Core-seismic study on the pre-glacial history of the Surveyor Fan deep-sea sedimentary system, Gulf of Alaska

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Introduction

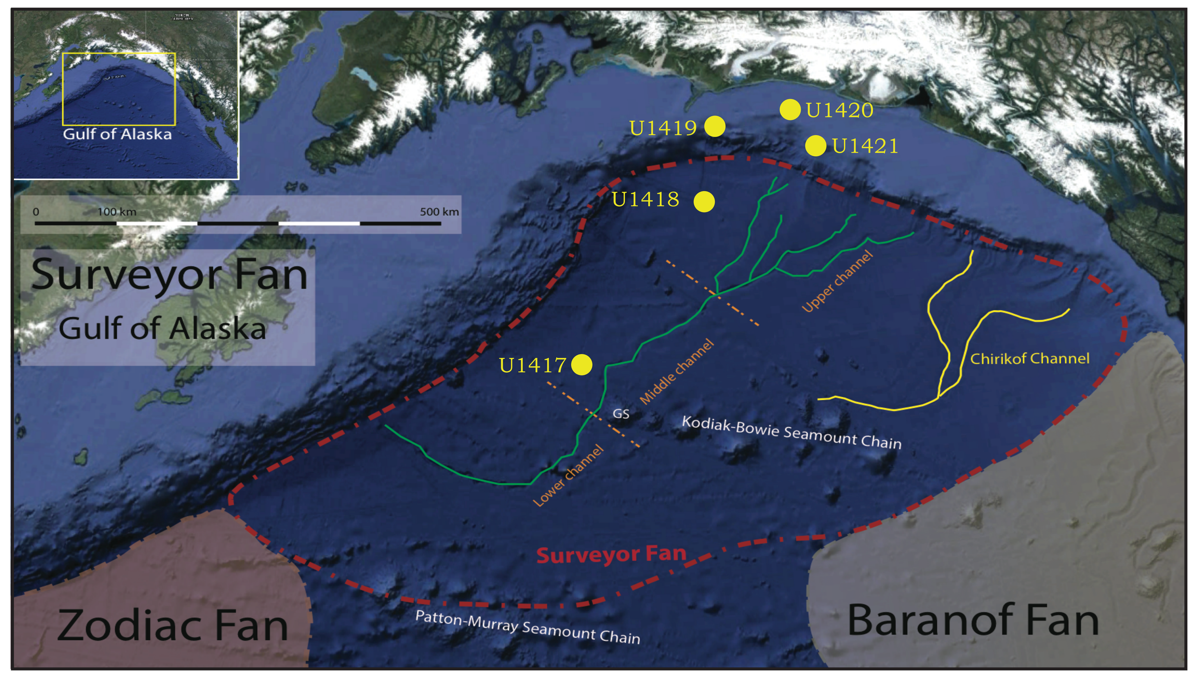
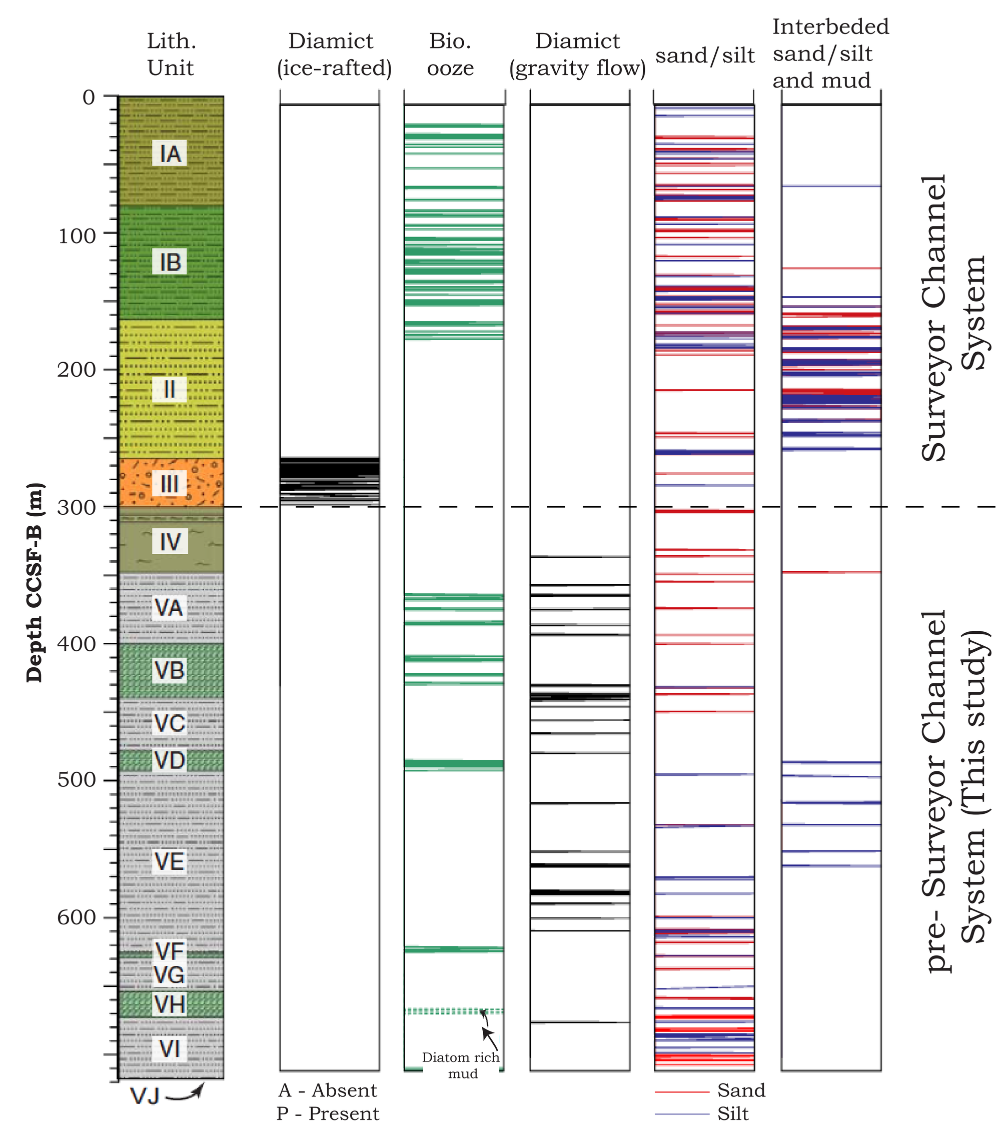


