CHAPTER 5

Qualitative Seismic Interpretation

The Karewa 3D seismic survey was acquired in the Northern Taranaki Basin, north-west of the North Island of New Zealand. In 2002-2003, one exploration well (Karewa-1) was drilled by the ConocoPhillips (UK) Ltd. in the survey area aiming to evaluate the reservoir properties and hydrocarbon potential in the Pliocene Mangaa C1 sands. A faulted 4-way dip closure was proposed, and elevated amplitudes across the structure could be observed on seismic data. The targeted Mangaa C1 turbidite sand proved to be gas-bearing formation. Karewa-1 well encountered a 12 m gas sand interval at the top of the Mangaa C1 sands (Conoco Northland Ltd., 2002-2003).

There are total 393 inlines (1001-1393 with an increment of 1) and 1001 crosslines (2800-4800 with an increment of 2) in the Karewa 3D survey. The inline spacing is 24.9938m and the crossline spacing is 12.497m. Maximum length of the survey is 12.5km and width is 9.8km. The survey area is approximately 122.5 square kilometres. Data polarity is negative (European polarity) based on the sea floor reflection. The phase of the data is -38^{o} degree (section 6.1).

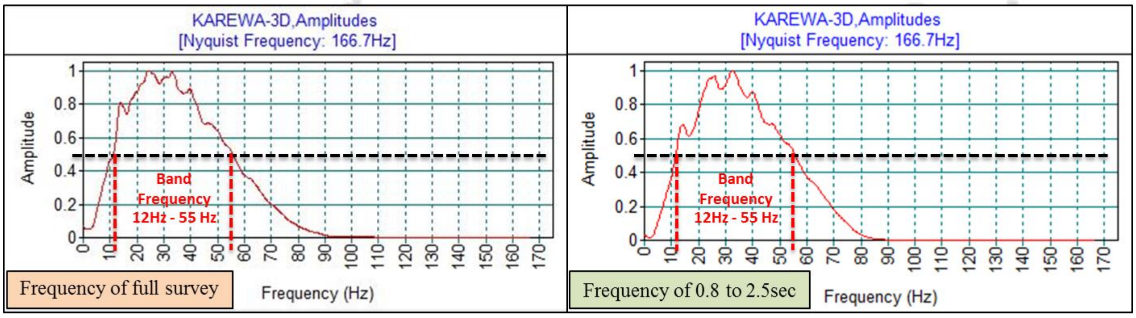

Figure 5-1: Data frequency of full seismic cube and seismic cube from 0.8 to 2.5sec

The bandwidth of 3D Karewa seismic data ranges from 12 to 55 Hz (Figure 5-1). The Nyquist frequency of the data is 167 Hz and the mean frequency of the seismic energy is around 30 Hz. The overall data frequency is thus high. In this research, the targeted zone is at a depth of 0.8 to 2.5 sec at the well position in inline 1177. In this zone, the observed bandwidth ranges from 12 to 55Hz and the mean frequency is around 30Hz. Amplitude equal to 1 is found at 25 and 32Hz (Figure 5-1).

In this chapter, the 3D Karewa dataset is interpreted qualitatively. Seismic interpretation started with interpretation of major faults throughout the survey area. Then the horizons were picked. Minor faults were picked simultaneously with the horizon picking if these were considered important. In a later stage, five seismic facies were defined based on the six picked horizons and analyzed.

5.1 Horizon Interpretation

Seven marker horizons were picked based on the reflection terminations on laterally consistent high amplitude reflectors. These marker horizons serve many purposes, such as (1) to check the data polarity, (2) to define the top of the reservoir and the seismic facies, and (3) to constrain the boundary of the inversion process. The horizons are labeled H-0 to H-6 from top (youngest) to bottom (oldest). The general characteristics of the horizons are described for inline 1178.

H-4 and H-5 were picked exactly on formation markers of well Karewa-1. H-1 and H-2 were picked a few seconds below the formation markers of well Karewa-1 (Conoco Northland Ltd., 2002-2003).

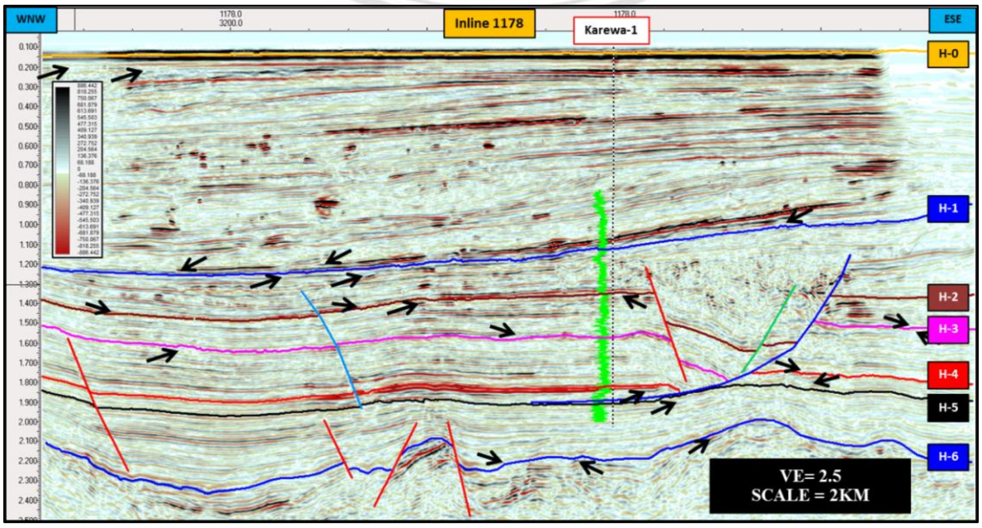

Figure 5-2: Picked horizons of 3D Karewa is presented on inline 1178

H-0 (123ms TWT at the karewa-1 well location in inline 1178)) was interpreted on a high negative amplitude reflection (trough) of high continuity (Figure 5-2). It is dipping from ESE to WNW. This horizon is located on a 0.119 sec (TWT) at structural high in the ESE, and 0.149 sec (TWT) in a structural low in the WNW. It is truncating the underlying reflections (Figure 5-3).

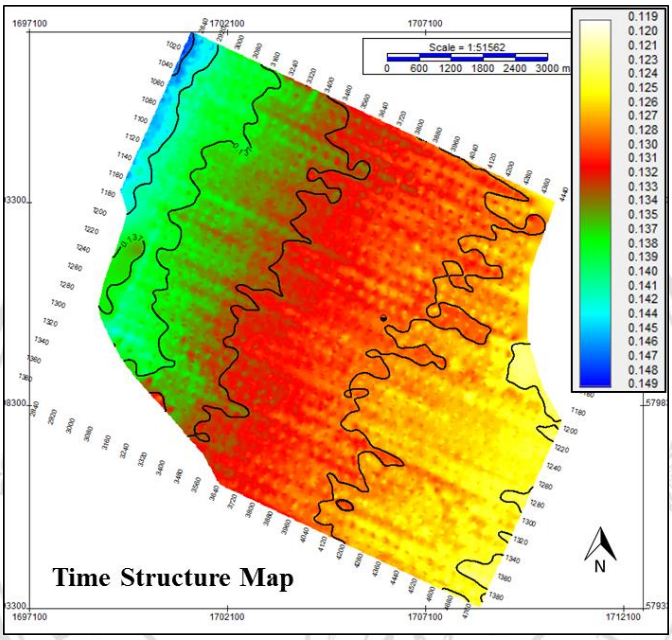

Figure 5-3: Time (TWT) structure maps of H-0 (Seabed)

