2018 한국수로학회 추계학술대회
12, 04, 2018

Seismic stratigraphy related to the evolution a submarine canyon in the northwestern margin of the Ulleung Basin, East Sea

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UST UNIVERSITY OF SCIENCE & TECHNOLOGY

KIGAM Korea Institute of Geoscience and Mineral Resources

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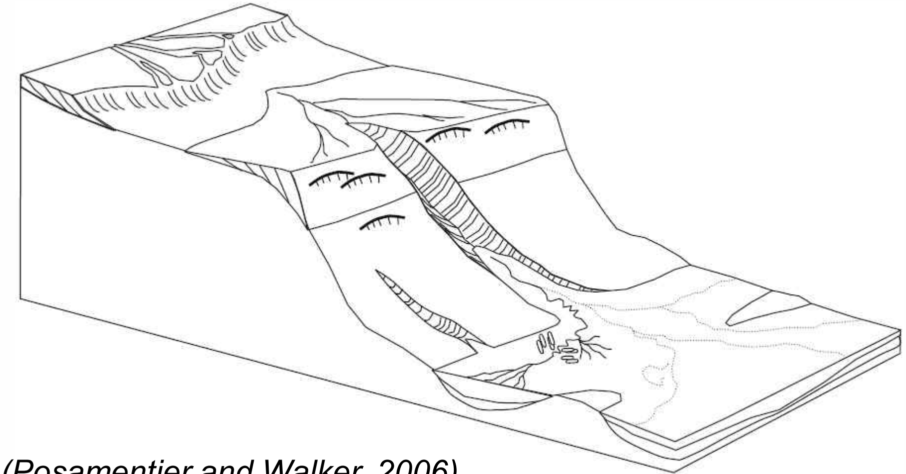
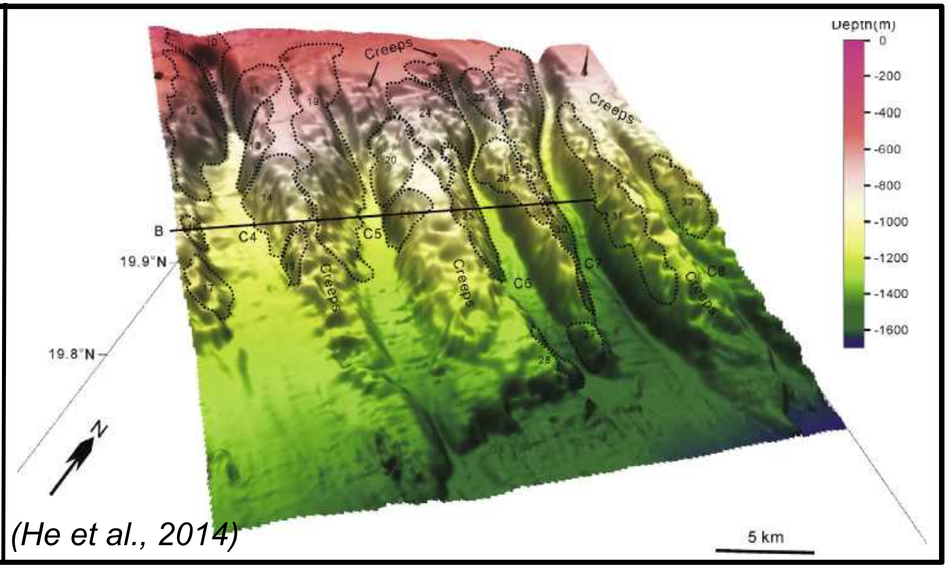
1. Introduction



(Posamentier and Walker, 2006)

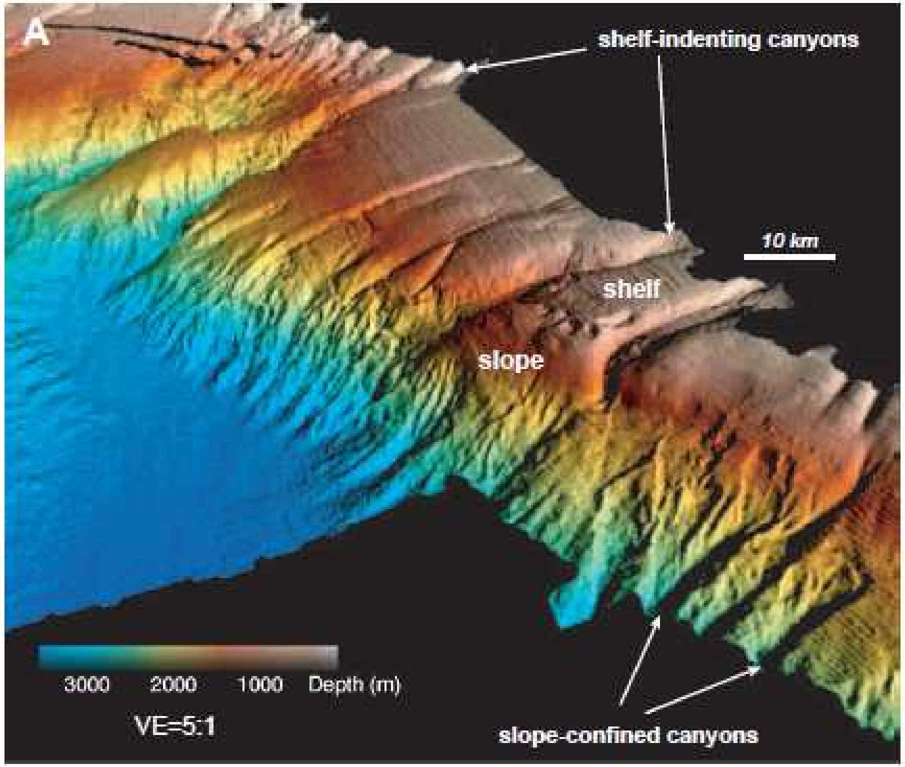


(He et al., 2014)

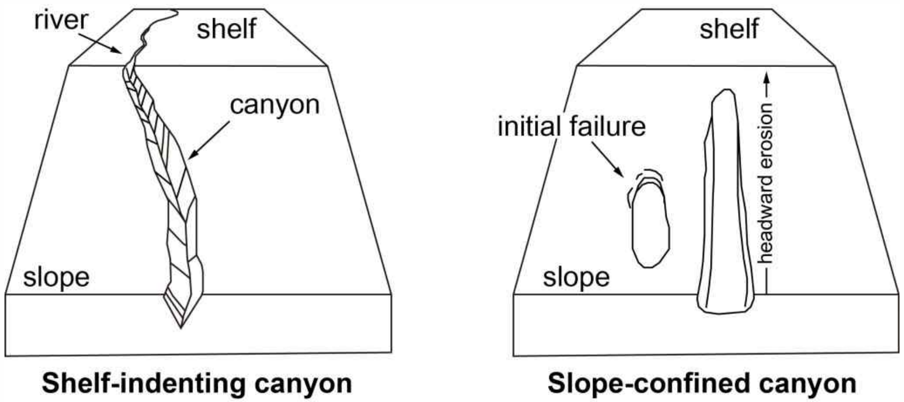
♦ **Submarine canyon** *(Shepard, 1981; Pratson et al., 2007)*

► Major morphological features that develop along the continental slope in most continental margin around the world
► The primary conduits for the transport of clastic detritus from the continental shelf into the deep sea
► Repeated erosion and deposition associated with geological and geophycal conditions
► Studies on the origin and sedimentary processes of submarine canyons *(Twichell and Roberts, 1982; Farre et al., 1983; Pratson and Coakley, 1996; Straub and Mohrig, 2009; Jobe et al., 2011; Iacono et al., 2014; Almeida et al., 2015)*

1. Introduction



(Pratson et al., 2007)



♦ Type of submarine canyon

(Twichell and Roberts, 1982; Farre et al., 1983; Pratson and Coakley, 1996; Pratson et al., 2007; Iacono et al., 2014)

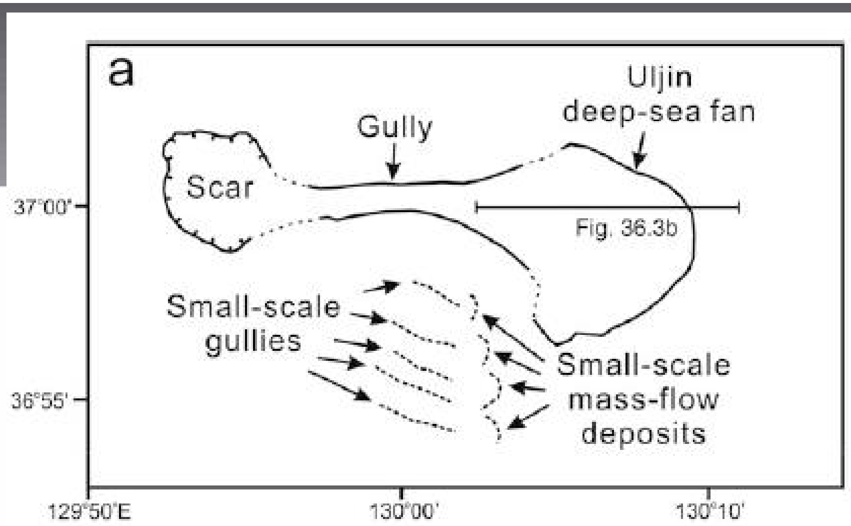
(1) Shelf-indenting canyon

► Occurrence from continental shelf to continental slope
► Transport of sandy sediments through gravity flows, and connection with fluvial systems during sea-level lowstand
► Gentle slope, long length, and meandering center axis
► Development on the high sediment supply and/or active margin