Figure 1. Gulf of Alaska study area with IODP Exp. 341 drill sites (yellow circles). The Surveyor Channel system shown in green, a nearby Chirikof Channel shown in yellow. Red dashed line denotes the approximate area of Surveyor Fan, nearby Zodiac and Baranof marine fans also shown here.

Previous studies show that the Plio-Pliestocene transition (PPT), a glacial intensification in the Northern Hemisphere at ~ 2.7 Ma, marks the genesis of the Surveyor Channel system in the northern Gulf of Alaska. Since that time, glacially eroded sediment from the St. Elias Mountains have dominated the evolution of this system. However, many questions remain about the provenance of sediment and the nature of sediment delivery to the deepwater regions prior to the evolution of the Surveyor Channel system. Integrated Ocean Drilling Program (IODP) Exp. 341 obtained sedimentary cores dated as old as ~10 Ma.

In this study, we use available 2D seismic data combined with the IODP Exp. 341 core and log data to analyse the depositional environment preceeding and leading up to the PPT (~2.7 Ma). The cores provide lithostratigraphy and an age model of sediment deposition, while seismic data allows us to extend interpretations across the Gulf of Alaska to identify broader depositional patterns associated with the evolving sedimentology of this source to sink system.

Core



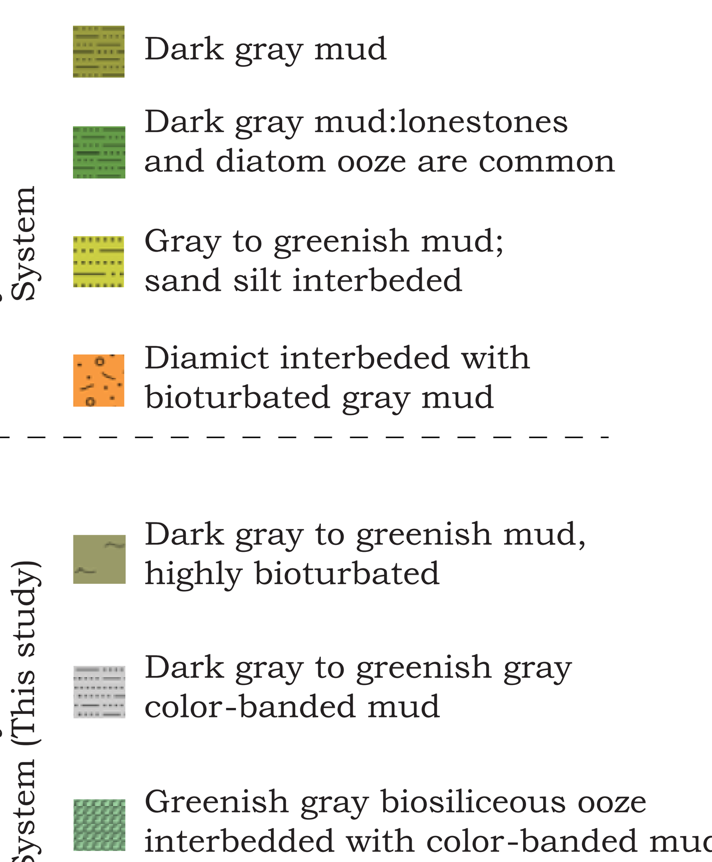


Figure 7. Lithostratigraphy of Site U1417 drilled core, includes the Diamicts, Biosiliceous ooze, sand and silt contents.

The genesis of the Surveyor Channel marks a big difference in the lithostratigraphic units of the U1417 core. Before the channel existed, the majority of sediment deposits consisted of mud with the absence of interbeded sand/silt layers or the ice-rafted diamict.