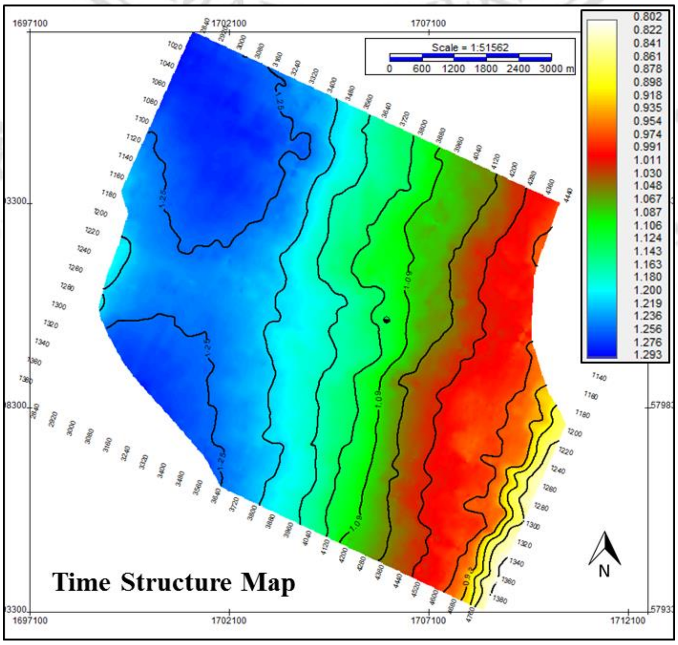

Figure 5-4: Time (TWT) structure maps of H-1

H-1 (Plio-Pleist Mkr + 39ms TWT at the karewa-1 well location in inline 1178) was interpreted on a high negative amplitude reflection (trough) of high to medium continuity (Figure 5-2). It is dipping from ESE to WNW. This horizon is located on a 0.802 sec (TWT) at structural high in the ESE, and 1.293 sec (TWT) in a structural low in the WNW. It is truncating the underlying reflections, and downlapping onto the overlying reflections. It is not cut by any faults (Figure 5-4).

H-2 (Intra Giant Foresets + 15ms TWT at the Karewa-1 well location in inline 1178) was interpreted on a medium positive amplitude reflection (peak) of medium to low continuity (Figure 5-2). This horizon is found between 1.199 sec (TWT) and 1.742 sec (TWT). Its lowest point is located between the growth fault and a large normal fault (N. Fault 10; section 5.3.2). It is truncating the underlying reflections. It is cut by a big growth fault, three splay faults, two normal faults, and one reverse fault (Figure 5-5). The reverse fault is shown in a Figure 5-2.

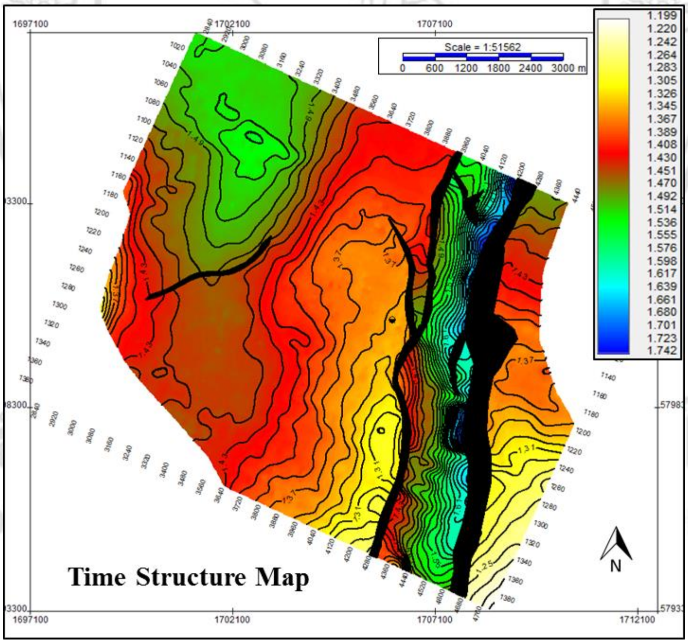

Figure 5-5: Time (TWT) structure maps of H-2

H-3 (1571ms TWT at the karewa-1 well location in inline 1178) was interpreted on a positive amplitude reflection (peak) of medium to low continuity (Figure 5-2). This horizon is located at 1.438 sec (TWT) at a structural high in the ESE and is lowest at 1.889 sec (TWT) between the growth fault and a large normal fault (N. Fault 10; section

5.3.2). It is truncating the underlying reflections. It is cut by a big growth fault, two splay faults, four normal faults, and one reverse fault (Figure 5-6). The reverse fault is shown in a Figure 5-2.

