Modelling the thickness and distribution of the Gas Hydrate Stability Zone in the Taranaki Basin, New Zealand.

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Introduction

Gas Hydrates in the Taranaki Basin

The Taranaki Basin (Figure 1) is the only hydrocarbon producing basin in New Zealand with vast amounts of oil and gas currently being produced. Gas hydrate studies in the Taranaki Basin are at the level of determining the thermoberic stability conditions for hydrates and analysis of the likelihood of the presence of hydrates within the stability zones, which include analysis of both direct and indirect indicators of gas hydrates. Previous studies on gas hydrates in the basin tried to assess the gas hydrate stability zone (GHSZ) depth by detecting the bottom simulating reflectors (BSRs) on seismic sections (Ogebule and Pecher, 2010) and basin modelling (Kroeger et al., 2017). The hydrate stability field of the entire Taranaki Basin has not been investigated, especially the contributions of higher-order hydrocarbons in the formation of hydrates in the basin.

Modelling approach

The objective of the GHSZ modelling was to shed light on the dynamics of gas hydrates formation and the expected depth of BSR formation, thereby investigating how thermoberic conditions affect the hydrate stability zone.
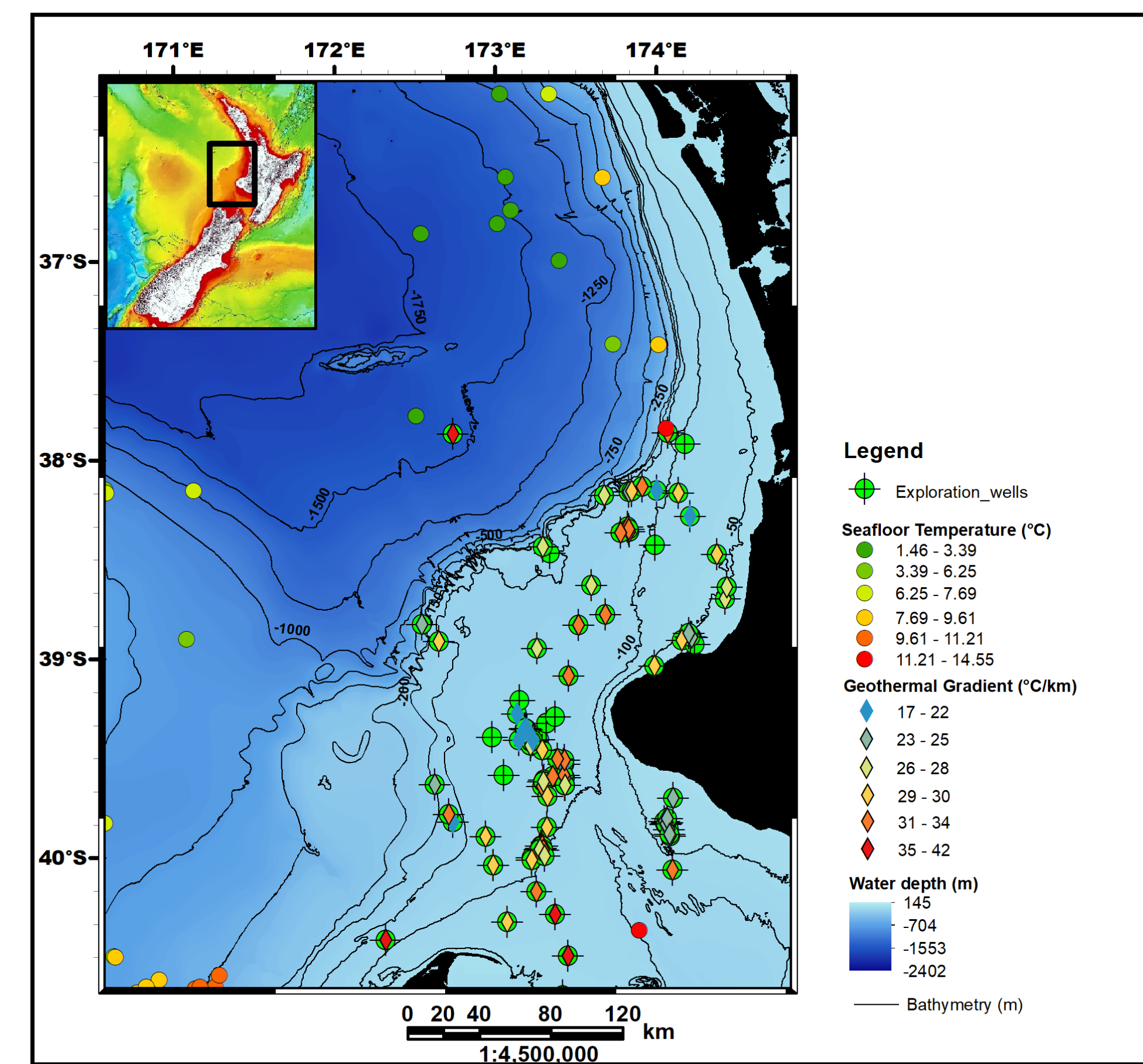