Core-seismic tie

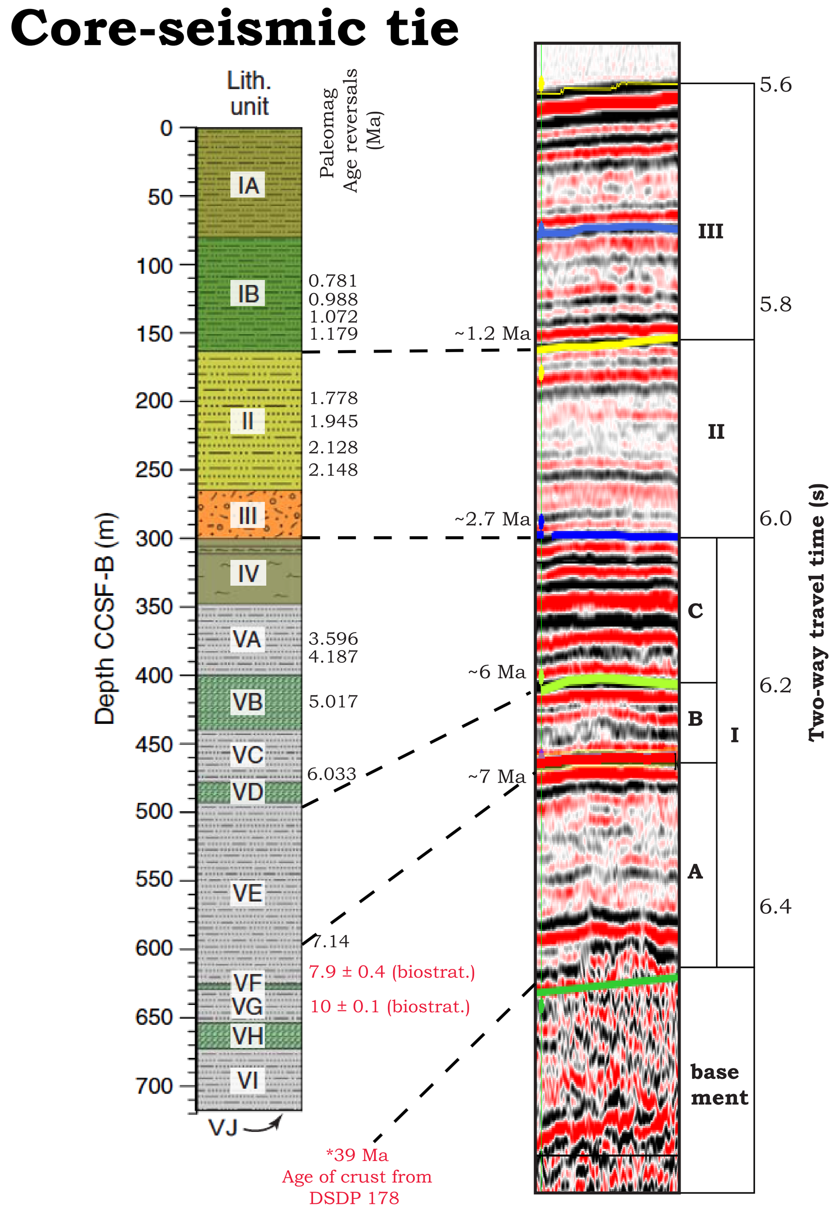


Figure 8. The correlation between core and seismic data. The conversion from time to depth was using a P-wave velocity interval of 100 m. The age model established using core data helped date the mapped horizons in this study.

Using log P-wave velocity to convert two-way travel time to depth, we established a tie between core and seismic data. With the age model from core data analyses available at the drill site, we are able to give ages to our mapped horizons.

From top to bottom (Fig.5):

-The boundary between seismic sequence I and II is dated ~2.7 Ma.

-The boundary of subunit IC and IB is dated ~ 6 Ma.

-The boundary of subunit IB and IA is dated ~ 7 Ma.

The tie allows us to correlate the changes in sediment lithology at core data to changes observed in seismic data.

The continous, high amplitude reflectors in subunits IC could relate to the litho. unit IV of the dark grey/greenish mud.

The boundary of seismic sequence I and II marks a big change in seismic amplitude, where a sharp decrease in amplitude can be observed moving upward, which also correlate to a change from litho unit IV to III (Fig.5).

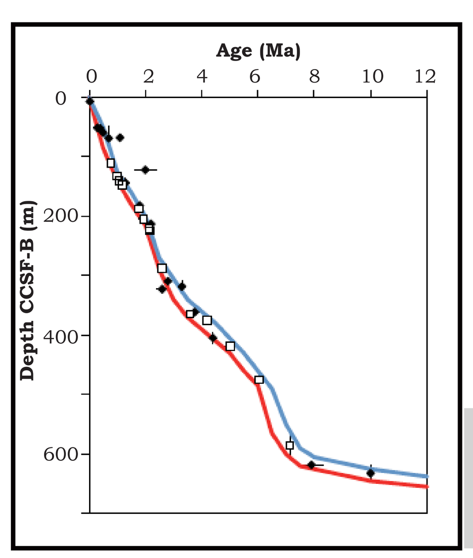
The presence of diamict (from gravity flow) and sand/silt beds could be the cause of the higher amplitude reflectors observed throughout seismic sequence I.

