CHAPTER 2

Data and Methodology

2.1 Seismic data

The data used for this study was available from the New Zealand Petroleum and Minerals 2014 data pack, and covers a total area of 30×15 km^2 (Fig. 2.1). The study area encompasses the Karewa 3D seismic and a set of 2D seismic lines with average line spacing around 750-1000 m. The Karewa 3D survey was acquired by Todd Energy in 2006. Karewa 3D data is 10 km wide and about 12 km long, and comprises 393 in-lines and 1001 cross-lines. The in-line and cross-line spacing is 25m and 12.5m, respectively. Record length is approximately 5s of two-way time (TWT). Both 2D and 3D seismic data have good quality with seismic resolution ranging from 30-40 Hz for 2D and 40-50 Hz for 3D.

2.2 Well log data

There are 4 wells, Karewa-1, Mangaa-1, Tangaroa-1 and Kora-1, located within the northern part of Taranaki Bain (Fig. 2.1). The Karewa-1 well is located within the 3D seismic survey and includes wireline logs and the well report. The well data have been used to support the seismic interpretation and also to verify lithology information in the study area. Key stratigraphic markers were annotated with the equivalent ages which are available from well completion report. Fig.2.2) Due to checkshots data were not available in this dataset. The velocity information was deriving from sonic logs. The formation tops at well locations was available from well completion report. The time-depth function used in this study is shown in Appendix figure D.1.

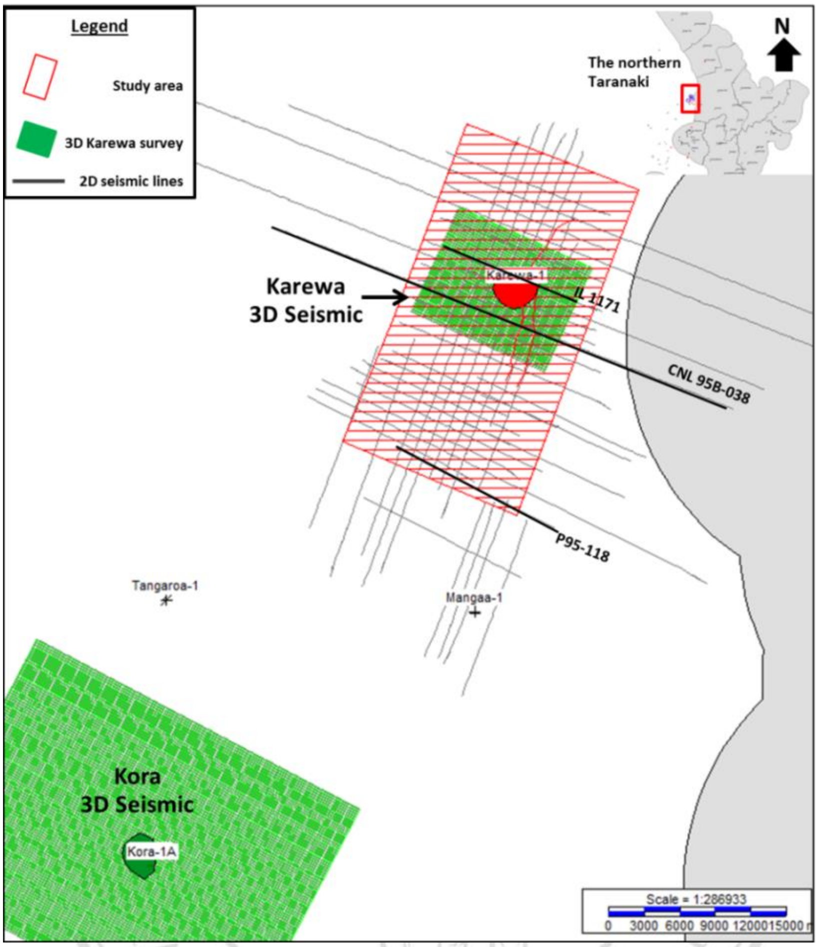

Figure 2.1: Base map shows 3D and 2D seismic data available from the New Zealand Petroleum and Minerals 2014 data pack. The majority of the 2D lines trend NNE-SSW and WNW-ESE, with average line spacing around 750-1000 m.