(2) Slope-confined canyon

► Development limited to continental slope
► Formed by retrogressive slope failure
► Steep slope, short length, and straight center axis
► Studies on the low sediment supply area

1. Introduction



(Lee et al., 2014)

♦ Previous studies

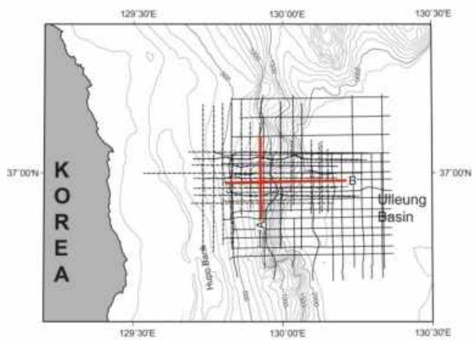
► Paleo-submarine canyons *(Park et al., 2015)*
► Submarine failures and related mass transport deposit (MTD)
(Lee et al., 1991; Lee et al., 1996; Chough et al., 1997; Lee and Suk, 1998, Lee et al., 1999; Lee et al., 2014; Cukur et al., 2016)

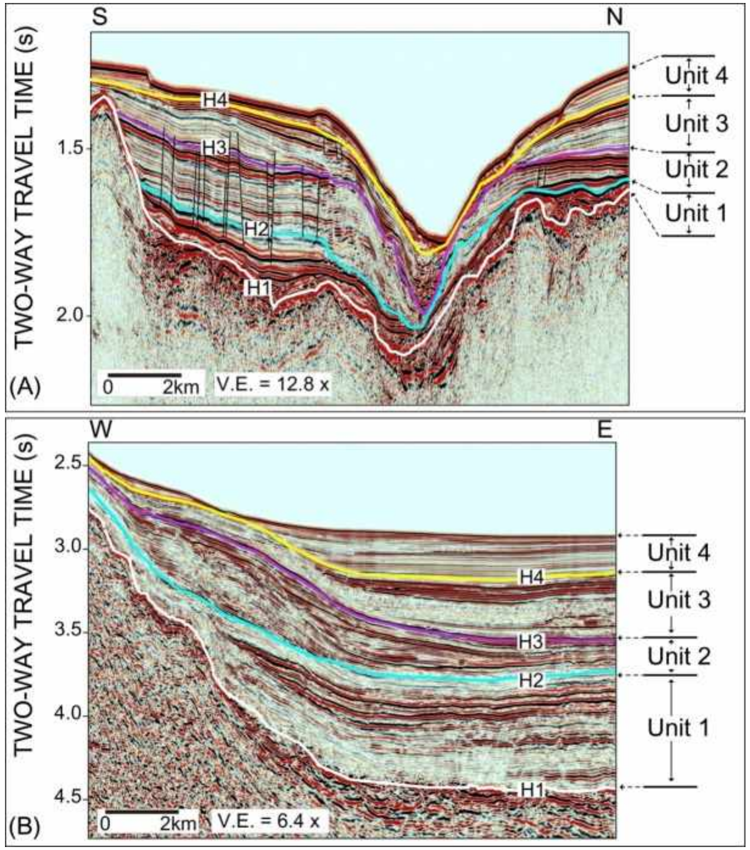
♦ Limitation

► Studies on the modern sedimentary processes
► Lack of relation between submarine canyons and MTD sedimentation
► Seismic stratigraphy study around the canyon
► Lack of geometric analysis of submarine canyon

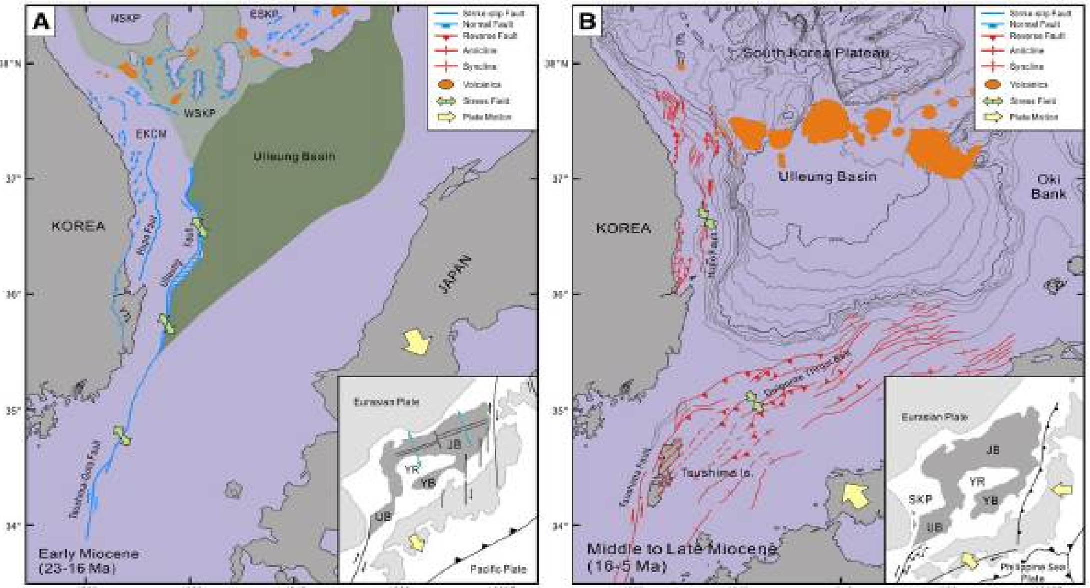
♦ Purpose of this study

► Seismic characteristics and distribution pattern
► Revealing the stratigraphy and depositional history of the canyon

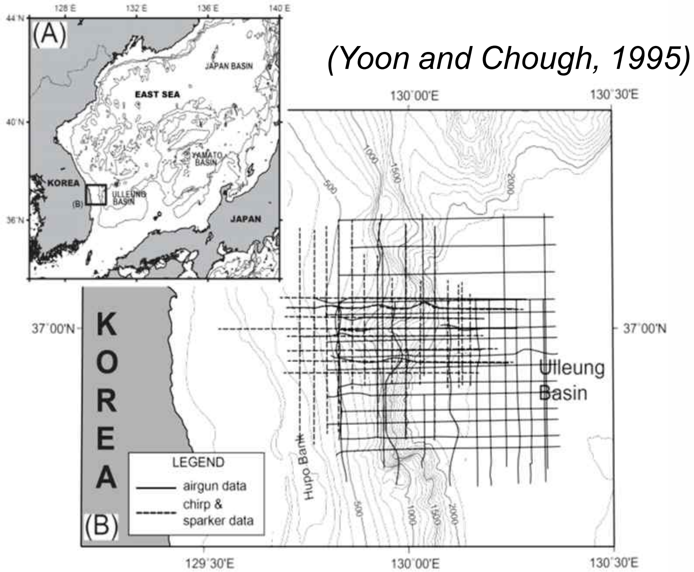




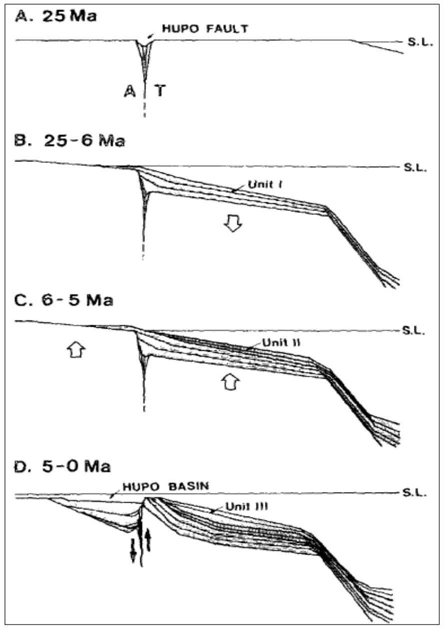
2. Geological setting



(Yoon et al., 2014)



(Yoon and Chough, 1995)



♦ Ulleung Basin *(Chough, 2000)*

► Marginal sea
► Three deep basin (Japan, Yamato, and Ulleung)
► Submarine highland (Korea Plateau, Yamato ridge, and Oki bank)