IODP Exp 341

The Integrated Ocean Drilling Program (IODP) Expedition 341 drilled five sites in the Northern Gulf of Alaska to study the complex interactions between climate change, tectonics, and deep sea sedimentology [Expedition 341 Scientists, 2014].

This study used an age model obtained from core data analyses at Site U1417 to correlate the timing of sediment deposition. We also used lithostratigraphic data at Site U1417 when possible to provide information on the past depositional environment in the deep sea.

The age model provides an updated choronology of sediment deposition as old as 10 Ma.



An age model of sediment deposition at Site U1417 is available using core data analyses. Exp. 341 scientists used biostratigraphy and magnetic data to construct the age model. We use this age model to constrain the mapped horizons in this study after the correlation of core and seismic data has been done.

Figure 2. Age model at Site U1417
□ Biostrat — Age max
● Paleomag — Age min
(Jaeger et al., 2014)

Seismic stratigraphy of the Surveyor Fan is divided into 3 sequences(I, II and III) after *Reece et al. 2011*. Exp.341 scientists further divided seismic sequence I into 3 subunits (A, B and C) based on characteristics of the reflectors. The boundaries of IA, IB and IC are the main targets for this study; they were regionally mapped across the Gulf of Alaska.

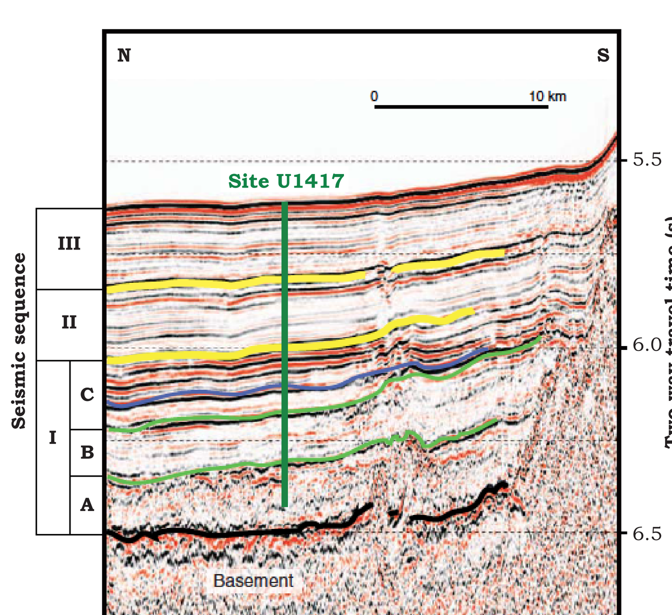
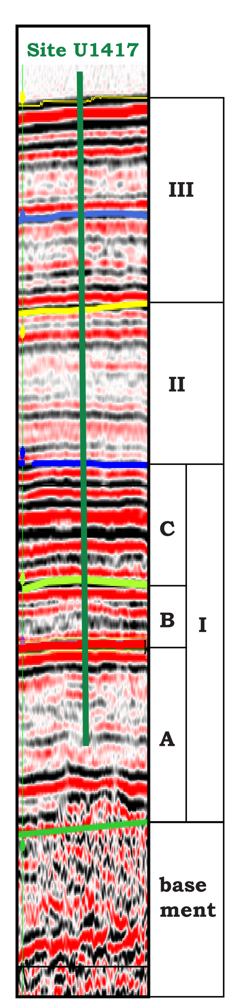


Figure 3. Seismic stratigraphy units at Site U1417.
(Jaeger et al., 2014)

Seismic data



Data and methodthology

This study uses 2-D seismic reflection data in the Gulf of Alaska from various surveys; i.e. single-channel USGS survey collected in the 1980s, multi-channel seismic (MCS) data acquired in the 1970s, 2004, 2008 and most recently in 2011 (Fig. 4).