Figure 1: Location map of the study area showing colour-coded and contoured bathymetric map of Taranaki Basin. The location of hydrocarbon wells and distribution of the Conductivity Temperature and Depth (CTD) casts and calculated geothermal gradients are shown. The inset displays a map of Zealand showing the location of the Taranaki Basin

Methods

The methodology adopted for this study is summarized in Figure 2. The publicly available Sloan's (1998) CSMHYD software from Colorado School of Mines for gas hydrate research was used to predict the thermodynamics of stable hydrate structures at particular temperatures using salinity of seawater for different hydrate-forming gas composition feeds. We integrated all input parameters (Table 2) to model the BGHSZ and thickness of GHSZ using MATLAB scripts. The schematic model (Figure 3) describes the modelling parameters used in determining the thickness of GHSZ and where gas hydrate reservoirs are likely to exist.

Table 1: Summary of hydrate-forming gas composition used for the modelling of BGHSZ and thickness of GHSZ (assumption of gas composition is based on data from well completion reports; Kings and Thrasher, 1996).

Gas Composition	CH_4	C_2H_6	C_3H_8	iC_4H_{10}	nC_4H_{10}	H_2S	CO_2	N_2	Hydrate structure
Model I	100								I
Model II	90	10							I
Model III	90	8	2						II
Model IV	90	7	3						II
Model V	74.43	5.82	3.72	1.72	1.15	4.77	6.68	1.72	II

Table 2: Summary of input parameters used for the modelling of BGHSZ and thickness of GHSZ. The pressure was calculated using Sloan's CSMHYD program.

Model	Geothermal gradient (ºC/Km)	Bottom water temperature (°C)	Pore water salinity (wt%)	Water depth (mbsl - m below sea-level)	Gas composition
I	36, 32, 28	8 - 2.25	3.5	674 - 2115	See table 1
II	36, 32, 28	10 - 2.25	3.5	540 - 2115	See table 1
III	36, 32, 28	11 - 2.25	3.5	433 - 2115	See table 1
IV	36, 32, 28	11 - 2.25	3.5	400 - 2115	See table 1
V	36, 32, 28	12 - 2.25	3.5	320 - 2115	See table 1

Results

The BGHSZ models of this study conceptualise the maximum depths at which gas hydrates could crystallise. The 1D models show how the thickness of the GHSZ is affected by presence of heavier hydrocarbons, local variations in geothermal gradients, water depth and bottom water temperatures (Figure 4). Table 3 shows a summary of the results obtained from the modelling of five gas composition models (Table 1) using the parameters outlined in Table 2. Figures 5 -7 shows the spatial distribution of the thickness of GHSZ in the basin.
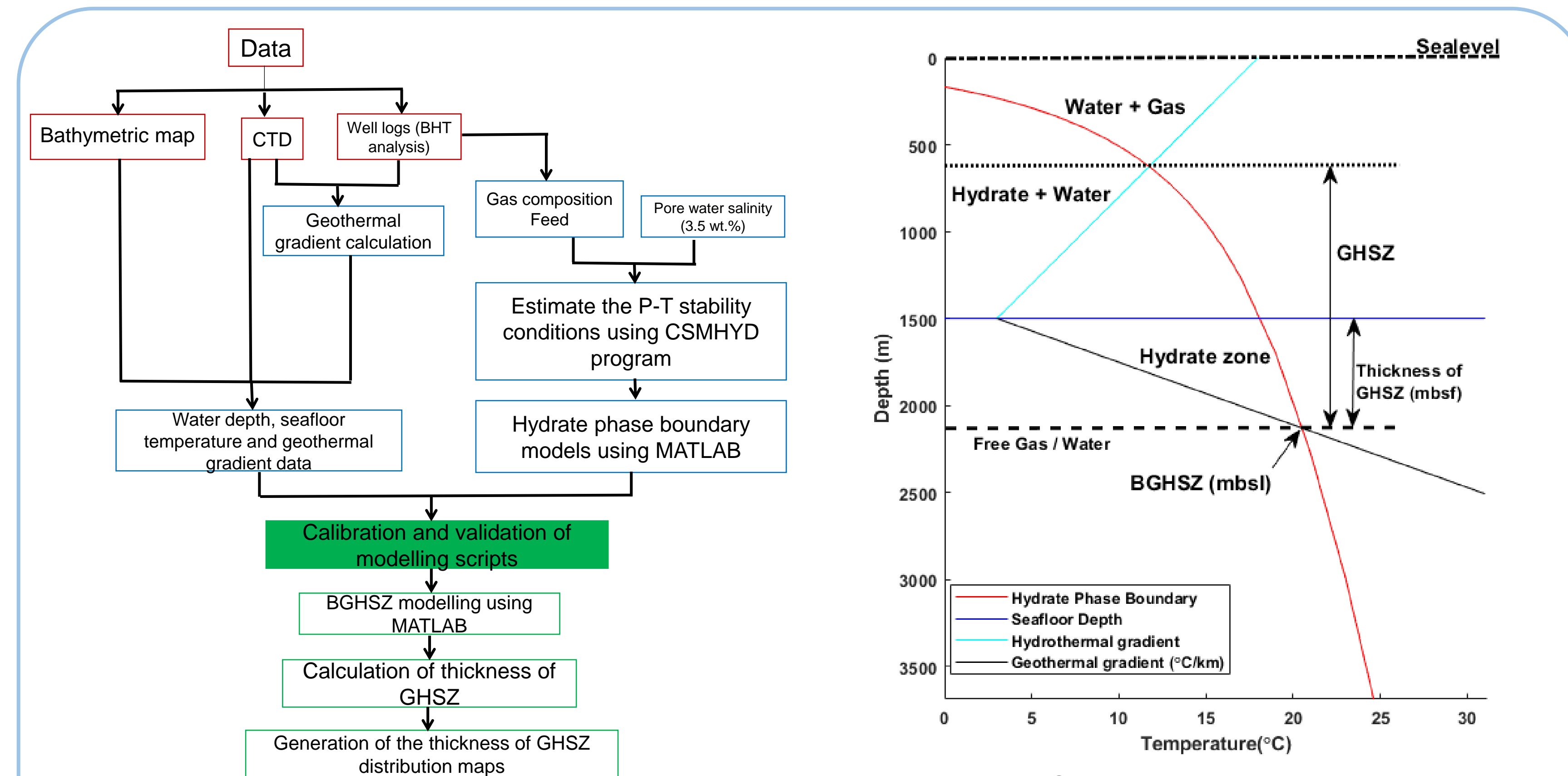