♦ Western margin *(Yoon and Chough, 1995; Chough, 2000; Yoon et al., 2014)*

► Bathymetry deepening E-W direction

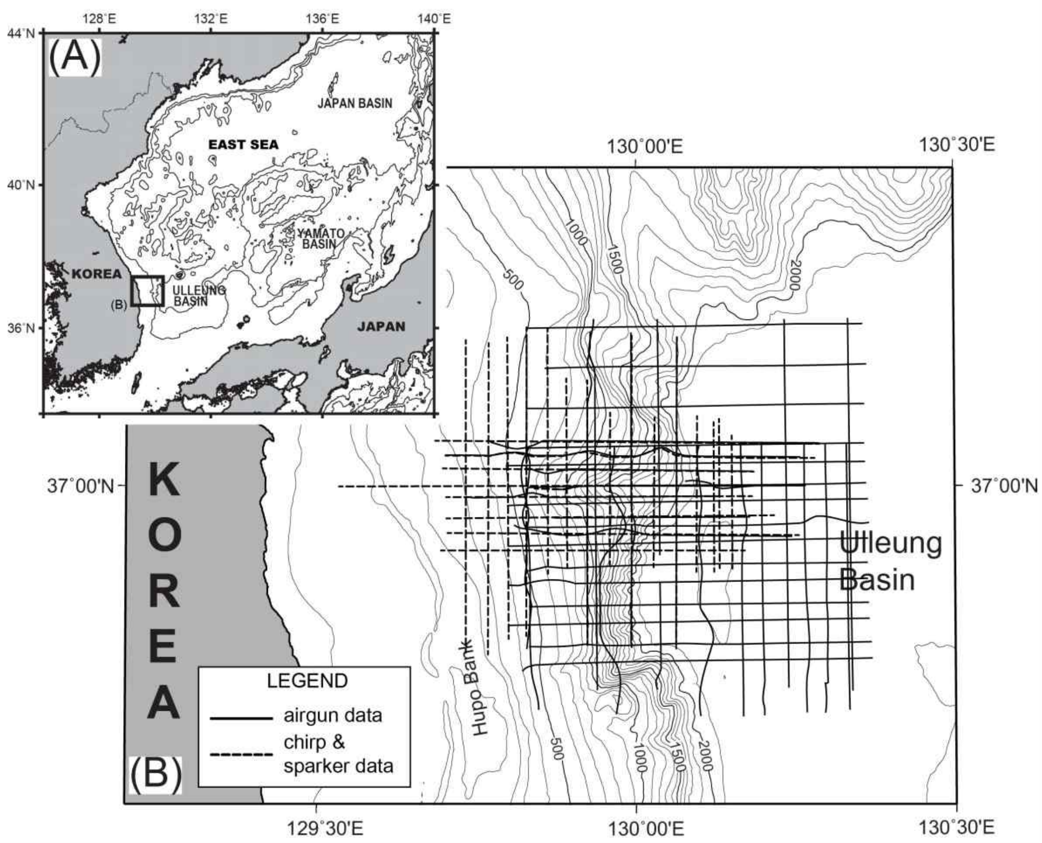
► Abrupt change of submarine topography
: Narrow continental shelf (<20 km)
: Steep continental slope (4-10 °)
: Deep sea

► Steep slope of middle-lower slope
: Failure scar and gravity flow deposits

► Sediment supply
: Namdae, Wangpyeong, Song river
: Absence of major fluvial systems

► Geological structures
: Hupo fault elongated N-S direction (~ 140 km)
: Hopo bank (length : ~ 80 km, width :1-20 km)

3. Data and method



♦ Data

	Type	Year
KIGAM	Multibeam data	2015
	Air-gun data	2001 2005 2015
	Sparker data	2015
	Chirp data	2015

♦ Method

- ► Stratigraphic analysis *(Mitchum et al., 1977)*
- ► Time-structure (Paleo-canyon)
- ► Isochron map (Submarine fan)

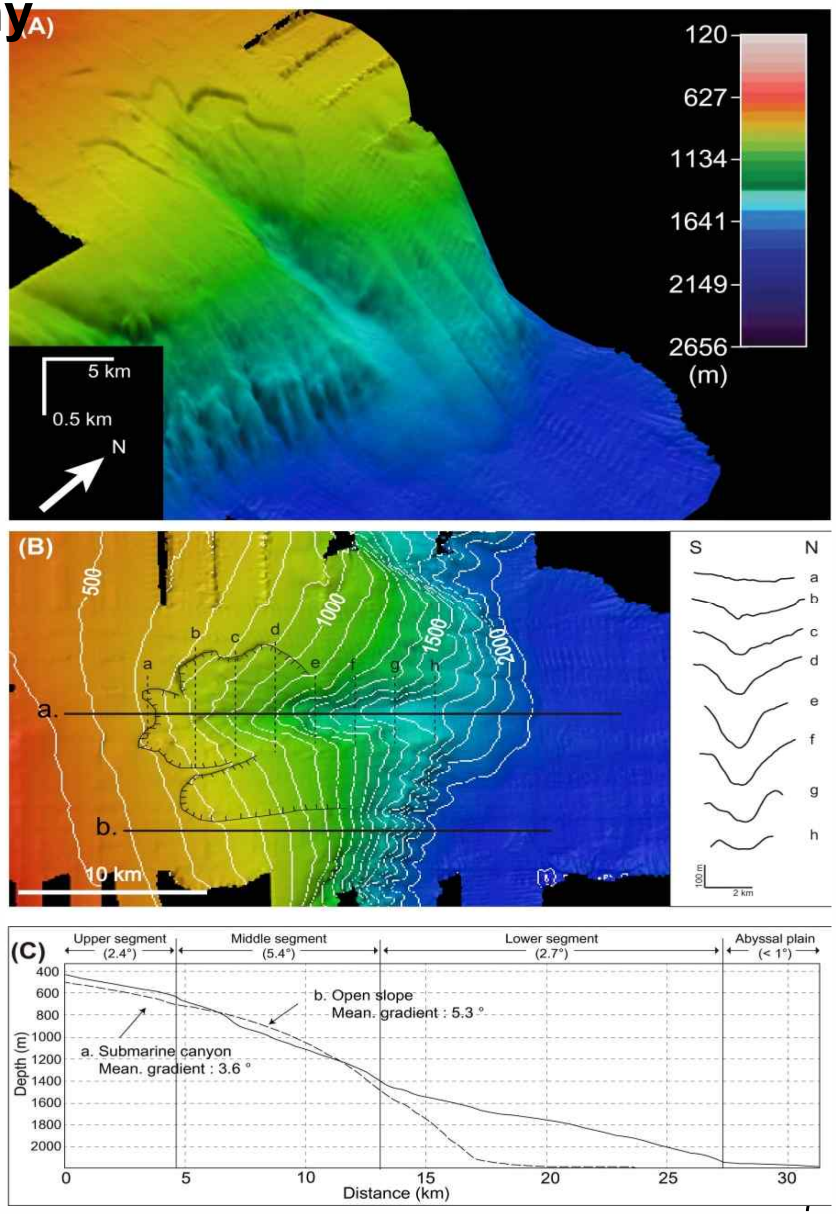
4. Results

♦ Characteristics of submarine topography

► Failure scar
: Occurrence at upper slope of 600 m depth
: Height of 60 – 88 m
: Max. Slope of 15 °

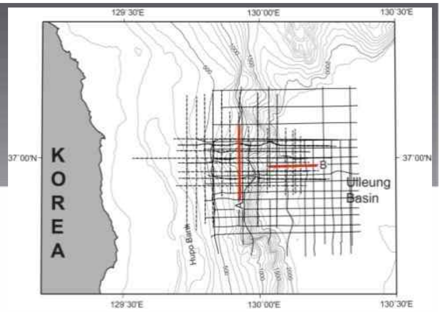
► Transversal profile
: U (a-d) to V (e-f) shape change
: Width of 2.5 – 7.7 km
: Increase in width toward slope
: Increase in depth toward basin
: Max. slope of 17 ° at the wall of canyon

► Longitudinal profile
: Concave-up
: Length of 14.7 km



Along-axis profile	Headwall scarp shape	Plain view path trajectory	Headwall scarp position	Type of evolution
concave-upward	amphitheater	straight	slope-confined	bottom-up