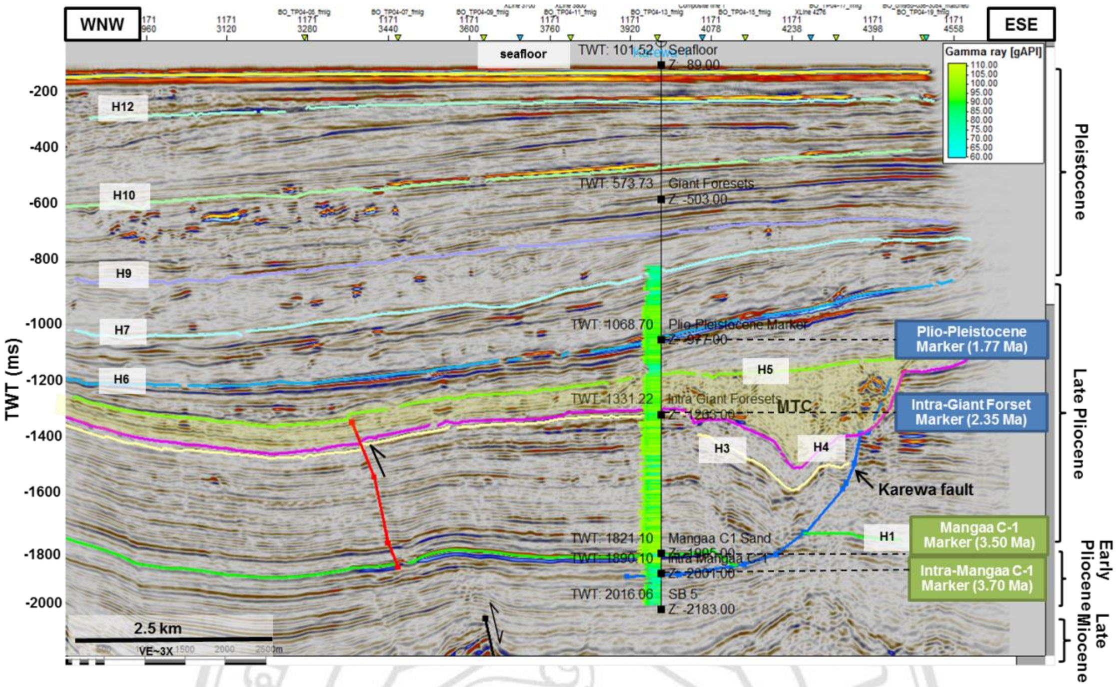

Figure 2.2: 3D seismic line (IL 1171) with gamma ray log showing interpreted horizons and key stratigraphic markers; pre-kinematic sequence (green), base-synkinematic of Karea fault (yellow), base MTC (pink), top MTC (light green). H6-H12 is interpreted horizons within the Giant Foresets Formation of Pleistocene age. See Fig. 2.1 for the location.

2.3 Interpretation workflow

The research workflow can be divided into three main steps, beginning with the background study, followed by seismic interpretation, and finally application of sequence stratigraphic principles. The standard workflow of the interpretation steps (Fig. 2.3) is as follows:

- Faults and Horizon Mapping:

  - Interpretation of large structures that are suspected to be of kinematic importance (e.g. basement faults) and faults with latest movement that are likely to offset older faults.

  - Identification of major bounding surfaces with good impedance contrast, major discontinuity surfaces associated with distinctive reflection patterns and stratal terminations (Fig. 2.4)

  - Produce time structure maps and isochron maps showing variations in sediment thickness of the target facies.