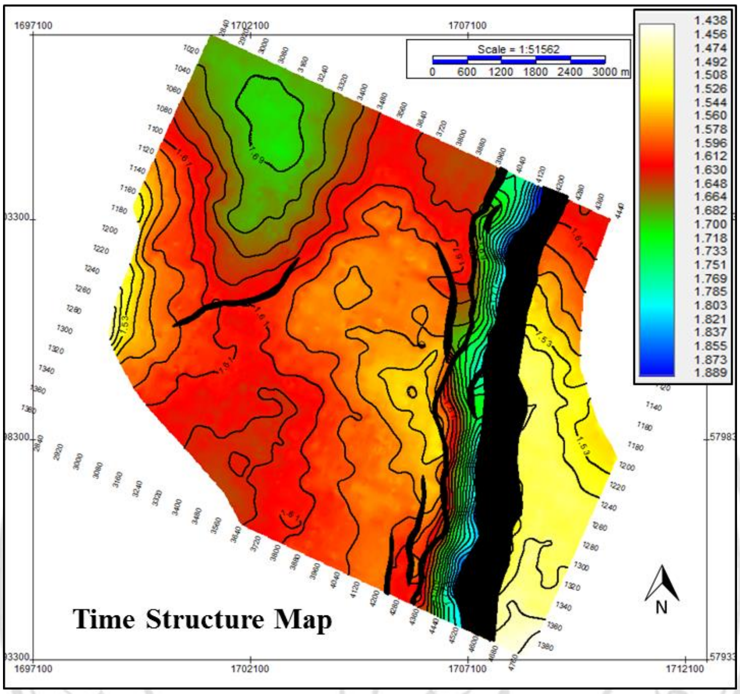

Figure 5-6: Time (TWT) structure maps of H-3

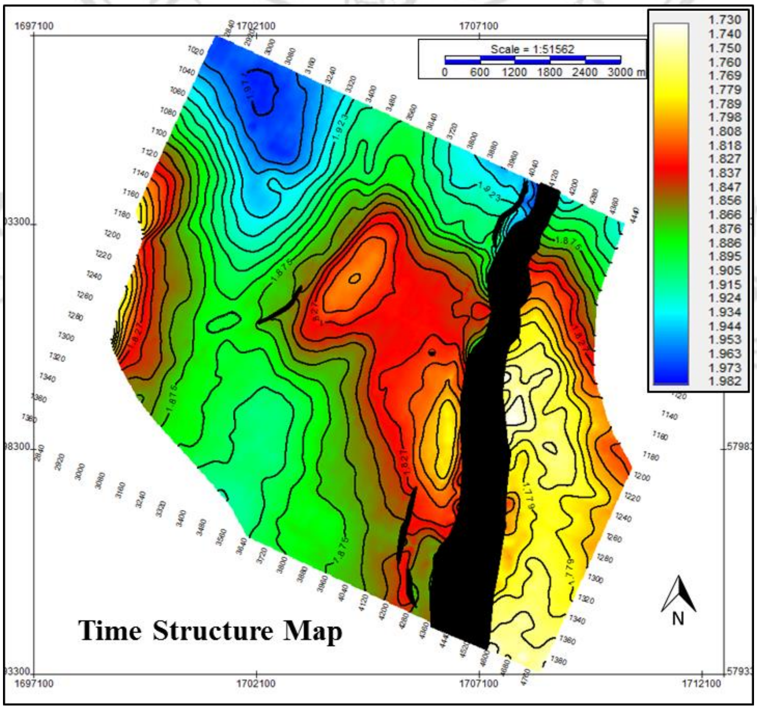

Figure 5-7: Time (TWT) structure maps of H-4

H-4 (top of Mangaa C-1 Sand) was interpreted on a prominent positive amplitude reflection (peak) of high to medium continuity (Figure 5-2). This horizon is located at 1.730 sec (TWT) at the structural high in the SE; its lowest point is found at 1.962 sec (TWT) in the WNW. It is truncating the underlying reflections. It is cut by a big growth fault, three normal faults, and one reverse fault (Figure 5-7).

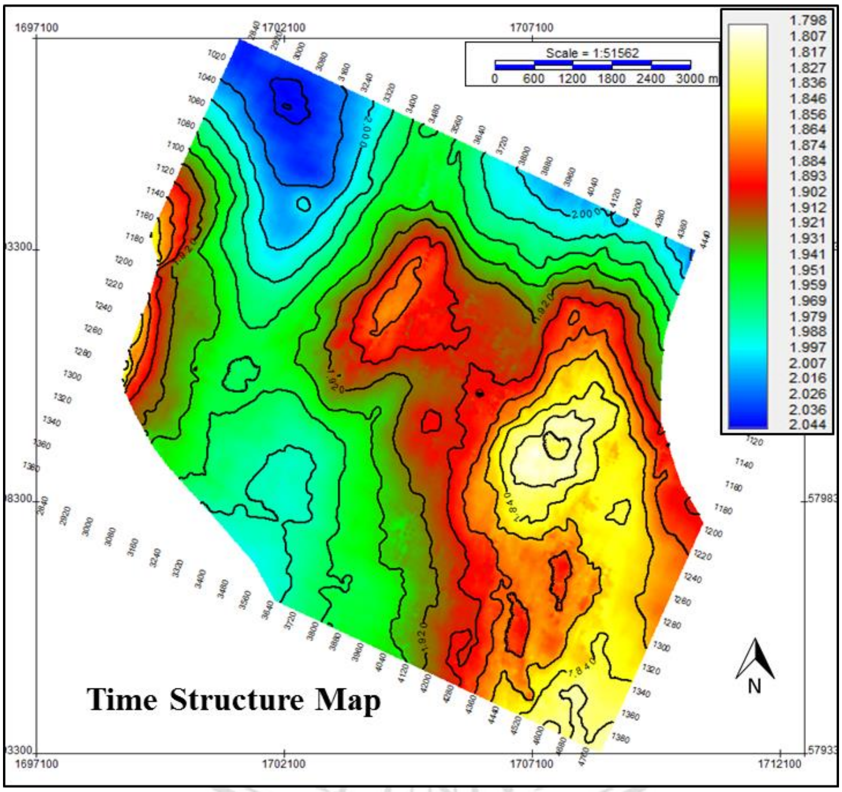

Figure 5-8: Time (TWT) structure maps of H-5

H-5 (Intra Mangaa C-1) was interpreted on a positive amplitude reflection (peak) of high continuity (Figure 5-2). This horizon is located at 1.798 sec (TWT) at a structural high in the east; its lowest point is found at 2.044 sec (TWT) in the NW. It is truncating the underlying and overlying reflections. It is not cut by any fault (Figure 5-8).

H-6 (2191ms TWT at the Karewa-1 well location in inline 1178) was interpreted on a prominent positive amplitude reflection (peak) of medium continuity (Figure 5-2). This horizon is located at 1.975 sec (TWT) at the structural high in the east; its structure point is found at 2.484 sec (TWT) in the south and NNW. It is truncating the underlying reflections. It is cut by eight normal faults (Figure 5-9).

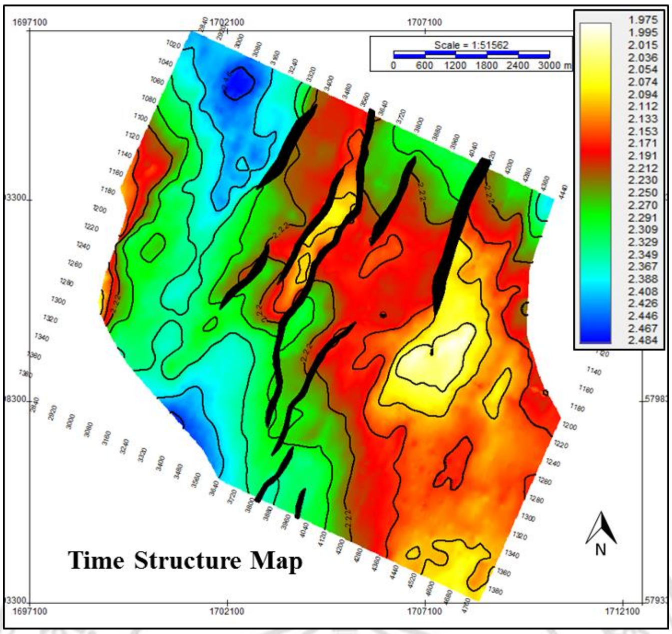

Figure 5-9: Time (TWT) structure maps of H-6

5.2 Seismic Facies Unit Interpretation

The subsurface of the study area was subdivided into five seismic facies units based on the horizon interpretation and labeled as Unit 1 to Unit 5 from top (youngest) to bottom (oldest). Each facies unit is defined by its boundary horizons (Figure 5-10). For each unit a description of thickness, external shape, and internal seismic character (reflector configuration, amplitude, frequency, and continuity) are provided.

Unit 1 (Figure 5-10) is bound at its top and bottom by H-1 and H-2 respectively. A mass transport complex (mtc), controlled by the growth fault (section 5.3.2), intersects Unit 1 from south to north. It is a high to medium amplitude reflection package in the west of the mtc and a low amplitude reflection package in the east of the mtc. Unit 1 has a wedge form and has medium frequency, and medium to low continuity. It is characterized by a sub-parallel configuration, and a chaotic configuration in the mtc. The isochron map (Figure 5-11) shows the thickness variation of Unit 1. The thickness of Unit 1 is variable and ranges from 0.1 sec to 0.75 sec. Unit 1 is thinning from east to west.