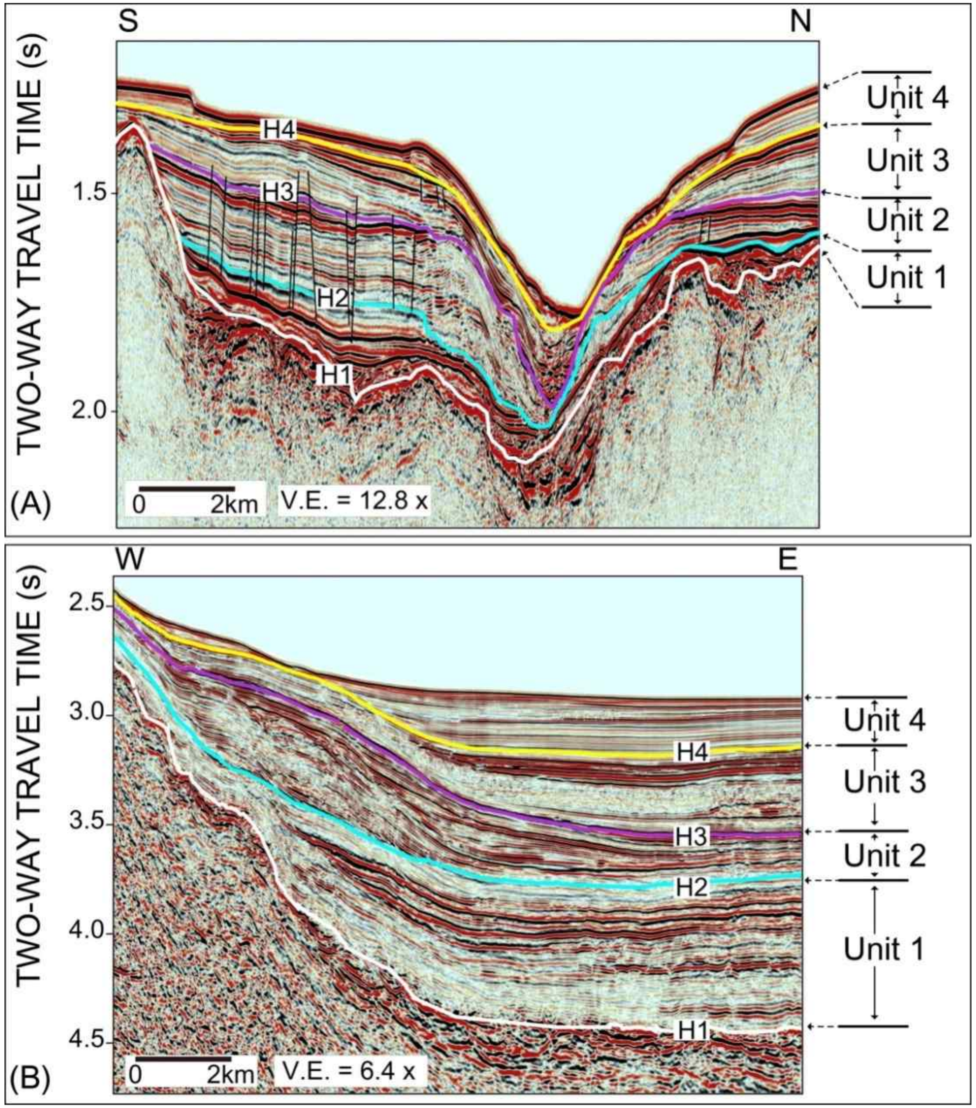
4. Results



♦ Seismic stratigraphy

► Four seismic units separated by erosional unconformities

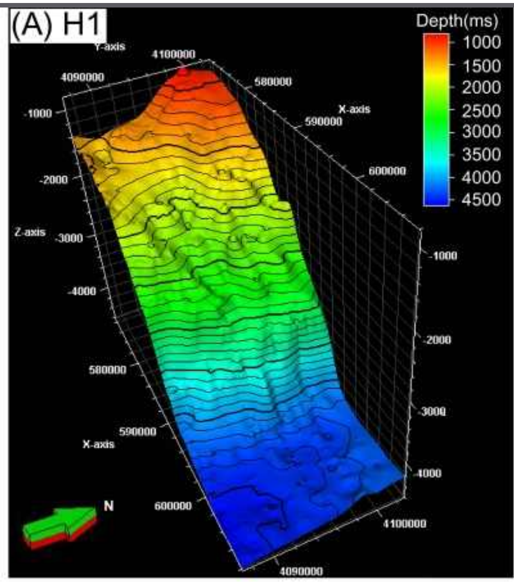
Unit		Slope	Basin
4	-	continuous and low-moderate amplitude	continuous and low-moderate amplitude
3	upper	*continuous and high amplitude*	*continuous and high amplitude*
	lower	*continuous and low amplitude*	chaotic
2	upper	*continuous and high amplitude*	*mainly well-stratified*
	lower	*continuous and moderate amplitude*	*alternation with well-stratified and chaotic*
1	-	*well-stratified with some slope failures*	*well-stratified and chaotic*

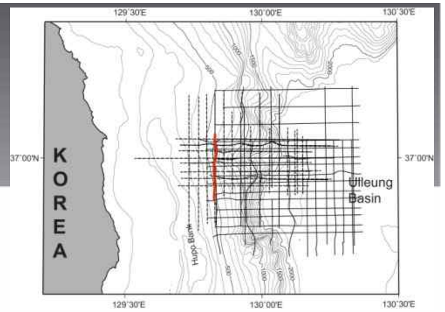


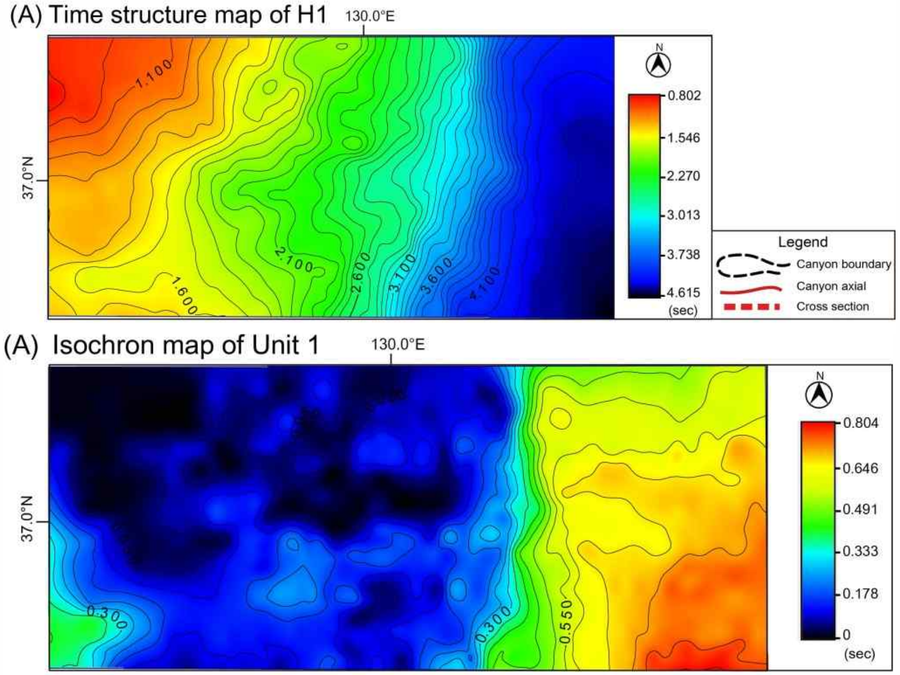
4. Results

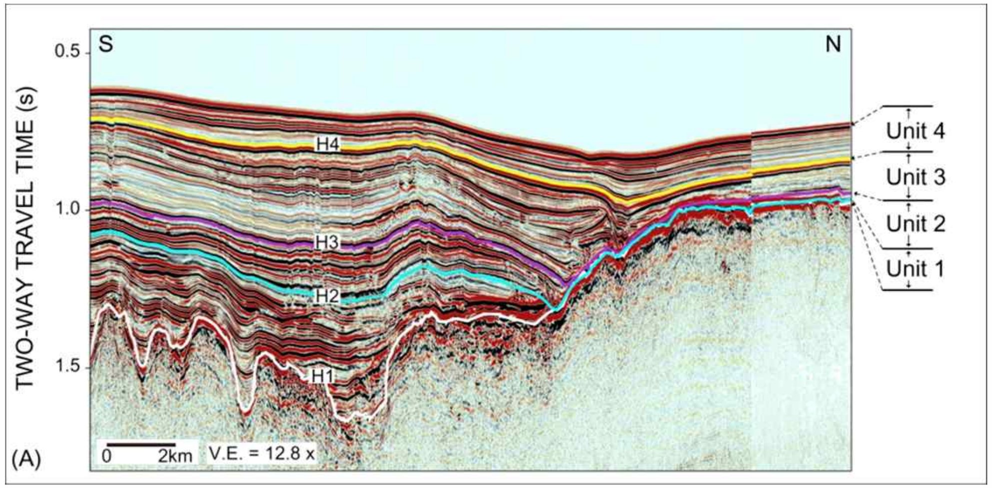
♦ Seismic stratigraphy

► Unit 1 (Early to Late Miocene)
: Overlying acoustic basement
: Deepening toward east (~ 4.6 s)
: Subdue trough in the center
: Thickness of 0.16 – 0.36 s in slope
: Depocenter of 0.8 s in basin