- Seismic facies analysis: analyze seismic facies from external form, internal reflections configuration as seen in 2D or vertical transects through 3D data (Fig. 2.5)
- Interpretation of stratigraphic sequences and systems tracts: during this step, the OpendTect SSIS software has been used as it enables sequence stratigraphic interpretation of HorizonCubes as well as the Wheeler transformation (chronological order of sediments filling and erosion events) and systems tracts.
- Attribute analysis: there are seismic attributes suitable to illuminate geological properties, and for clastic depositional system in particular (Pigott. J. D., 2012) such as Variance, Amplitude Envelope, Chaos, Instantaneous Frequency, Dip Deviation, etc. During interpretation, seismic attributes were extracted along time slices and horizons of interest within the depth interval of 0.2-2 sec (Pliocene-Recent).

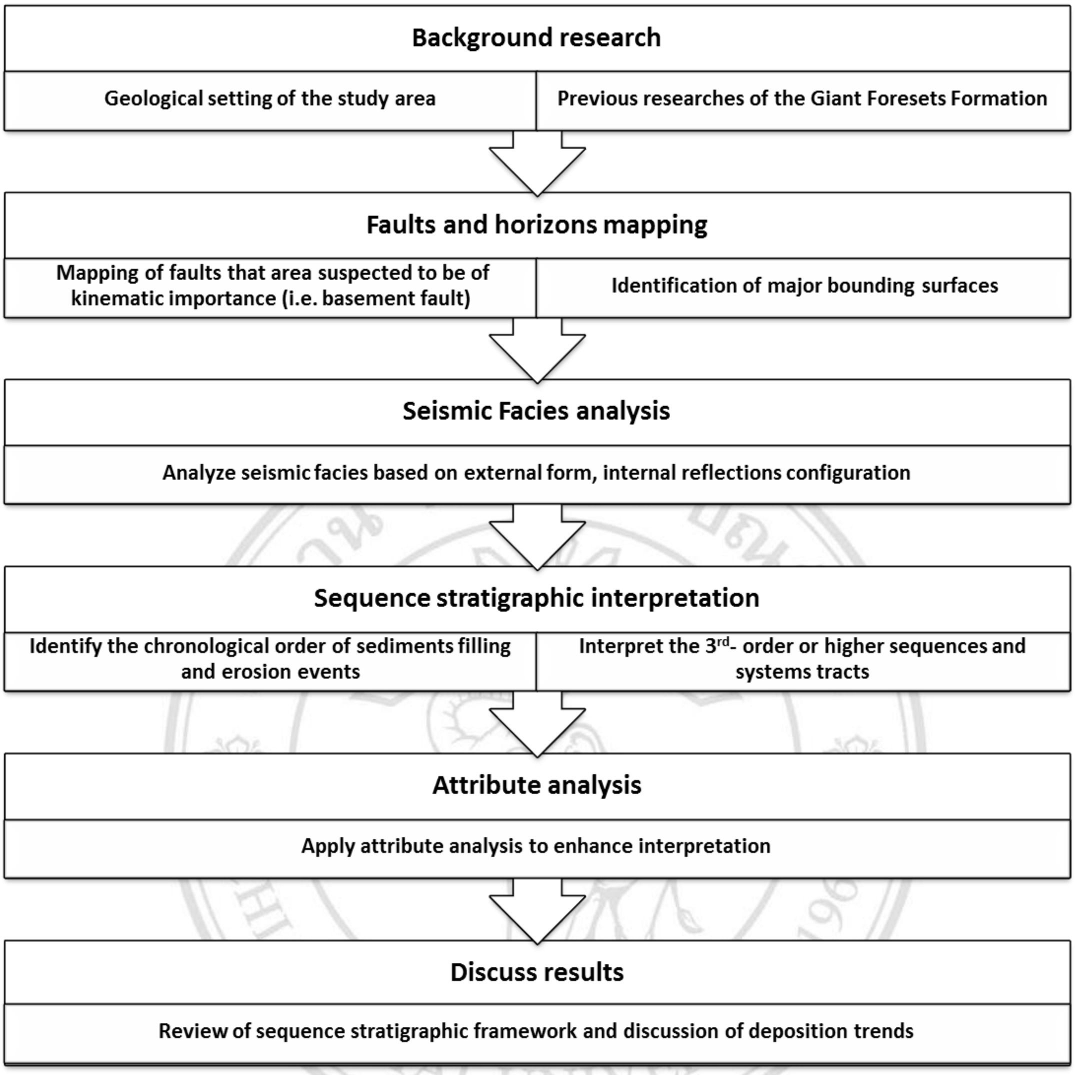

Figure 2.3: Summary of research workflow

2.3.1 Seismic interpretation

Seismic interpretation was carried out using the Schlumberger's software Petrel 2013 for fault and horizon mapping. Seismic interpretation was conducted to understand the structural style in the study area. Seismic interpretation can be broadly categorized into structural interpretation and stratigraphic interpretation (Hart, 2011).

The interpretation workflow starts with the background study (e.g. geologic setting) of the study area, followed by mapping of major structural framework in order to constrain the horizon picking. The purpose of the fault and horizon mapping is to identify and map the major structural features from seismic section. The horizon being picked in the study area is primarily based on changes of depositional facies (i.e.

indicated by stratal termination) or changes in the thickness across the bounding faults. More importantly, the picked horizons should be an indicator of fault movement during deposition (i.e. pre-kinematic, syn-kinematic, and post-kinematic). Furthermore, mapping of more than one horizon in the faulted area can indicate the thickness change of the syn-depositional strata and help establish the timing of the fault movement.