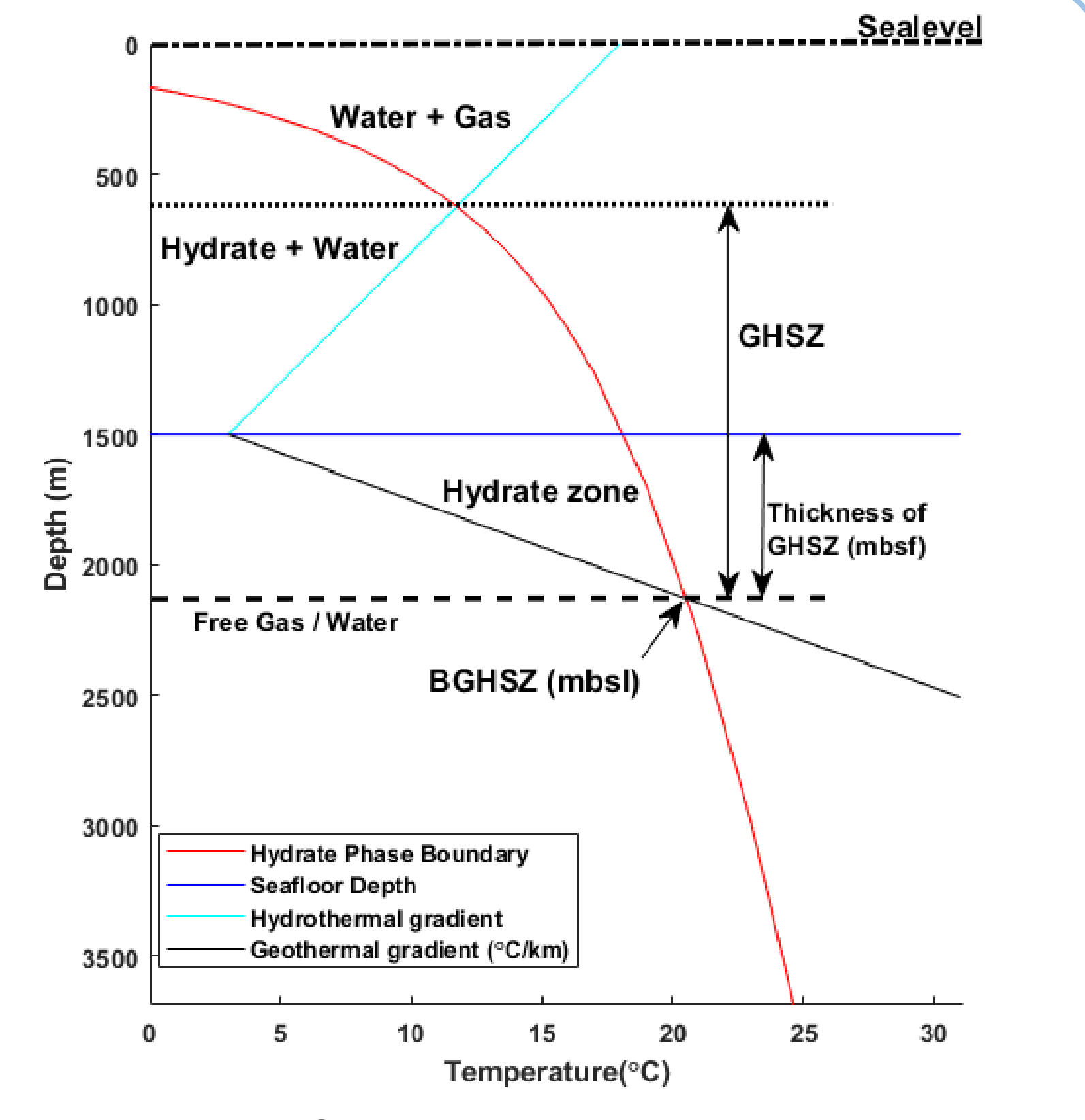Figure 2: Flowchart showing the methodology adopted in this study

