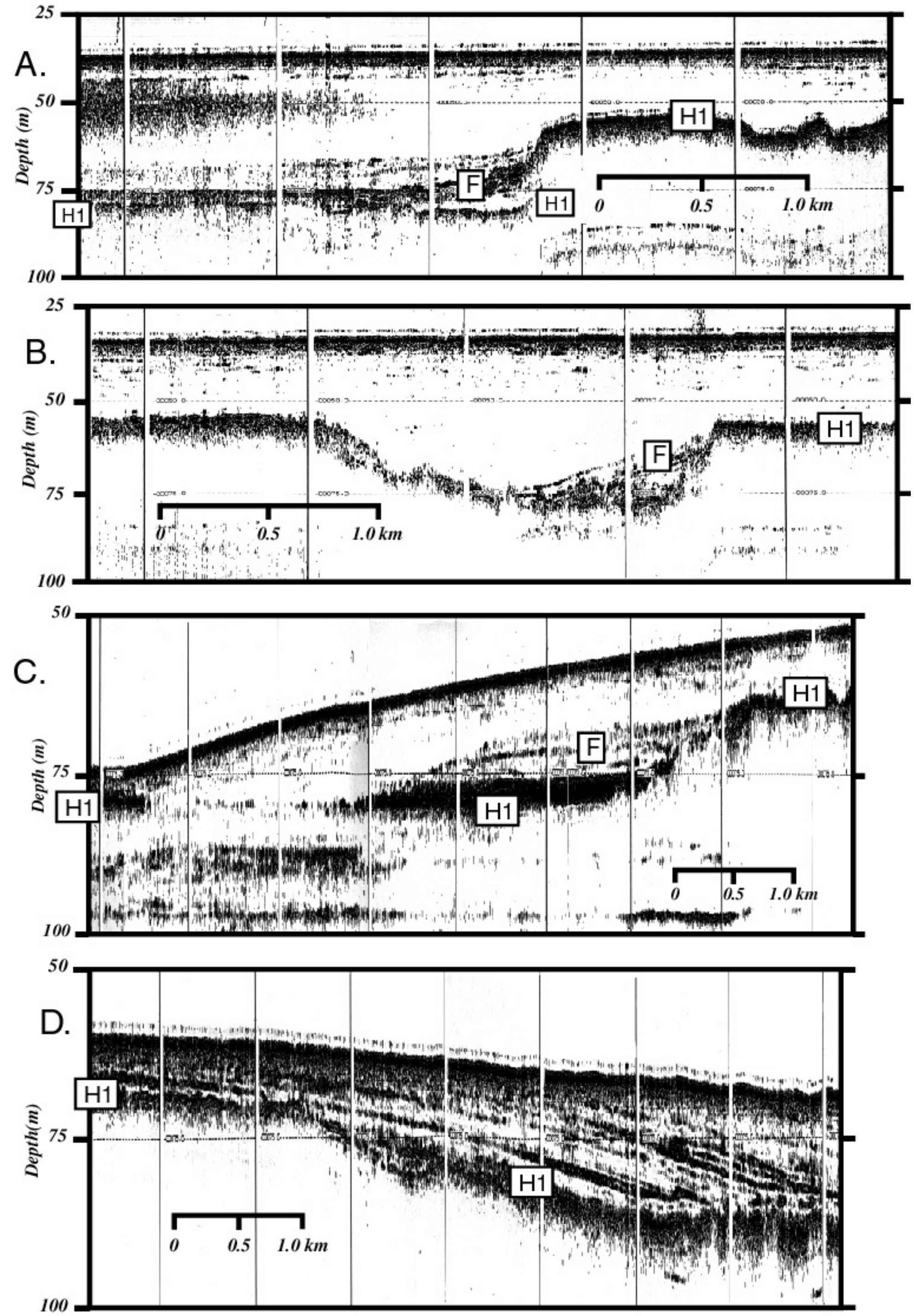

Figure 3. Subbottom profiles (hull mounted 3.5 kHz) showing a fluvial channel (b) buried beneath Holocene marl and abrupt steepening of the Horizon 1 (H1) surface along the edge of the underlying delta deposits (a, c, and d). "F" indicates fluvial sediments filling the channel and bounding the scarp. In (d) reflectors within the Holocene unit downlap onto Horizon 1 towards the west into the central basin. Locations are shown in Figure 2b.