In order to understand the structure style and the depositional history in the study area, the workflow integrated the data available with the structure and sequence stratigraphic concepts to ensure that the faults and horizons being picked in the study area are reasonable and consistent. Available 2D and 3D seismic data may provide different advantages, for example, 2D lines allow the broader view of the regional structure while 3D seismic data provided an advantage above 2D in terms of variety of ways to visualize the data. In 3D seismic data, dip-oriented transects (arbitrary lines), time slices and stratal slices are examined and interpreted concurrently. A standard workflow was followed based on Hart (2011), e.g. beginning with creating a fault framework by picking faults on a regularly spaced grids of the dip lines and cross-checked with the strike lines. On 3D data, faults can also be picked from arbitrary lines and from time slices using a coherency volume. Ultimately, the fault framework was used to constrain the interpretation of the horizons. Fault interpretation was updated in tandem with the horizon mapping. On the 3D seismic data, the horizons were picked on a grid of dip lines and strike lines followed by using auto-tracking to fill the gaps. The results were checked through different visualizations concurrently. For this data auto-tracking was particularly useful in the shallow part of the seismic data due to prominent reflections, greater continuity and low structural complexity. In the syn-kinematic interval (faulted area), the horizons cannot be auto-tracked. Therefore, picking manually for every 10th in-line and cross-line was required because the top and the base surfaces of the mass transport complex were quite challenging due to their low continuity and highly disrupted reflections.

Attribute extractions were used for visualizing and highlighting the structural and/or stratigraphic features in the data set. Attribute extraction was combined with RGB blending techniques, which can be effective for analyzing depositional environment and revealing greater details of stratigraphic features (e.g. detail of the overbank, thalweg, lithology and thickness changes of the channel system). The attribute extraction was performed concurrently during fault and horizon mapping and sequence stratigraphic interpretation.