Figure 3: Schematic model of the thermobaric conditions for gas hydrate stability modelling.

Table 3: Summary results of the calculated thickness of GHSZ ($GHSZ_t$) and the temperature at the BGHSZ ($BGHSZ_T$).

| Parameter	Model I $GHSZ_t$ (mbsf)	$BGHSZ_t$ (°C)	Model II $GHSZ_t$ (mbsf)	$BGHSZ_t$ (°C)	Model III $GHSZ_t$ (mbsf)	$BGHSZ_t$ (°C)	Model IV $GHSZ_t$ (mbsf)	$BGHSZ_t$ (°C)	Model V $GHSZ_t$ (mbsf)	$BGHSZ_t$ (°C)
36°C/Km	495	20.08	551	22.1	570	22.76	593	23.60	602	23.92
32°C/Km	564	20.30	627	22.31	647	22.96	673	23.78	683	24.09
28°C/Km	655	20.59	726	22.59	748	23.18	778	24.02	789	24.33
Minimum Seafloor Temperature (°C)	8		10		11		11		12	
Minimum Water Depth (m)	660		540		433		400		300	
Salinity (w%)	3.5		3.5		3.5		3.5		3.5	
Gas composition	see table 1		see table 1		see table 1		see table 1		see table 1	
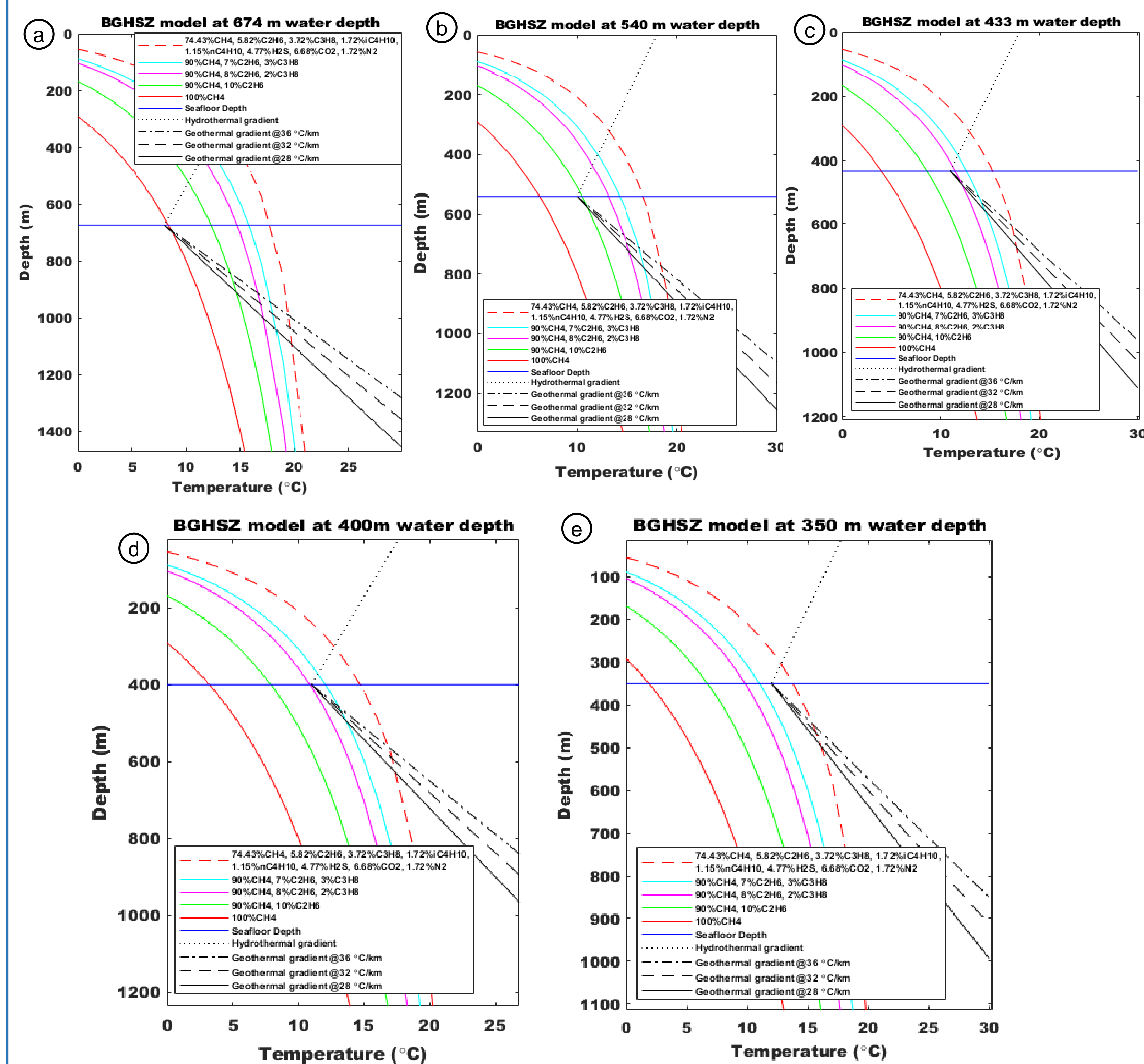
Figure 4: 1D models of gas hydrate stability curves for different gas compositions and thermoberic conditions using CSMHYD program (Sloan, 1998). (a) The model I at 660 m WD and 8°C BWT. (b) Model II at 540 m WD and 10°C BWT. (c) Model III at 433 m WD and 11°C BWT. (d) Model IV at 400 m WD and 11°C BWT. (e) Model V at 350 m WD and 12C BWT. This figure demonstrates the relation between BWT, WD, and Gg to the depth of GHSZ. See Table 4 for modelling parameters. Variability in BWT determines the stability condition for gas hydrates in a given basin. Changes in Gg result in changes in the BGHSZ depth and thicknesses of the gas hydrate stability zone. WD = water depth, BWT = bottom water temperature, Gg = geothermal gradient.
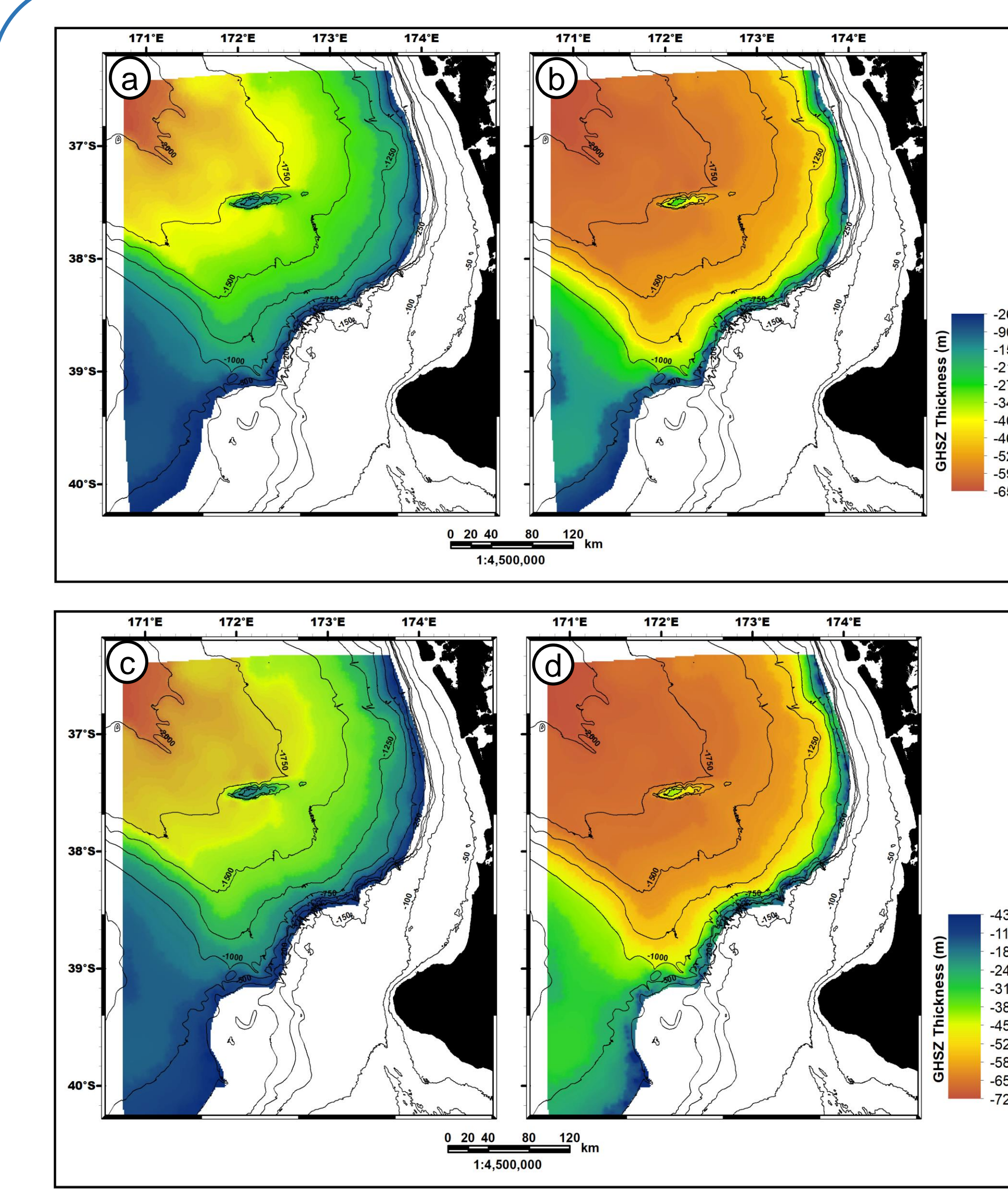