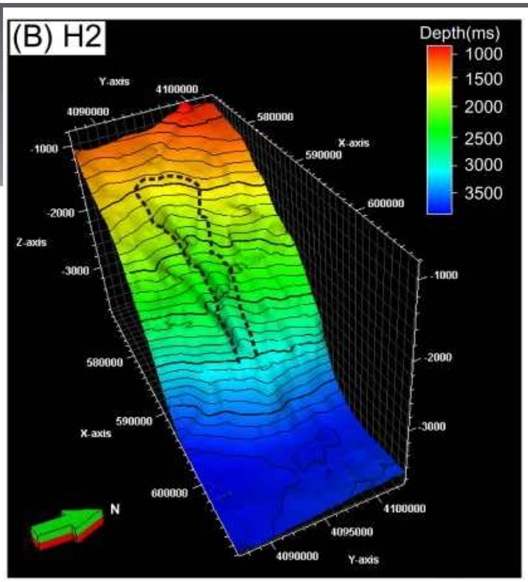


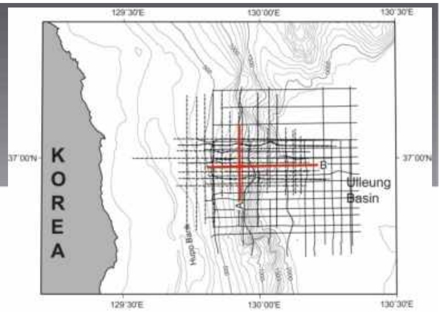


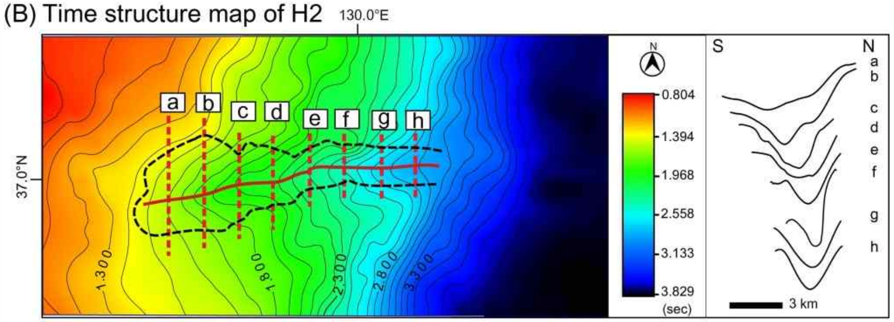
4. Results

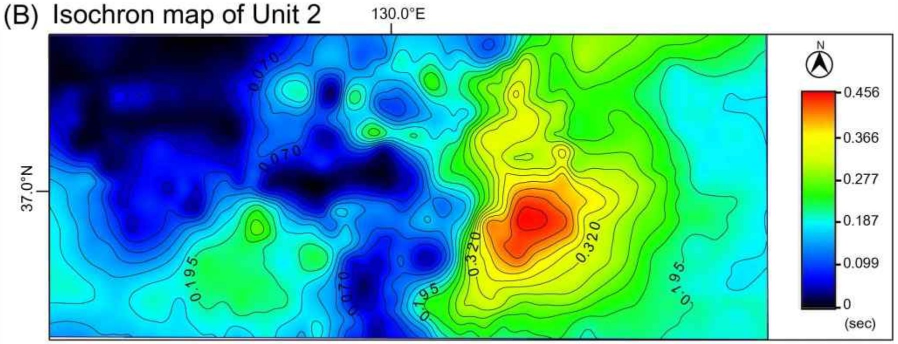
♦ Seismic stratigraphy

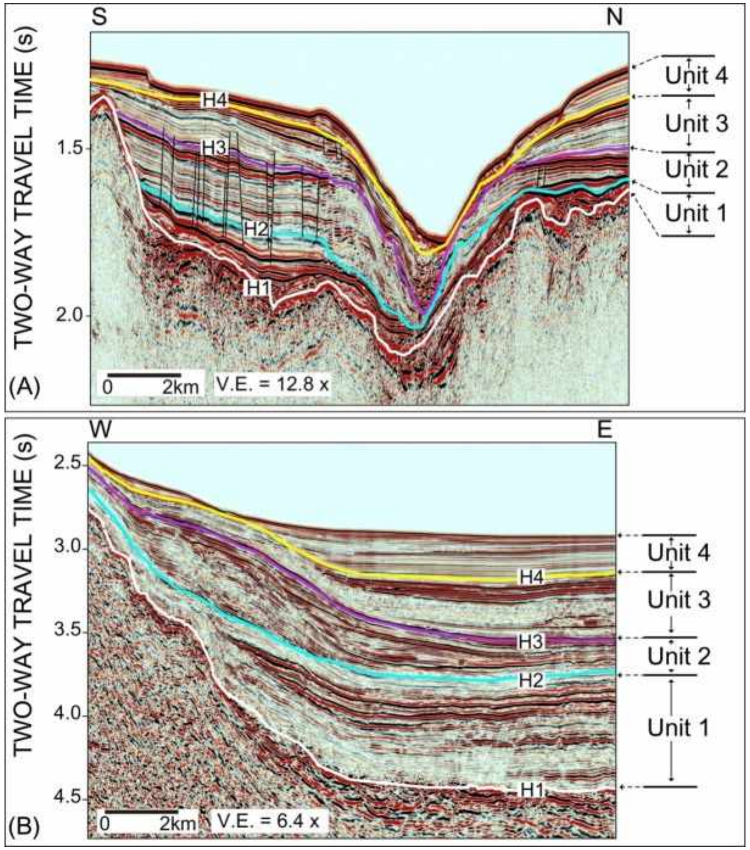
► Unit 2 (Late to late Late Miocene)
: Overlying unit 1
: Deepening toward east (~ 3.8 s)
: Trough in the center
: Width of 1.9 – 5.4 km
: Length of 17.5 km
: Max. height of 193.5 m
: Thickness of 0.13 – 0.20 s in slope
: Depocenter of 0.25 – 0.45 s in base of slope



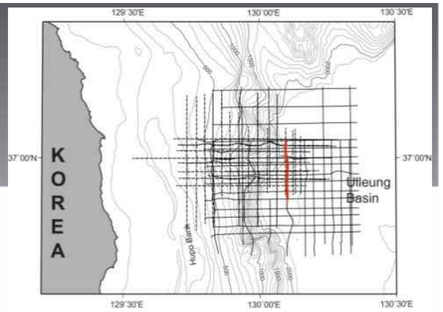






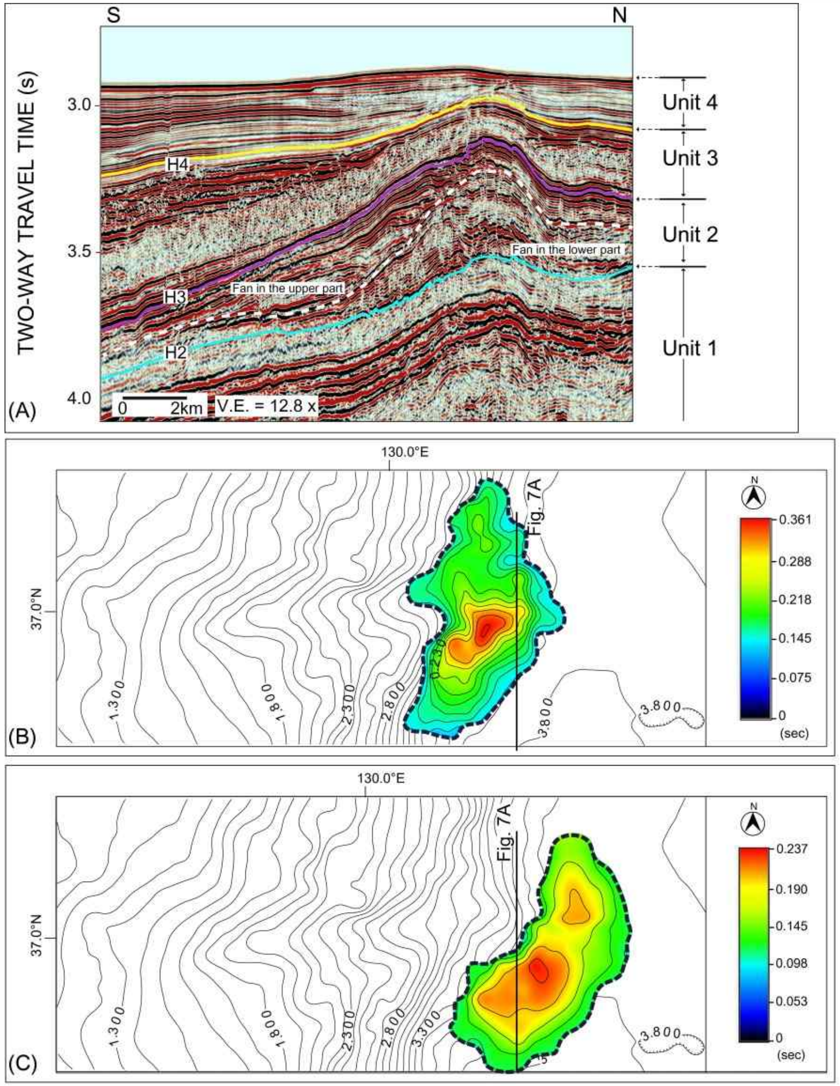


4. Results



♦ Seismic stratigraphy

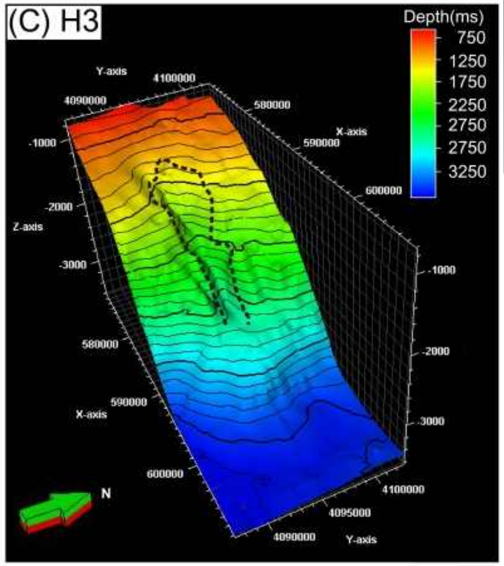
► Unit 2 (Late to late Late Miocene)
: Fan shape of deposit in the base of slope
: Two part of fan deposit bounded by reflection termination (onlap)
: Max. thickness of 0.36 s in the lower part
: Max. thickness of 0.23 s in the upper part

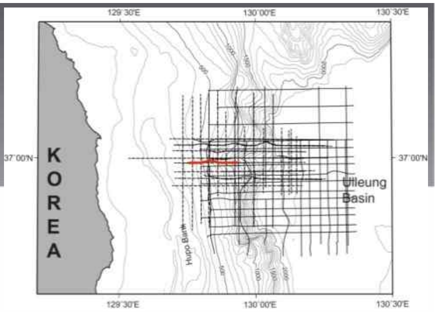


4. Results

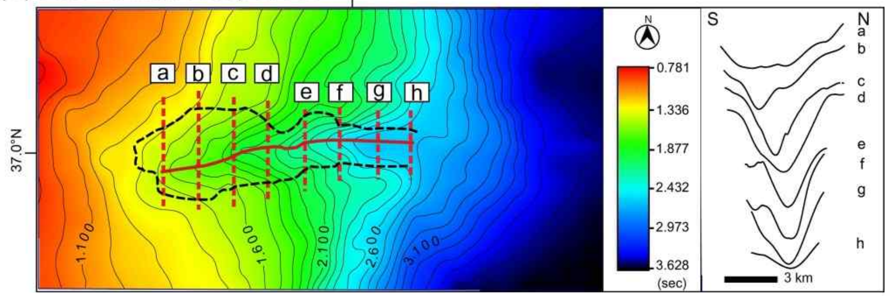
♦ Seismic stratigraphy

► Unit 3 (late Late Miocene to Pliocene)
: Overlying unit 2
: Deepening toward east (~ 3.6 s)
: Trough in the center
: Width of 2.0 – 5.1 km
: Length of 16.4 km
: Max. height of 287.3 m
: Thickness of 0.14 – 0.24 s in slope
: Depocenter of 0.47 s in basin