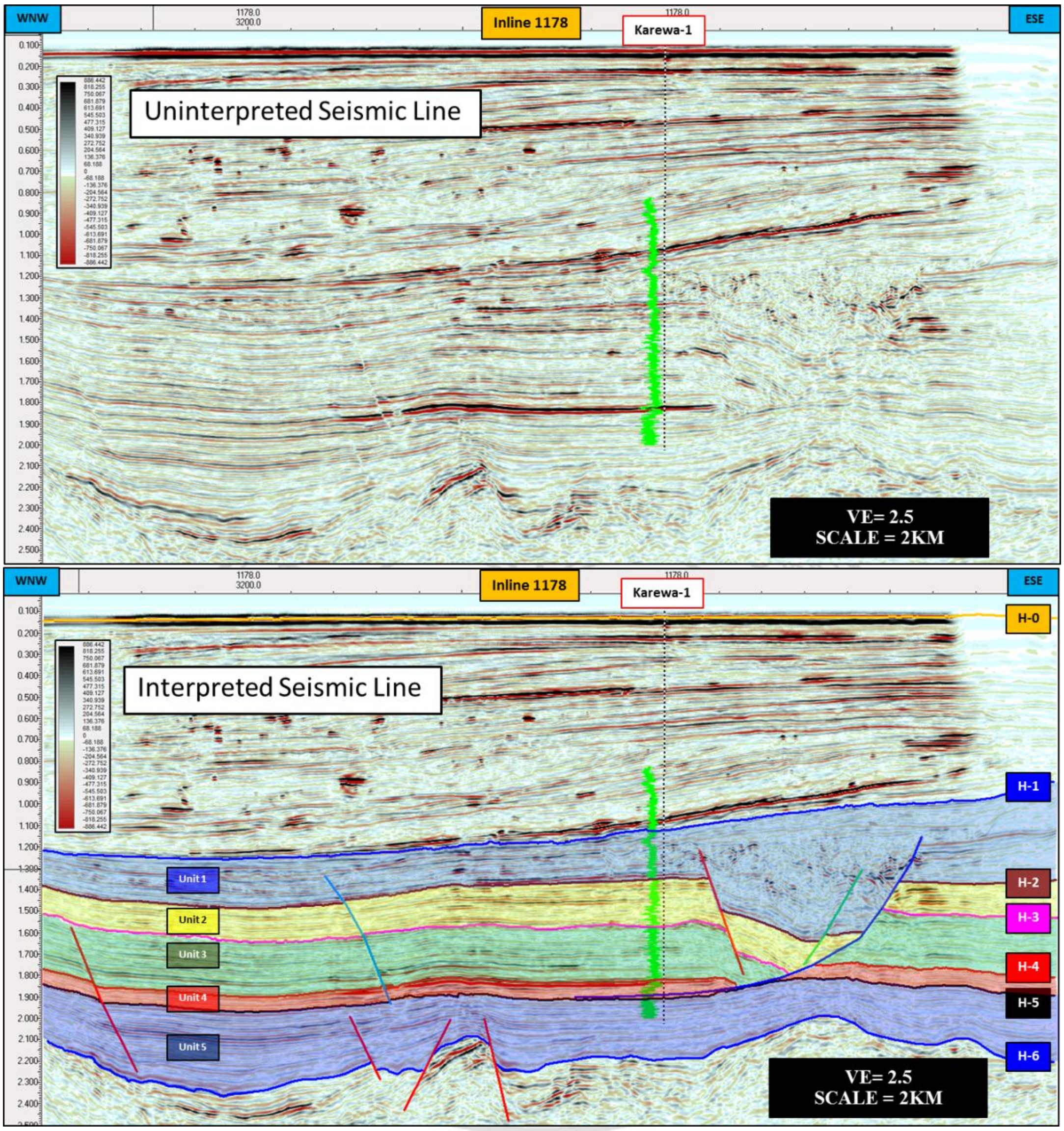

Figure 5-10: Uninterpreted and interpreted seismic inline 1178. Units are defined by their boundary horizons.