Figure 5: Spatial distribution of thickness of GHSZ calculated for model I (100% methane) at a geothermal gradient of (a) 36°C/Km and (b) 28°C/Km; and model II (90% methane and 10% ethane) at geothermal gradient of (c) 36°C/Km and (d) 28°C/Km. Contoured values represent the bathymetry.
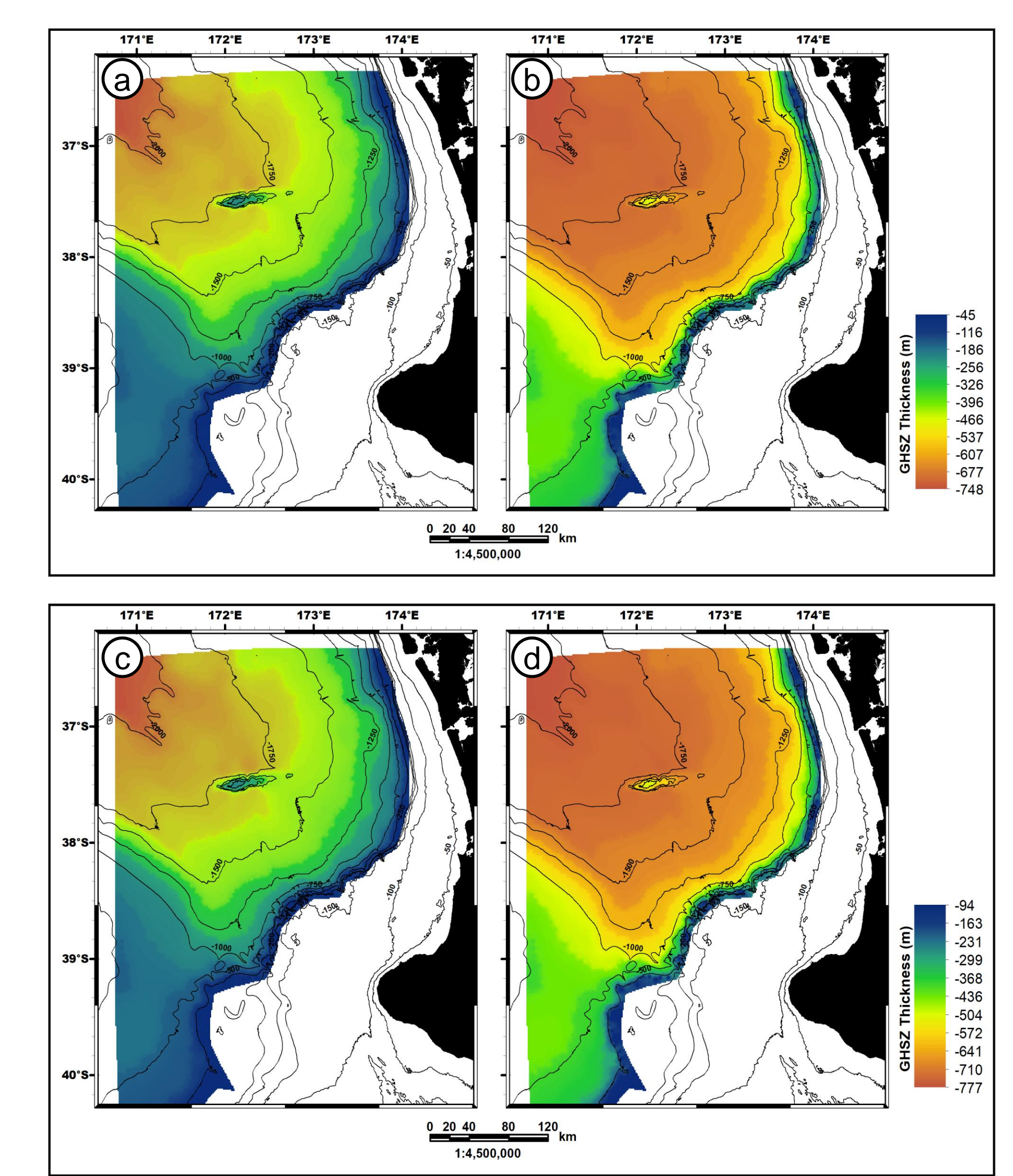