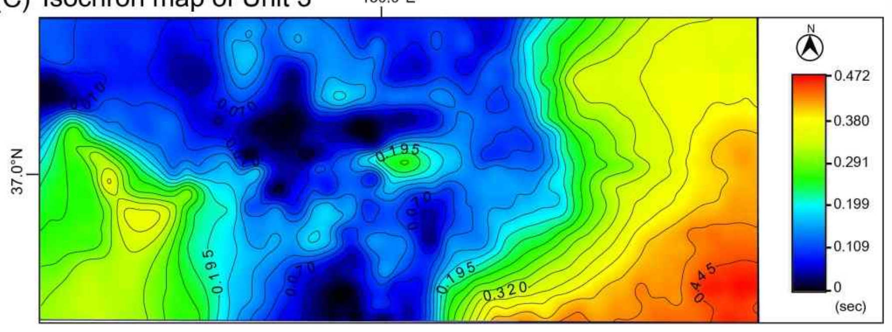


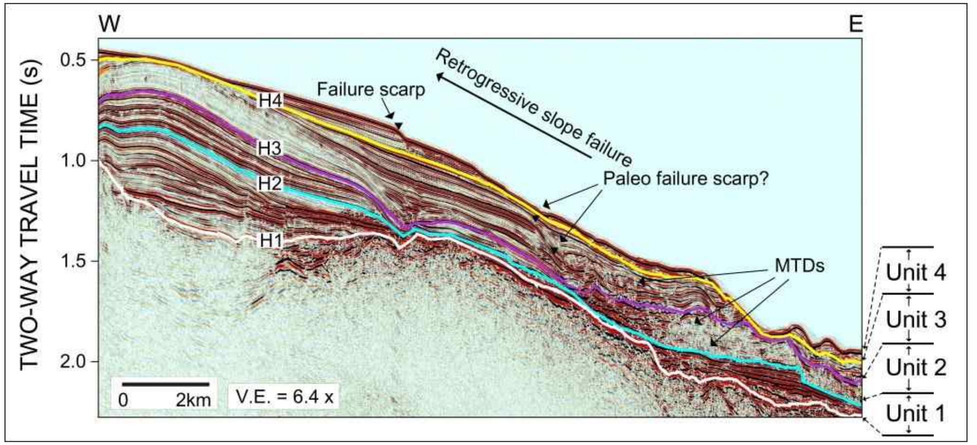


(C) Time structure map of H3



(C) Isochron map of Unit 3

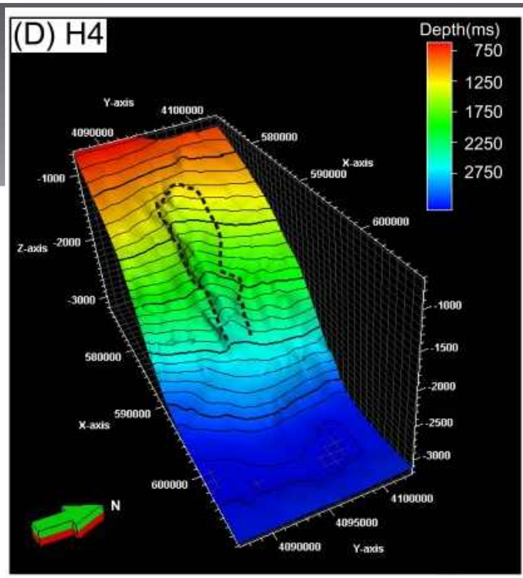


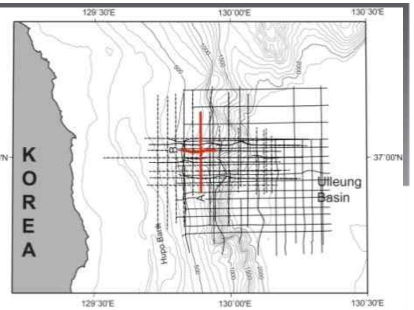


4. Results

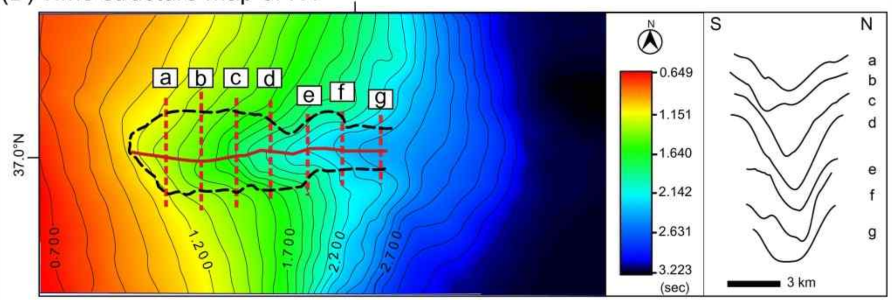
♦ Seismic stratigraphy

► Unit 4 (Quaternary)
: Overlying unit 3
: Deepening toward east (~ 3.2 s)
: Trough in the center
: Width of 2.3 – 4.4 km
: Length of 14.7 km
: Max. height of 228.7 m
: Thickness of 0.06 – 0.13 s in slope
: Depocenter of 0.20 – 0.27 s in basin