Using the Paradigm suite's software, we mapped the boundaries of subunits IA, IB and IC starting at Site U1417 and extending as far as we were confident, to see if changes in the seismic data can be observed regionally.

Two-way travel time thickness maps of the 3 subunits were also created to see the pattern of sediment depositions in the past. The age model at Site U1417 allows us to constrain the age of each subunit after the core-seismic tie has been established.

The seismic reflection data are analyzed to see changes in geomorphology of deep sea marine fan.

Observations

Seismic sequence I is the oldest and deepest stratigraphic unit of the Surveyor Fan with high amplitude, laterally semi-continous reflections (Reece et al., 2011) (Fig.5).

Seismic subunit IA is the deepest unit in sequence I. It contains mostly chaotic, discontinuous, high amplitude reflectors.

Seismic subunit IB is made up of semi-continuous, varying amplitude reflectors. This unit is relatively thin compared to subunit IC and IA above and below.

Seismic subunit IC is the topmost subunit in this sequence. This subunit contains high-amplitude, laterally continuous reflectors.

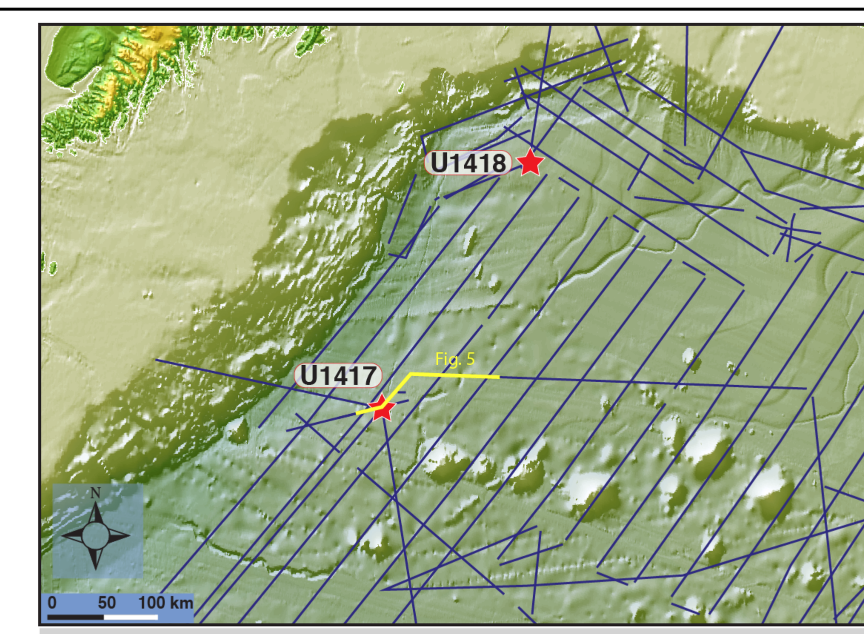


Figure 4. Map of seismic data in the Gulf of Alaska available for this study. Red Stars are the two deep sea sites of IODP Exp. 341

From the isopach

Subunit IA deposit: Sediment deposition is randomly distributed, most likely to fill up the topography lows of the basement.

Subunit IB deposit: This is the thinnest package among the three. It appears that sediment is thickest at the Northern corner of the Gulf of Alaska, thinning distally.

Subunit IC deposit: It appears that sediment thickness is concentrated along an elongate North-South trend. This depocenter is co-located with the modern position of the Surveyor Channel system.