Figure 6: Spatial distribution of thickness of GHSZ calculated for model III (90% methane, 8% ethane and 2% propane) at a geothermal gradient of (a) 36°C/Km and (b) 28°C/Km; and for model IV (90% methane and 7% ethane and 3% propane) at geothermal gradient of (c) 36°C/Km and (d) 28°C/Km. Contoured values represent the bathymetry.
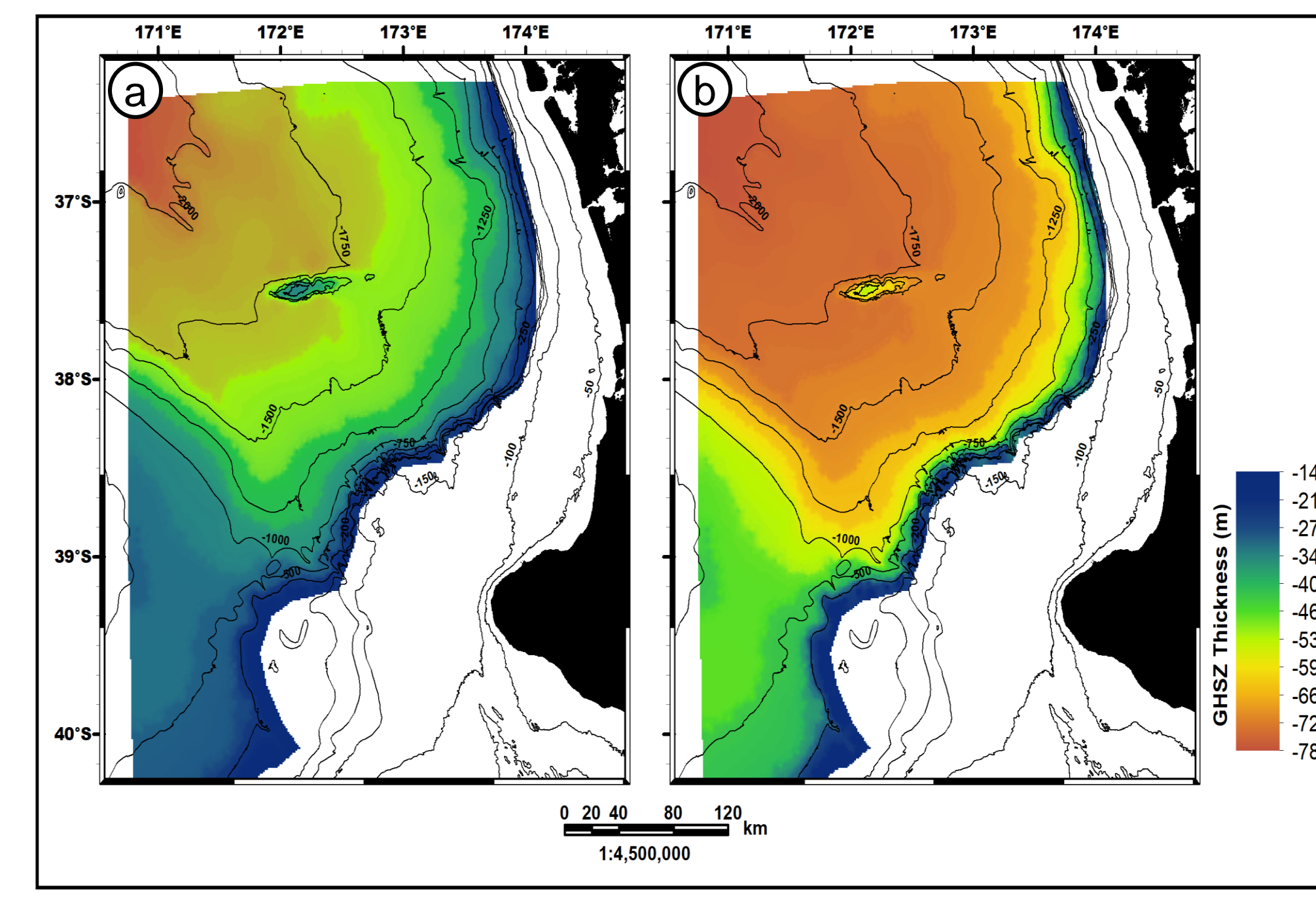