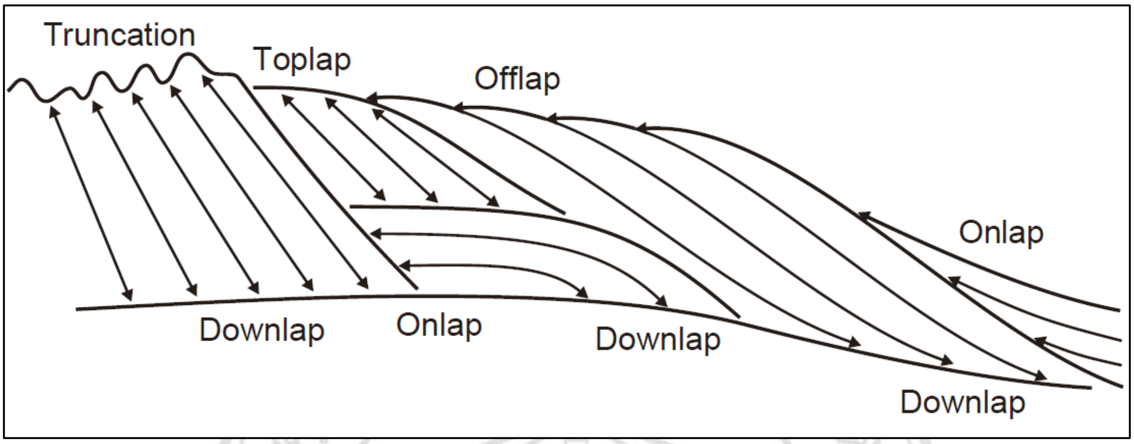

Figure 2.4: Type of stratal terminations (Catuneanu, 2006, modified from Emery and Myers, 1996)

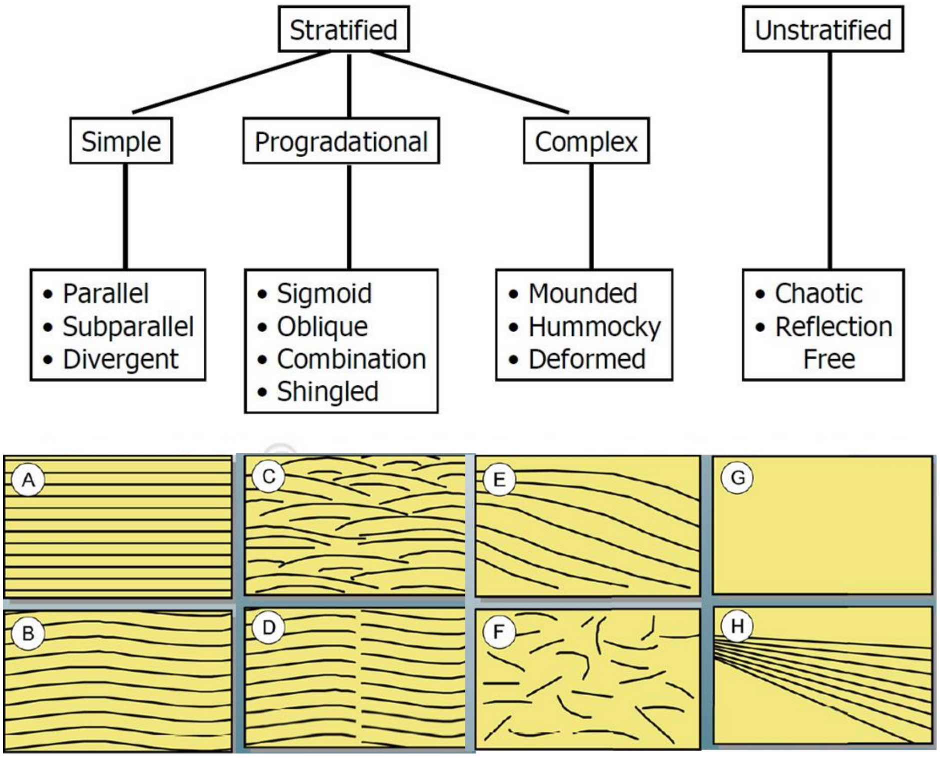

Figure 2.5: Internal reflection patterns (modified from AAPG Memoir 26) and some examples of seismic descriptions: A) parallel, continuous, even, B) parallel, continuous, wavy, C) hummocky, D) parallel, wavy, disrupted, E) clinoforms, F) chaotic, G) reflection free, H) divergent (modified from Hart, 2011).