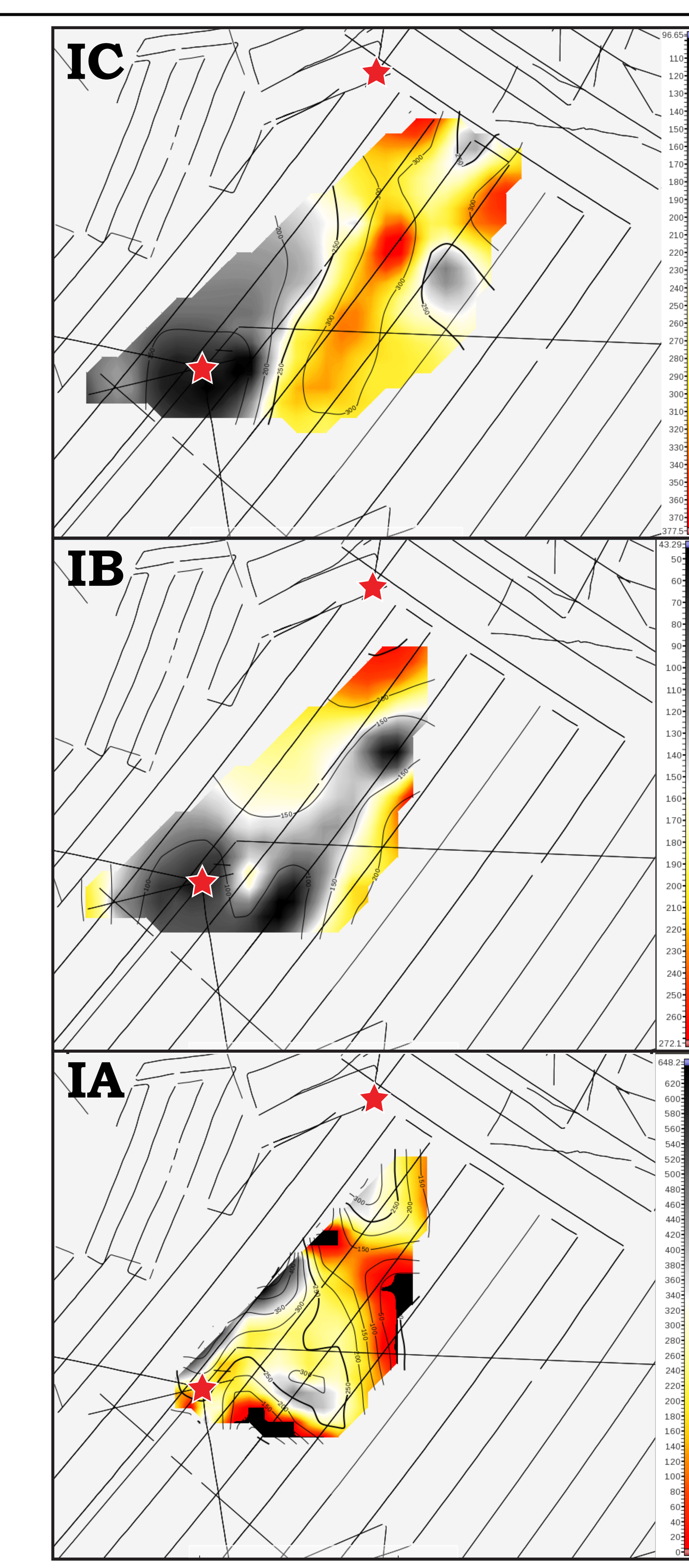


Figure 6. Two-way travel time thickness (isopach) maps of the subunits IC, IB and IA (youngest to oldest) from top to bottom respectively. Red stars denote the two drill sites (U1417, U1418) from IODP Exp.341 in the deep sea Gulf of Alaska.