Figure 7: Spatial distribution of thickness of GHSZ calculated for model V (74.43% methane, 5.82% ethane, 3.72% propane, 1.72% i-butane, 1.15% n-butane, 4.77% hydrogen sulfide, 6.68% carbon dioxide and 1.72% nitrogen) at geothermal gradient of (a) 36°C/Km and (b) 28°C/Km. Contoured values represent the bathymetry.
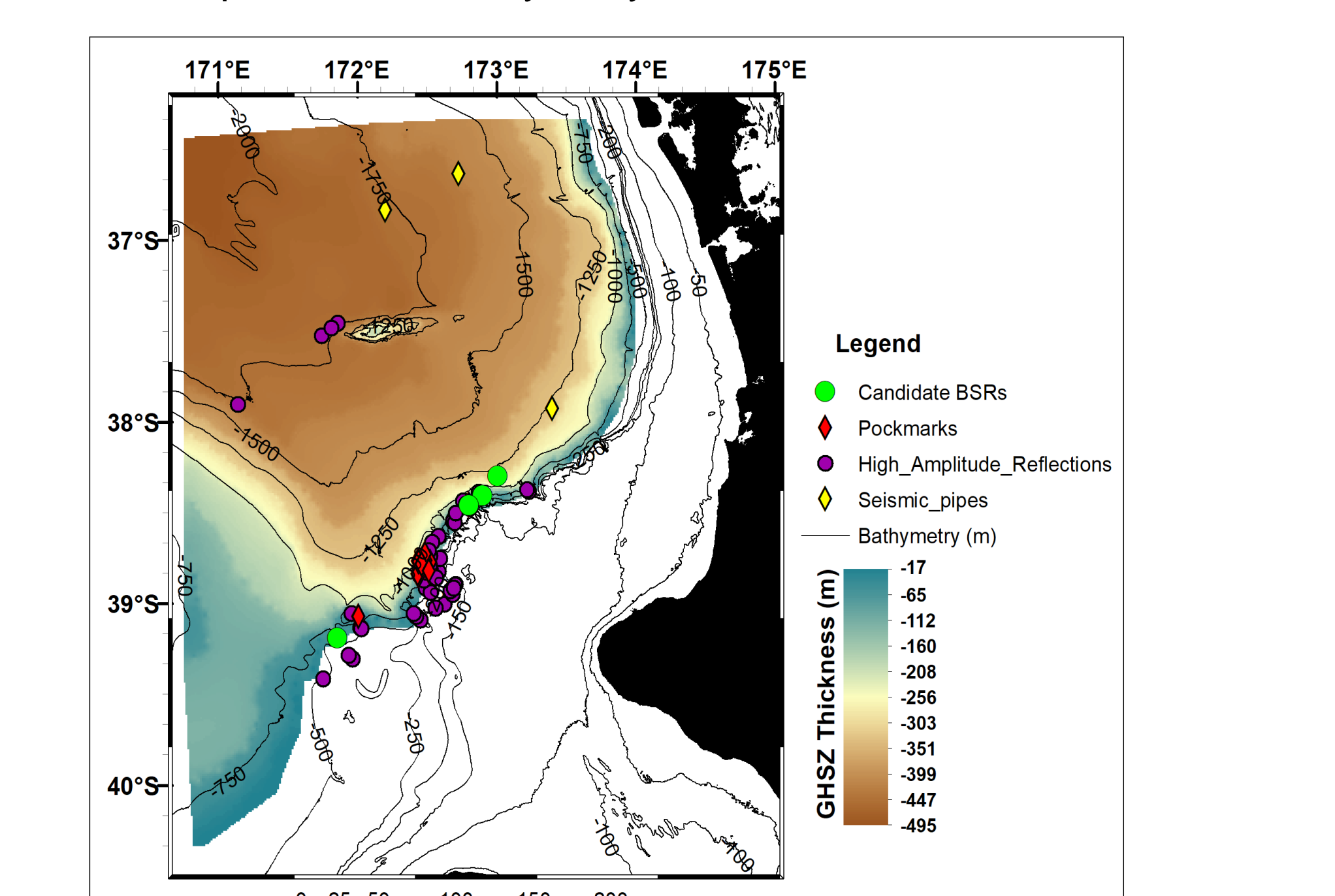

Figure 8: Thickness of GHSZ map for model I (100% methane) at 36°C/Km showing the locations of interpreted potential hydrate indicators.

Conclusions

The following conclusions have been made from this study:

- The Taranaki Basin has all suitable conditions necessary for the formation and stability of gas hydrates. The thermoberic models for BGHSZ and thickness of GHSZ vary significantly across the basin.
- The structure I hydrates could form at a minimum water depth ranging from 540 m to 660 m, maximum seafloor temperature ranging from 10°C to 8°C and could be stable in sediments as deep as 551 mbsf and 495 mbsf respectively.
- The Structure II hydrates could form at a minimum water depth of 300m to 433 m, maximum seafloor temperature ranging from 12°C to 11°C, and could be stable in sediments as deep as 602 mbsf and 570 mbsf respectively.
- Hydrates in the Taranaki Basin are likely to dissociate if BGHSZ temperature exceeds 23.92°C and if the seafloor temperature exceeds 12°C.

Limitations of the present study include the uncertainty in temperature gradient in offshore areas due to lack of data, and insufficient or lack of geochemical data for proper molecular composition of the hydrate-forming gases.

References

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