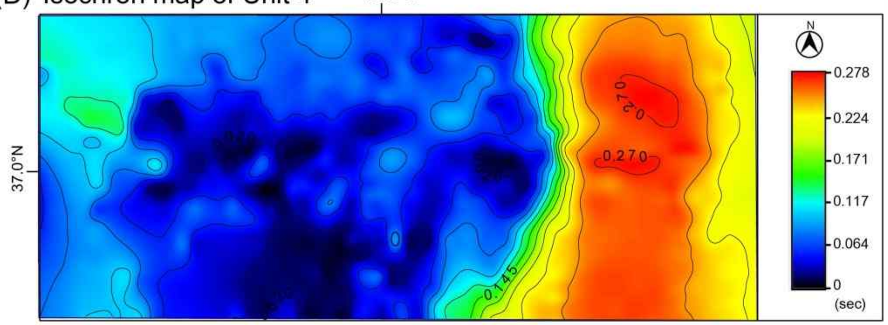


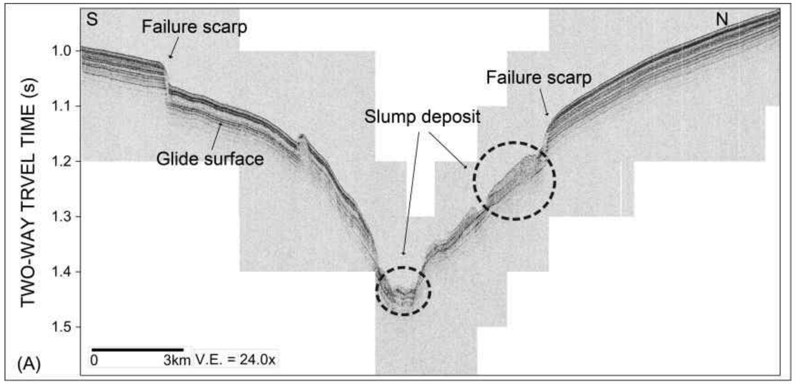


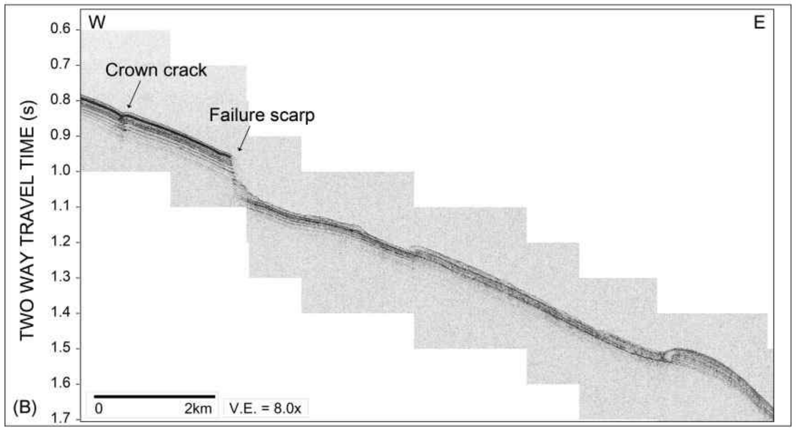
(D) Time structure map of H4



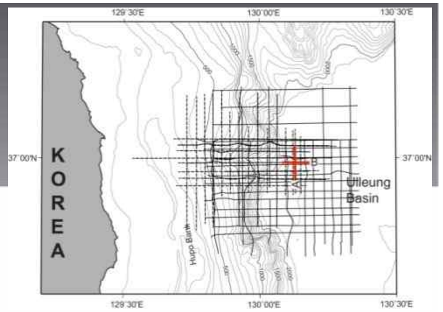
(D) Isochron map of Unit 4





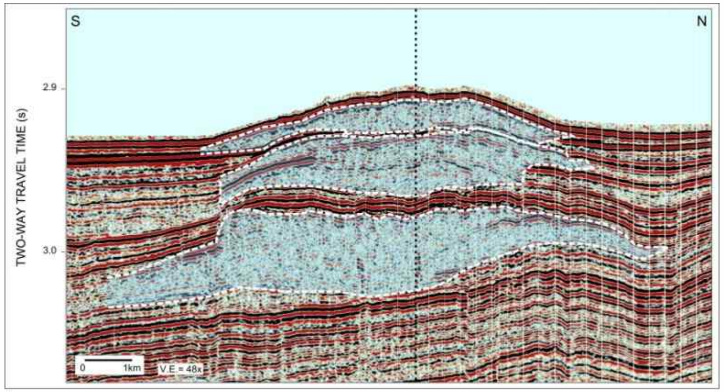


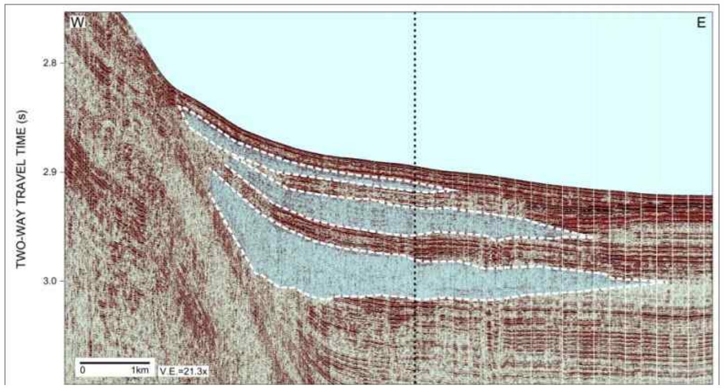
4. Results

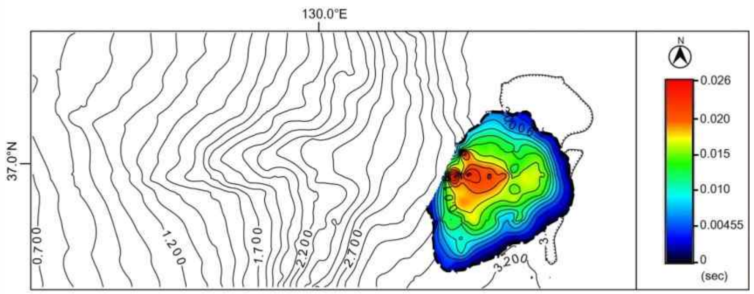


♦ Seismic stratigraphy

► Unit 4 (Quaternary)
: Three debris lobe in the base of slope
: Lenticular form characterized by transparent and chaotic
: Max. thickness of 17 m
: Area of 65 km^2
: Volume of 0.5 km^3





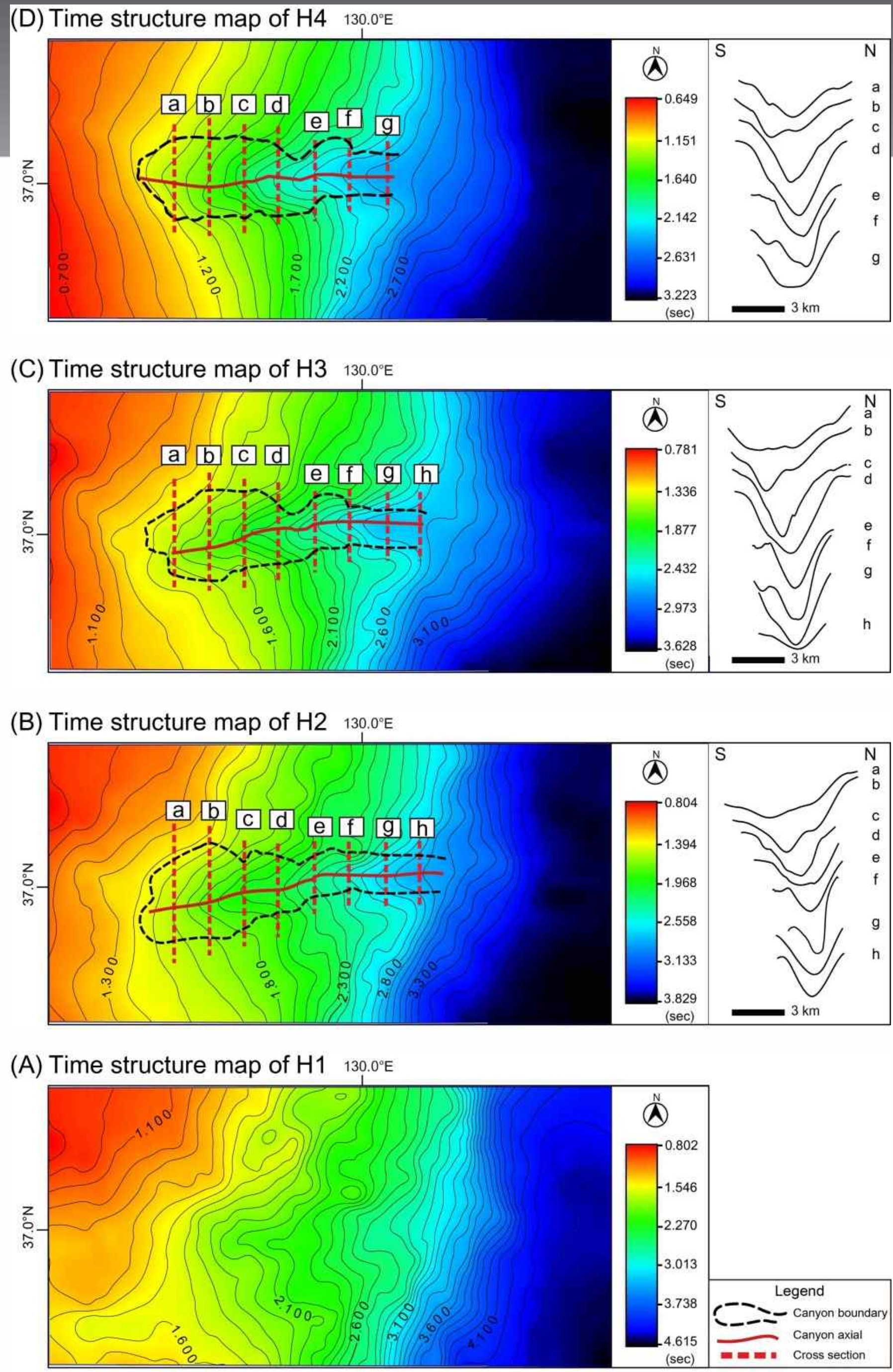


4. Results

♦ Geometry of submarine canyon

- ► From U to V shape
- ► Increase in width toward slope
- ► Increase in depth toward basin

Horizon	Width (km)	Length (km)	Max. height (m)	Thalweg path	Change of shape
H2	1.9-5.4	17.5	193.5	straight	U -> V
H3	2.0-5.1	16.5	287.3	straight	U -> V
H4	2.3-4.4	14.7	228.75	straight	U -> V
SF	2.5-7.7	14.7	360	straight	U -> V

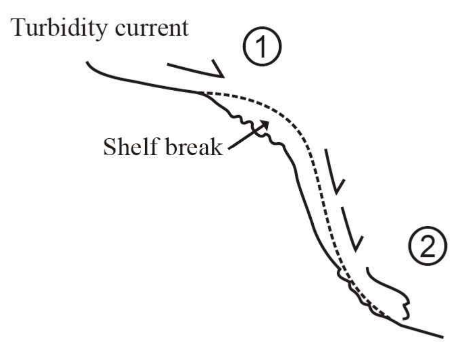
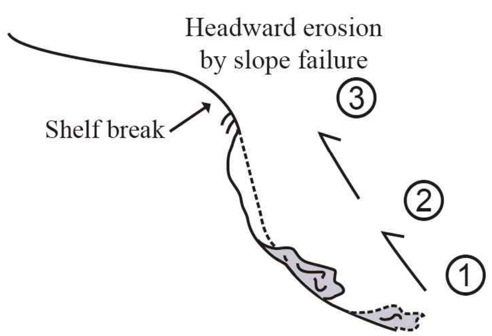


♦ Development of submarine canyon *(Shepard, 1981)*

► Long-live and erosional processes
(1) Turbidity current
(2) Slope failure by slumping and mass wasting

♦ Models for development of submarine canyon

(1) Top-down model
(2) Bottom-up model

Type	(A)	(B)
		
Mechanism	Top-down process	Bottom-up process
Submarine erosion	Turbidity current	Slope failure and associated mass wasting
Location of initiation	Shlef and upper slope	Lower to middle slope
Internal fill	Relict sand deposit	Mass wasting deposit or hemipelagic deposit