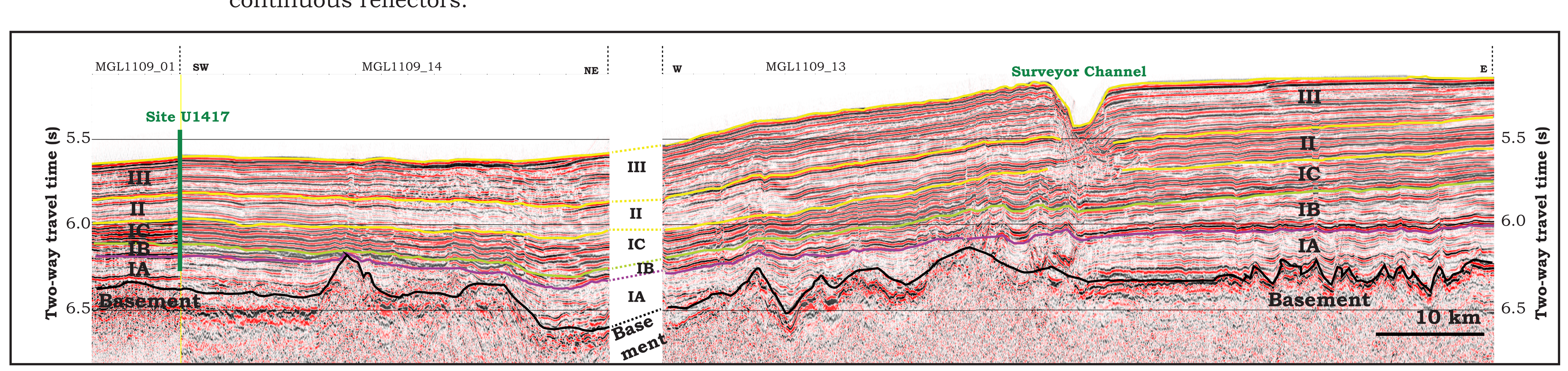


Figure 5. A seismic transects extending from Site U1417across the main Surveyor Channel (see line location in figure 4). Seismic sequence I existed before the Surveyor Channel. The boundaries between subunits IA, IB and IC can be mapped regionally. The mapping stops at seamounts where we cannot map across confidently. (VE ~ 12.5X)

Conclusion

- Changes in the characteristics of seismic data can be observed at the boundaries between subunits IA, IB and IC in seismic data which correlate with ages of ~7, 6 and 2.7 Ma respectively. Changes in core stratigraphy can be observed at the boundary that distinguishes the Surveyor Channel's formation.
- The boundaries of IA, IB and IC can be regionally mapped. The isopachs of the units show different depositional patterns during the three time periods:

-IA: From ~39 Ma (age of oceanic basement) to ~7 Ma, the sediment was randomly distributed, mostly deposited in bathymetric lows.

-IB: From ~7- 6 Ma, the sediment distribution was more organized; the depocenter was centered around the U1418 drillsite in the northwest GOA

-IC: From ~6- 2.7 Ma, sediments moved away from the shelf located around the modern day position of the Surveyor Channel. In addition of the depocenter to the northwest, another depocenter in the northeast can be observed in this period, either it did not exist in IB or could not be mapped.

Pacific plate motion relative to the North American plate shifted to a more orthogonal convergence ~6 Ma; this change in plate motion could have influenced increased sedimentation during this time period through increased convergence, and therefore uplift and glaciation.

Future work

- Map and extend the horizons in this study toward the shelf if possible in order to better understand source-to-sink transportation system prior to the existinence of the Surveyor Channel.
- Improve precision of core-seismic tie by creating synthetic seismic from core-log data if possible.
- Include the role of tectonic influences to sediment transportation. The Pacific plate moves at ~5 mm/year relative to the North American plate. The movement in the past 10 Ma (approximately 500 km) could have a large impact on sediment tranportation to the deep sea.
-Collaborate with sediment provenance group to identify the source of sediment prior to the Surveyor Channel system.

Acknowledgement/ References

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-#ReeceGeophysics Group

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• Reece, R., S. Gulick, B. Horton, G. Christeson, L. Worthington (2011), Tectonic and climatic influence on the evolution of the Surveyor Fan and Channel System, Gulf of Alaska, Geosphere, v. 7, no. 4, p. 830-844, doi: 10.1130/GES00654.1.

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