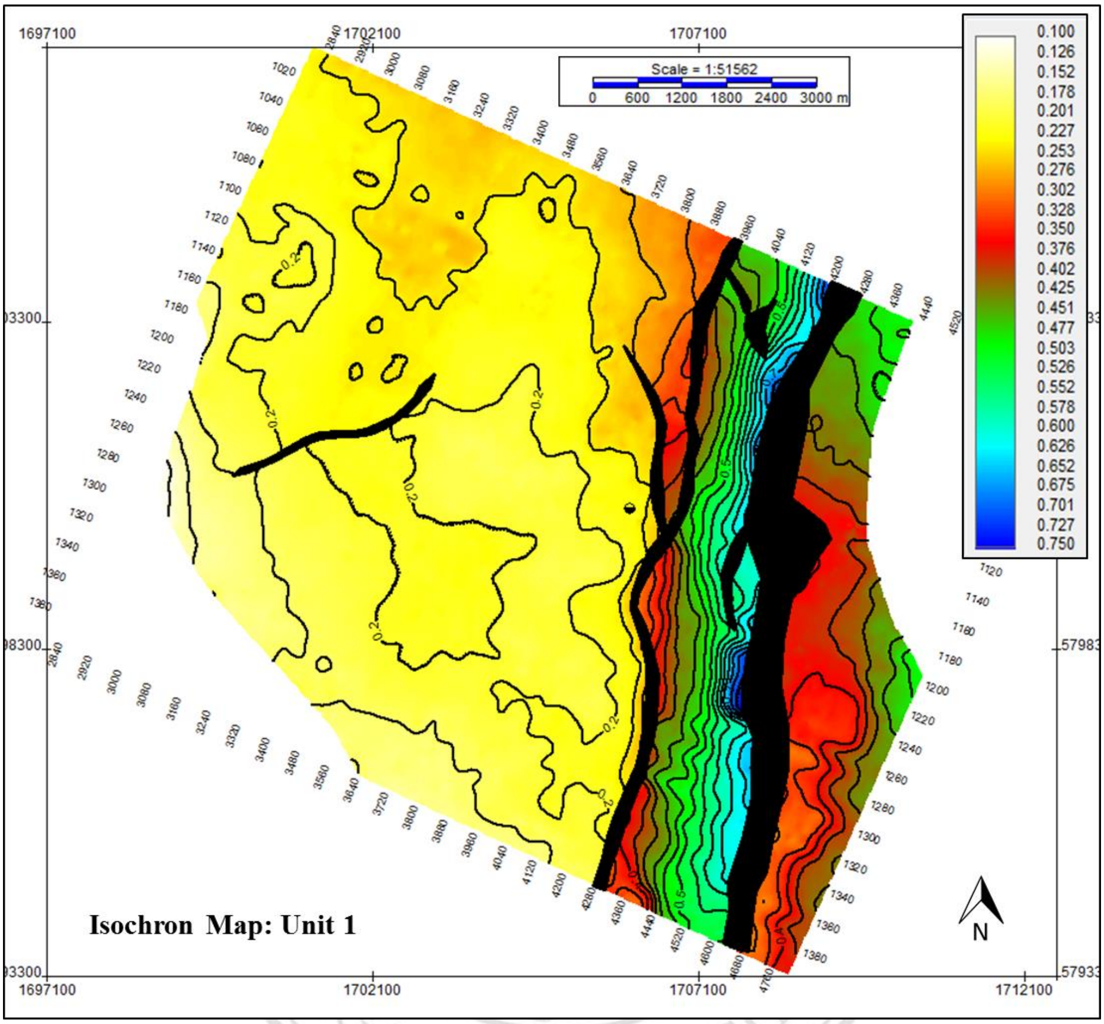

Figure 5-11: Isochron map of Unit 1 shows the thickness variation

Unit 2 (Figure 5-10) is bound at its top and bottom by H-2 and H-3 respectively. It is a high to medium amplitude reflection package in the west of the growth fault and low amplitude reflection package in the east of the growth fault (section 5.3.2). Unit 2 has a sheet-drape form and has reflections of medium frequency and medium continuity. It is characterized by a sub-parallel reflection configuration in the west of fault (N. Fault 10; section 5.3.2) and in the east of the growth fault, and a hummocky configuration in the zone between N. Fault 10 and growth faults. The isochron map (Figure 5-12) shows the thickness variation of Unit 2. Thickness of Unit 2 is variable and ranges from 0.068 sec to 0.370 sec. Unit 2 is thickest in the south and thinning to the west and east.

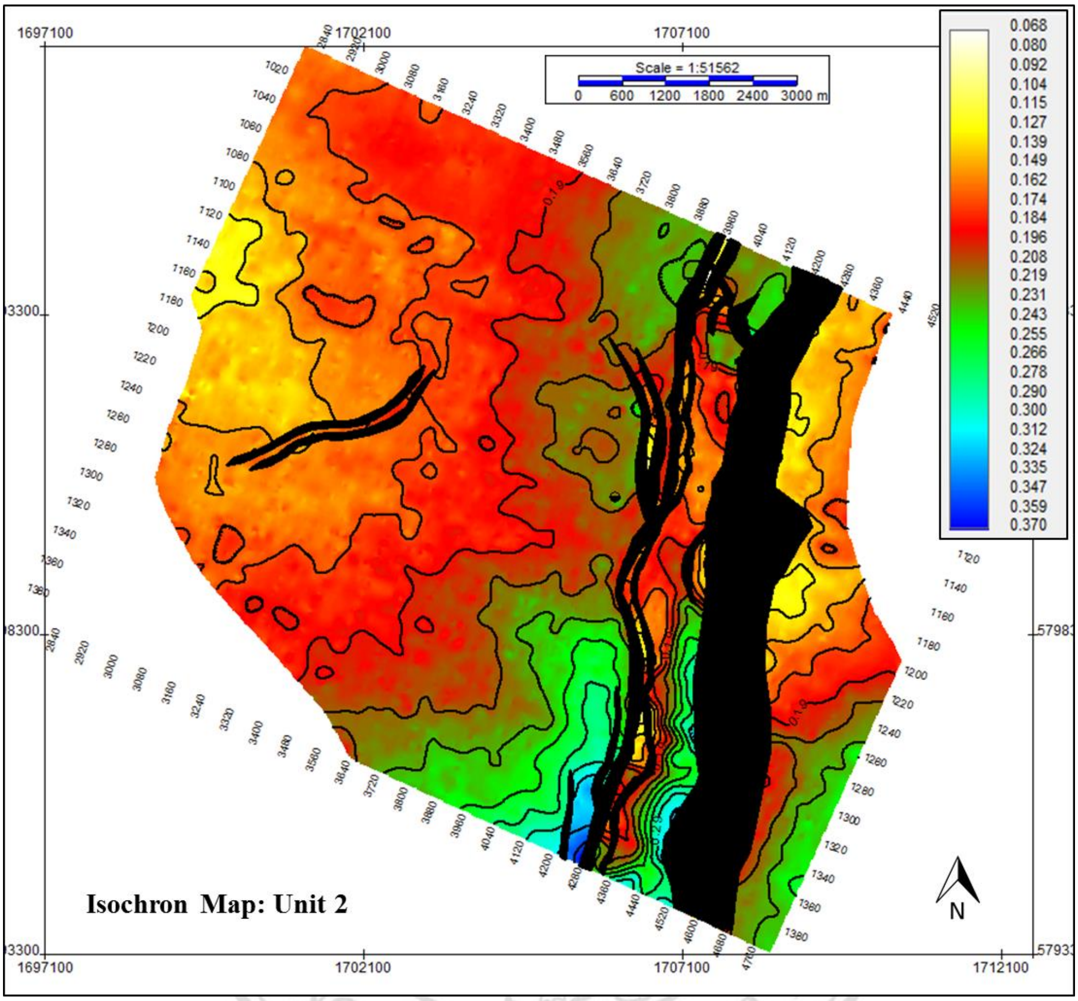

Figure 5-12: Isochron map of Unit 2 shows the thickness variation

Unit 3 (Figure 5-10) is bound at its top and bottom by H-3 and H-4 respectively. It is a high to medium amplitude reflection package and has an external sheet-drape form. Unit 3 has a high frequency and medium continuity. It is characterized by a sub-parallel reflection configuration in the west of N. Fault 10 and in the east of the growth fault, and hummocky configuration in the zone between N. Fault 10 and the growth faults (section 5.3.2). The isochron map (Figure 5-13) shows the thickness variation of Unit 3. The thickness variation of Unit 3 is not too much throughout the unit and ranges from 0.093 sec to 0.307 sec. Unit 3 is the thinnest adjacent the N. Fault 10 in the center.