5. Discussion

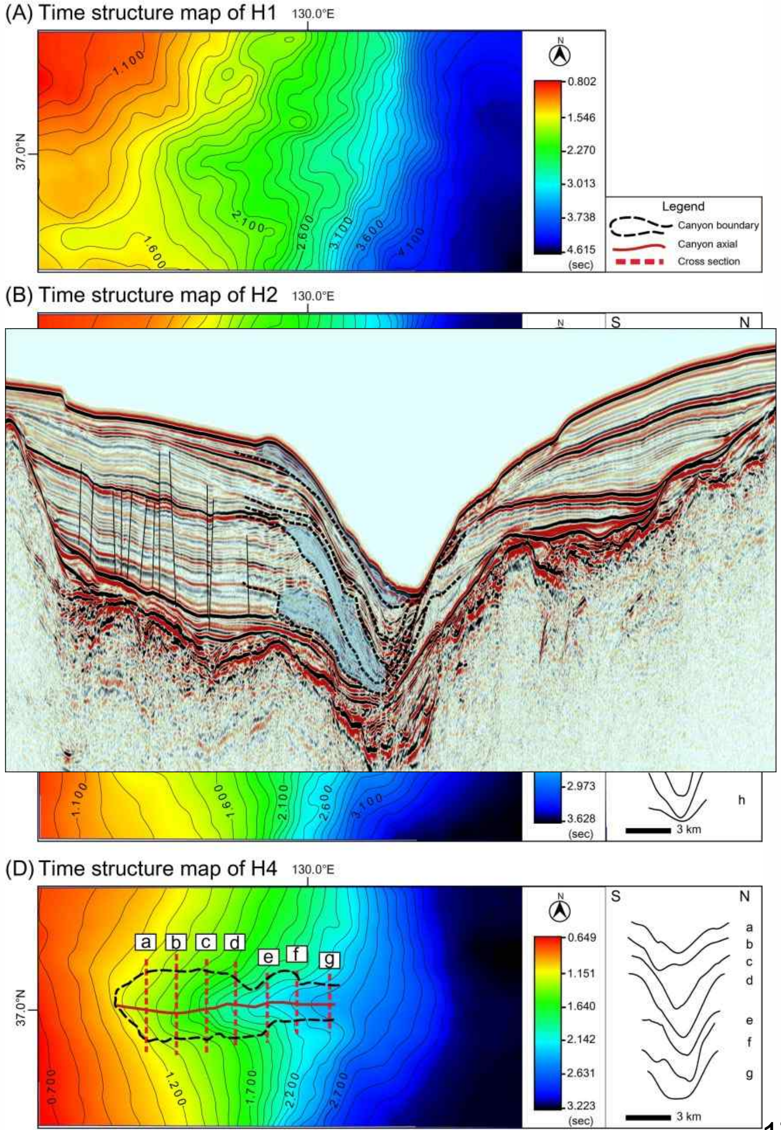
♦ Characteristics of submarine canyon in the study area

(1) Distribution pattern
: Limited occurrence at the slope
: Absence of major fluvial system (Chough, 2000)

(2) Geometric characteristics *(Rise et al., 2014)*
: U to V shape
: Increase in width toward slope
: Increase in depth toward basin

(3) Seismic facies
: Transparent and chaotic indicating MTD

→ Bottom-up model developed by slope failure

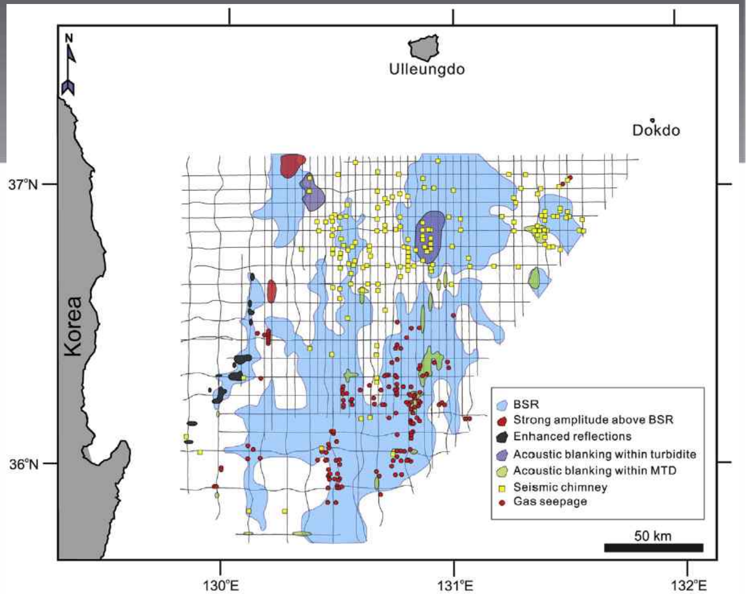


5. Discussion

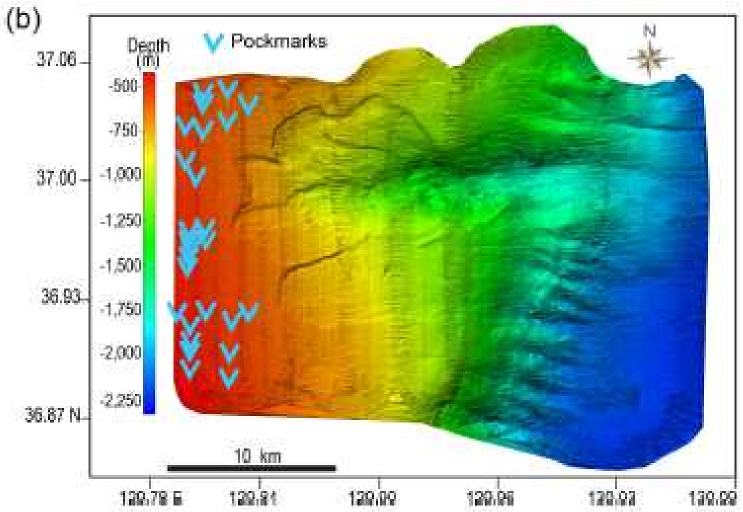
♦ Control factors

(1) Tectonic movement *(Ediger et al., 1993; Elliott et al., 2006; Mountjoy et al., 2009; Dantec et al., 2010; Restrepo-Correa and Ojeda, 2010; Jobe et al., 2011)*
: Basement low formed by basin rifting (Unit 1)
: Fault activity induced by compressional tectonic (unit 2)

(2) Sea-level change *(Hampton et al., 1996; Lee et al., 1996; Paull et al., 1996; Rao et al., 2002)*
: Failure by decrease of hydrostatic pressure in sediment
: Gas hydrate distribution
: Pockmark around headwall scarps



Distribution map of seismic indicators of gas hydrate and gas *(Yoo et al., 2013)*



Distribution of pockmarks concentrated in upslope regions of headwall scarps (Cukur et al., 2016)

5. Discussion

♦ Depositional history of submarine canyon

(1) Stage 1 (Early to Late Miocene)
: Basement low formed by tectonic movement

(2) Stage 2 (Late to late Late Miocene)
: Slope failures due to fault activities
: Deposition of submarine fan in the base of slope

(3) Stage 3 (late Late Miocene to Pliocene)
: Subdued activity of submarine canyon

(4) Stage 4 (Quaternary)
: Slope failures because of sea-level change
: Occurrence of stacked debris flow deposit in the base of slope

Horizon	Width (km)	Length (km)	Max. height (m)	Thalweg path	Shape change
H2	1.9–5.4	17.5	193.5	straight	U -> V
H3	2.0–5.1	16.5	287.3	straight	U -> V
H4	2.3–4.4	14.7	228.75	straight	U -> V
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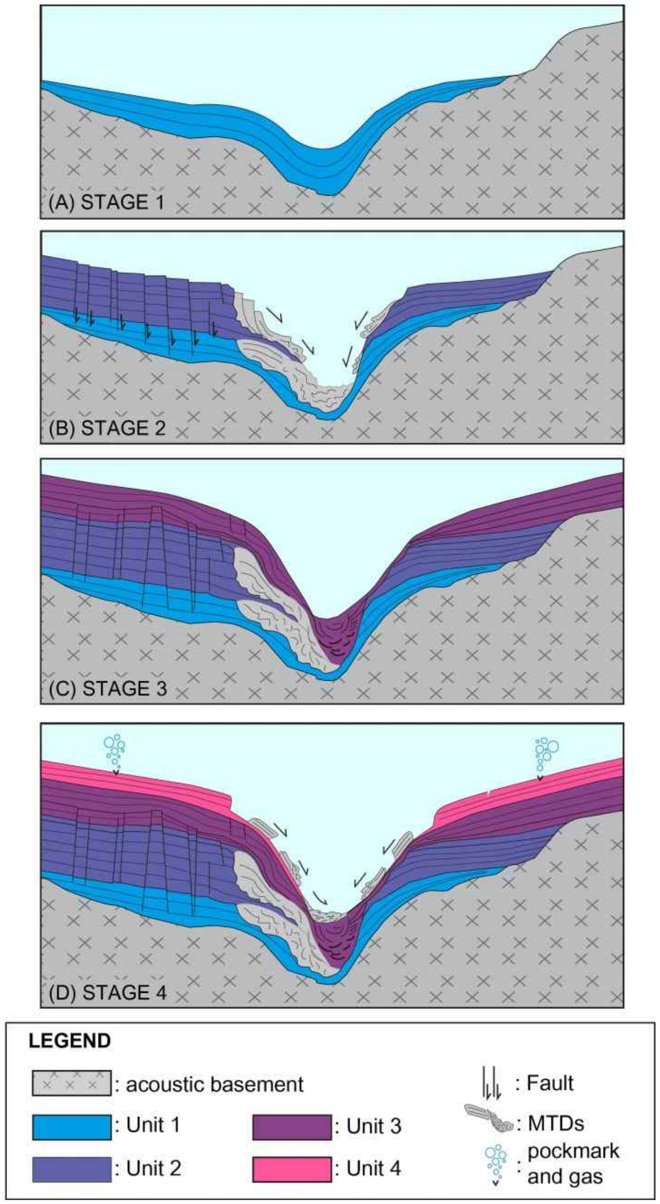

6. Conclusion

1. Slope-confined submarine canyons occurred in the continental slope of the study area.

2. Seismic stratigraphic analysis reveals that sedimentary sequences in the study area are separated by erosional unconformities and consists of four seismic units. The timing of development of submarine canyon is correlated with each seismic unit.

3. Based on seismic characteristics and distribution pattern, submarine canyon was mainly developed at stage 2 and 4, when submarine fan deposition that show well-stratified and chaotic seismic facies occurred. Unit 2 is caused by the slope instability due to fault activities, and unit 4 is mainly attributed by sea level fluctuations under conditions of subdued structural movement.

4. The stratigraphy of the study area associated with the submarine canyons is controlled by sediment supply due to slope failure, tectonic movement, and sea level change.

Thank you.