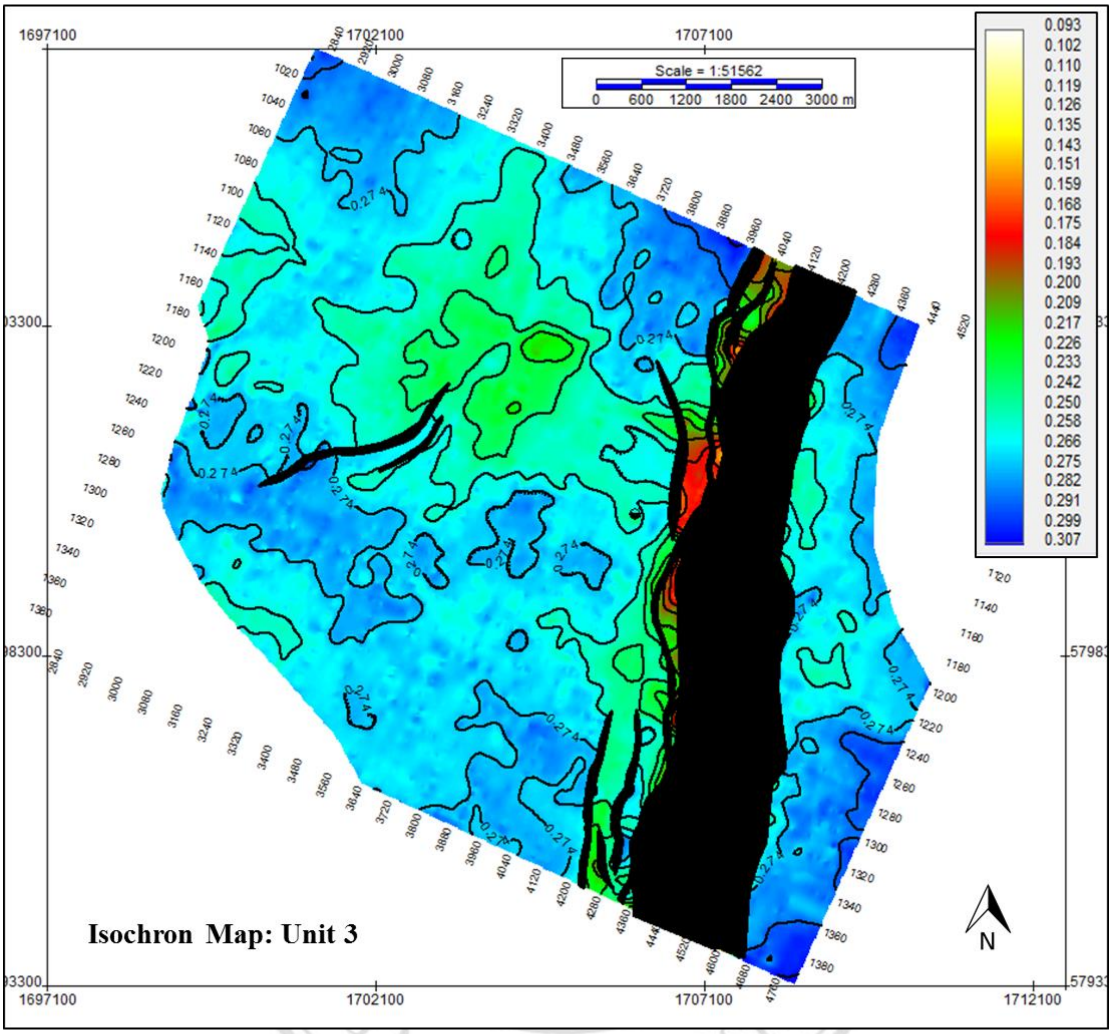

Figure 5-13: Isochron map of Unit 3 shows the thickness variation

Unit 4 (Figure 5-10) is bound at its top and bottom by H-4 and H-5 respectively. It is a high amplitude reflection package in the center and medium to low amplitude reflection package in other areas. Unit 4 has a sheet-drape form. It has a low frequency, and medium continuity. It is characterized by a sub-parallel reflection configuration in the west of the growth fault, and contorted configuration in the east of the growth fault (section 5.3.2). The isochron map (Figure 5-14) shows the thickness variation of Unit 4. The thickness ranges from 0.0003 sec to 0.107 sec. Unit 4 is the thinnest adjacent to the N. Fault 10 (section 5.3.2) in the west.

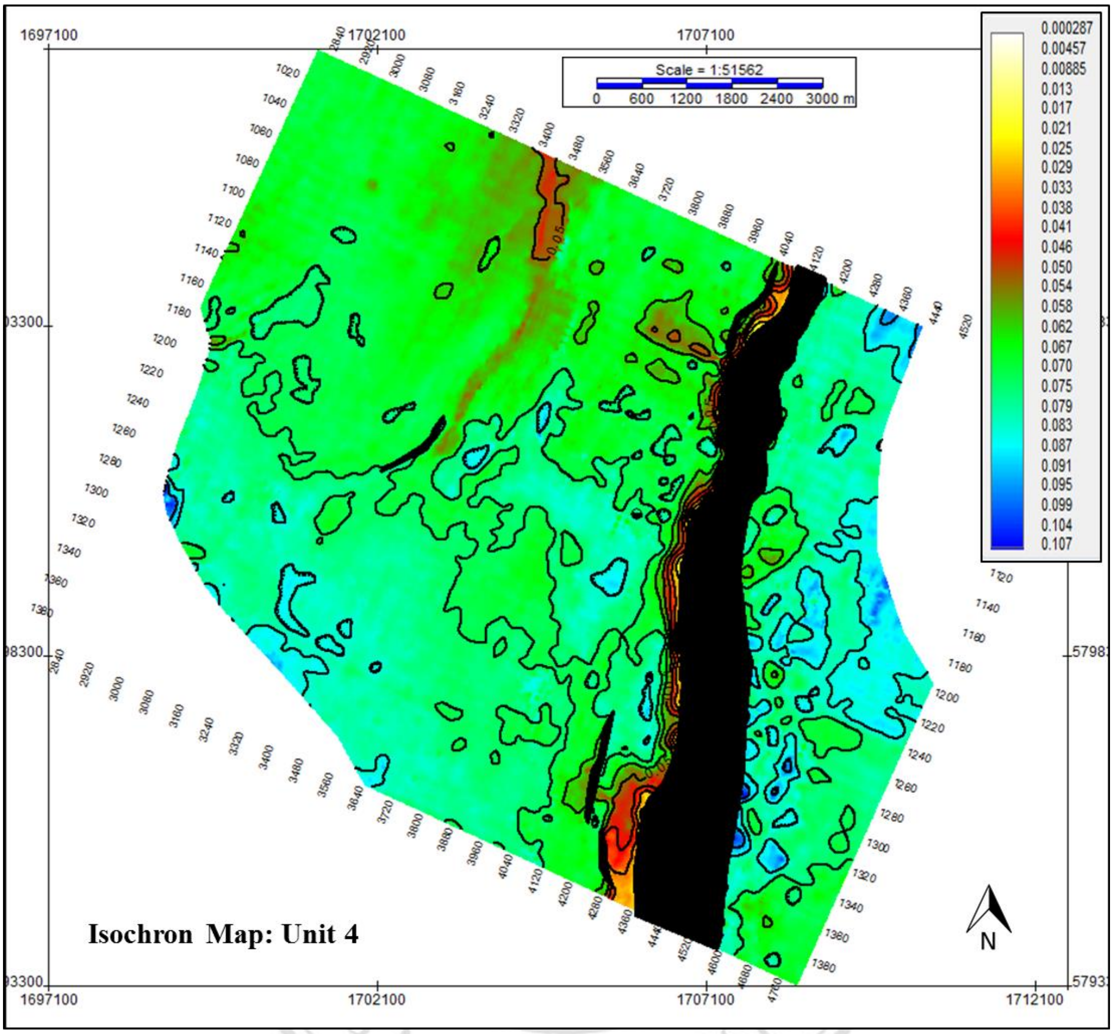

Figure 5-14: Isochron map of Unit 4 shows the thickness variation

Unit 5 (Figure 5-10) is bound at its top and bottom by H-5 and H-6 respectively. It is a high to medium amplitude reflection package in the west, and a low amplitude reflection package in the east. Unit 4 has a medium reflection frequency, and high to medium continuity in the west and medium continuity in the east. It is characterized by a parallel reflection configuration at its top in the west, a sub-parallel configuration at the bottom in the west and center, and a hummocky (lenticular?) configuration in the east. The isochron map (Figure 5-15) shows the thickness variation of Unit 5. The thickness of Unit 5 is variable and ranges from 0.156 sec to 0.484 sec. Unit 5 is thinning west to east.

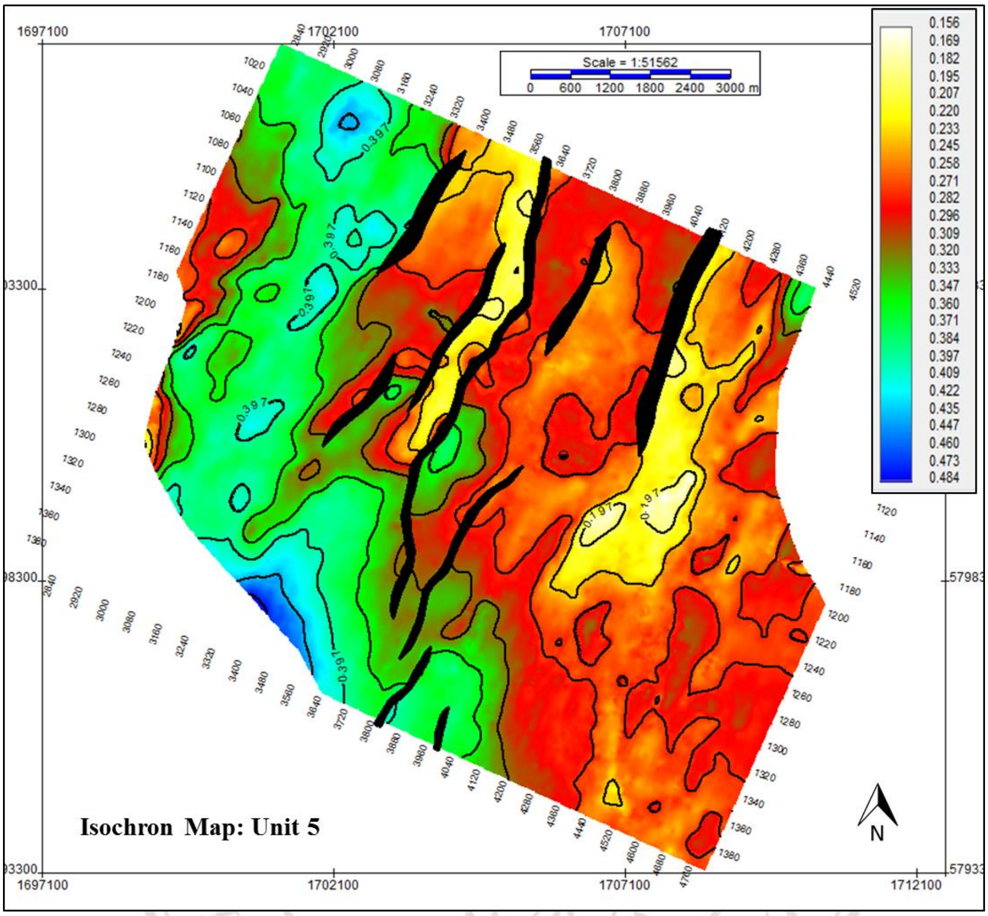

Figure 5-15: Isochron map of Unit 5 shows the thickness variation

5.3 Fault Interpretation

Major and minor faults were interpreted and analysed to get the detailed structural analysis of the study area. One major growth fault (Karewa Fault), 3 splay faults, 13 normal faults, and one reverse fault were interpreted throughout the study area. Based on the times of activity and the respective intersections of horizons the faults can be divided into two sets. The type, orientation, length, and stratal offset are mentioned for each fault.

5.3.1 Fault Set 1

Nine extensional faults cut H-6 as well as the Unit 5, indicating that these faults were activated after the formation of Unit 5 and reflecting the stress state of that time (Figure 5-16). These are the oldest faults of the study area. The overall orientation of the faults of Fault Set 1 is north to south. The type, orientation, length, and staratal offset (based on H-6) are shown in Table 5-1.

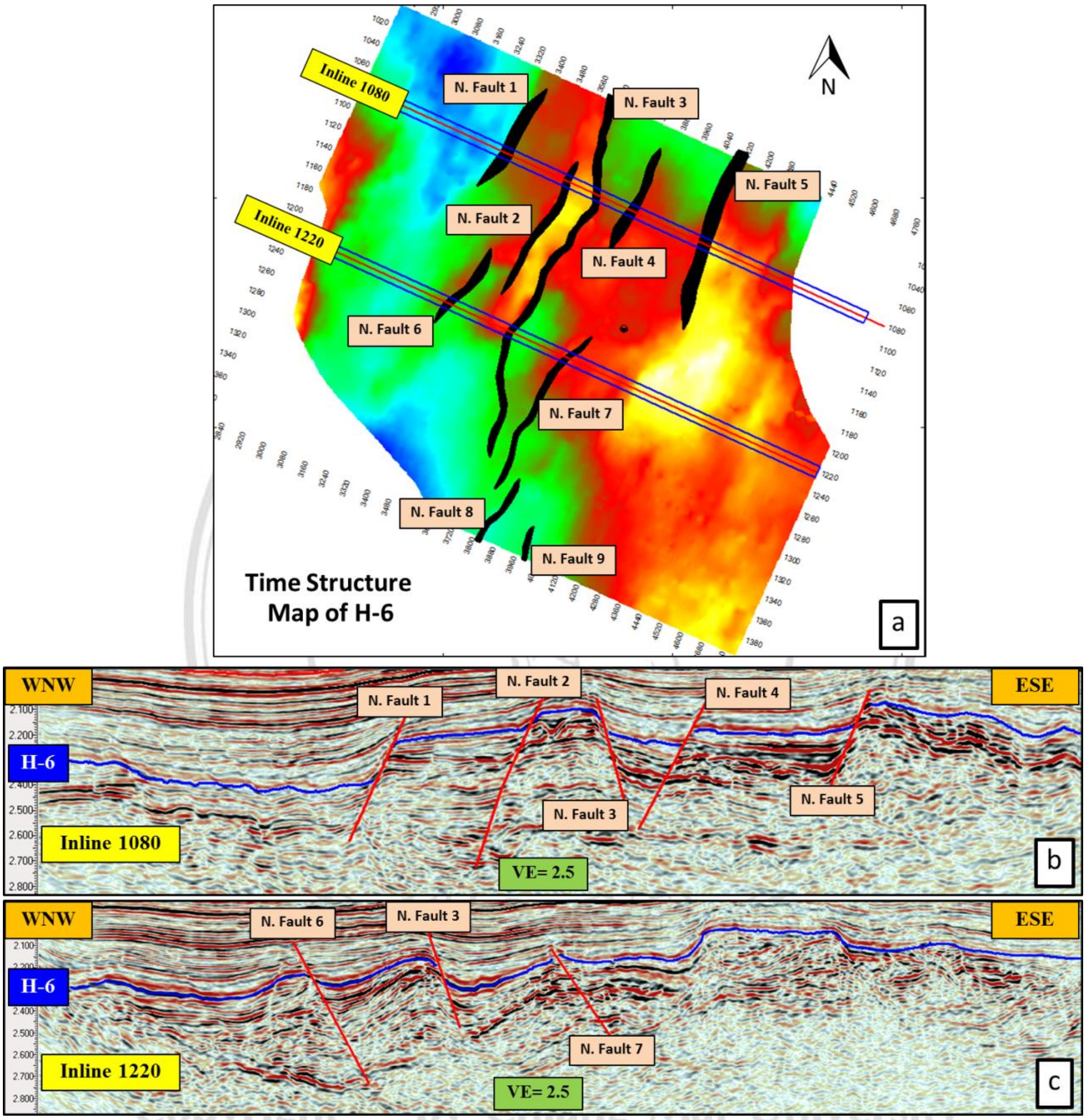

Figure 5-16: (a) Time structure map of H-6 shows the location and orientation of nine normal faults, and location of inline 1080 and 1220, (b) inline 1080 shows five extensional normal faults cut the H-6, and (c) inline 1220 shows three extensional normal faults cut the H-6.

Table 5-1: The type, orientation, length (in 3D Karewa survey only), and stratal offset of nine extensional faults (based on H-6)

Fault	Type	Orientation	Length (km)	Stratal Offset (ms)
N. Fault 1	Normal	North to south	2.6	152
N. Fault 2	Normal	North to south	3.45	104
N. Fault 3	Normal	North to south	8.25	78
N. Fault 4	Normal	North to south	2.5	62
N. Fault 5	Normal	North to south	3.97	90
N. Fault 6	Normal	North to south	2.02	45
N. Fault 7	Normal	North to south	4.08	17
N. Fault 8	Normal	North to south	1.70	29
N. Fault 9	Normal	North to south	0.8	15

5.3.2 Fault Set 2

One large growth fault (Karewa Fault) controls the MTC, while secondary faults include: one large antithetic normal fault (N. Fault 10), three small normal faults, and one reverse fault. The faults cut H-3 as well as the Unit 3 (Figure 5-17). These faults were activated after the deposition of Unit 2 and 3. The reverse fault is related to compression at the toe of the Karewa Fault. The sediment was deposited in the hanging wall of the Karewa Fault after its activation and the N. Fault 10 is antithetic to, and related to movement on the Karewa Fault. The overall orientation of the faults except for the reverse fault is north to south. The orientation of the reverse fault is SW to NE. The type, orientation, length, and stratal offset (based on H-3) are shown in Table 5.2.

Table 5-2: The type, orientation, length (in 3D Karewa survey only), and staratal offset of the faults (based on H-3)

Fault	**Type**	**Orientation**	**Length (km)**	**Stratal Offset (ms)**
N. Fault 10	Normal	North to south	10.15	15
N. Fault 11	Normal	North to south	2.72	9
N. Fault 12	Normal	North to south	1.63	2
N. Fault 13	Normal	North to south	1.39	4
Growth Fault	Normal (Listric)	North to south	10.42	240
Splay Fault 1	Normal	North to south	0.72	2
Splay Fault 2	Normal	North to south	1.46	3
Splay Fault 3	Normal	North to south	0.96	2
Reverse Fault	Reverse	SW to NE	3.32	3

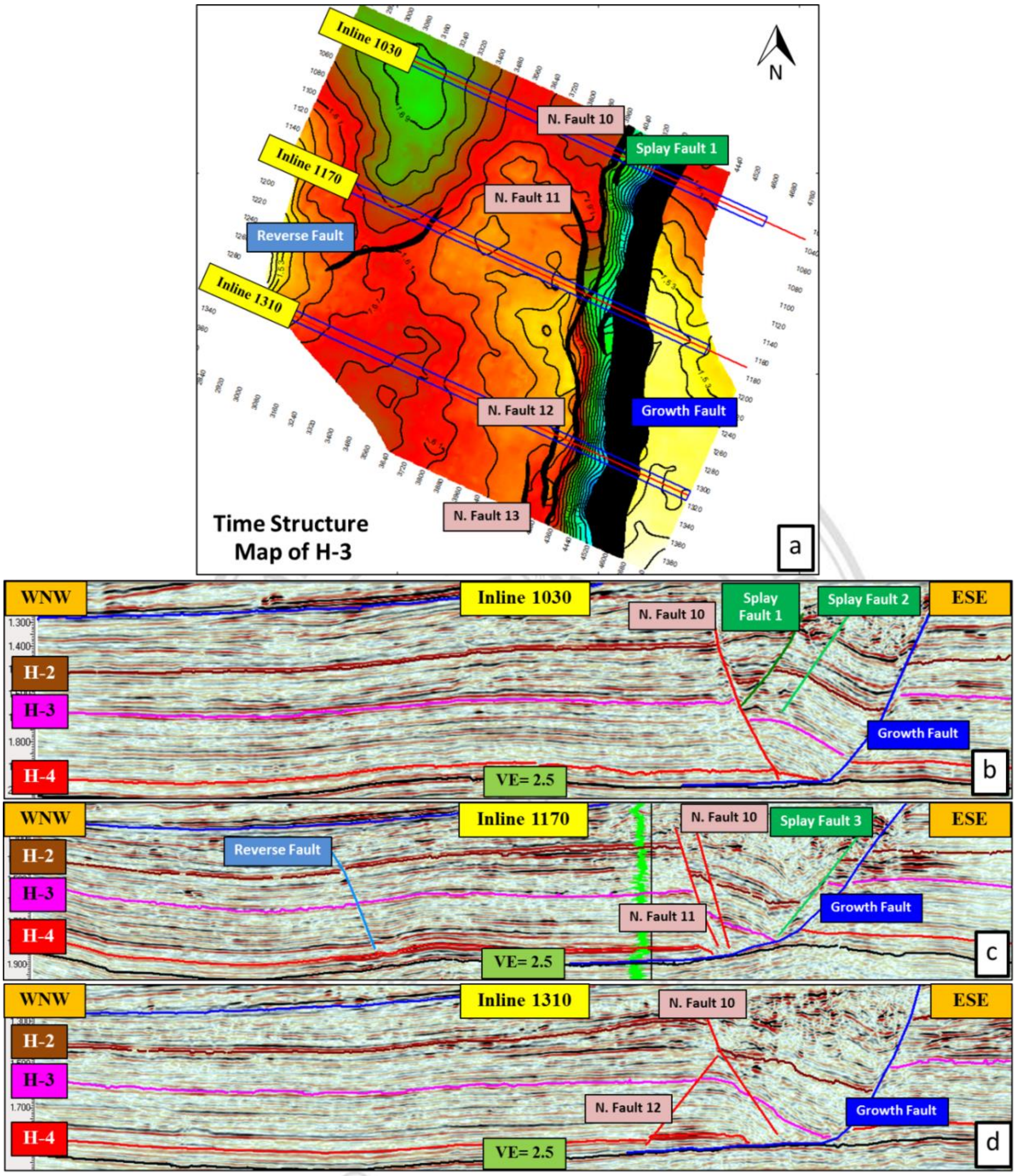

Figure 5-17: (a) Time structure map of H-3 shows the location and orientation of four normal faults, one growth fault, one splay fault, and one reverse fault, and the location of inline 1030, 1170, and 1310, (b) inline 1030 shows one normal fault, one growth fault, and two splay faults cut the H-3, (c) inline 1170 shows two normal faults, one growth fault, and one splay fault cut the H-3, (d) inline 1310 shows two normal faults, and one growth fault cut the H-3.