2.3.2 Seismic attribute extraction

The brief concepts of seismic attributes used in this study are described in the following sections.

2.3.2.1 Variance

The variance attribute measures the similarity of waveforms or adjacent traces over a given window. Therefore, it emphasizes discontinuities in seismic data related to faulting or stratigraphy. The variance attribute is a very effective tool for delineating faults and channel edges on both horizon slices and time slices (Fig. 2.6) (Pigott et al., 2013).

2.3.2.2 Sweetness

Sweetness is the frequency weighted envelope attributes defined by the following formula:

Sweetness = (Instantaneous Amplitude)/SQRT(Instantaneous Frequency)]

Sweetness is an attribute designed to identify “sweet spot” places that are oil and gas prone and improves the imaging of relatively course-grained (sand) intervals or bodies. The definition of sweetness is motivated by the observation that hydrocarbon reservoirs imaged in seismic data tend to have high amplitude and low frequencies. Hence, high sweetness values are most likely to indicate hydrocarbon but this can also indicate lithology variation.

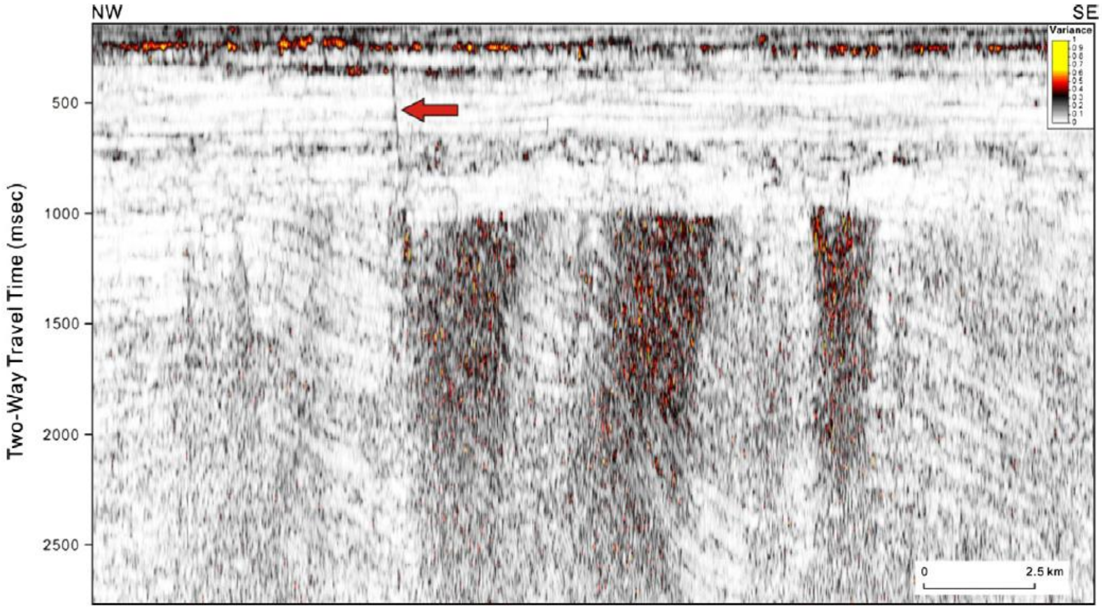

Figure 2.6: Example of the variance attribute showing fault highlighted by red arrow. (Pigott et al. 2013)

2.3.2.3 RGB spectral decomposition

The concept of spectral decomposition comes from the seismic data in which each frequency responds in different ways (for example, higher frequency ,shorter wavelength) may indicate a thin channel). Since the data were previously spectrally whitened during the seismic processing stage, the spectral component exhibits the effects of the geology with different channel thicknesses and infill exhibiting different spectral responses (Del Moro, 2012). In a specific frequency band, certain size structures are more visible due to the tuning effect. Therefore, this attribute is very useful for identifying thin-bed sand layers. In general the thin beds will be better displayed with higher frequency, and the thicker beds with lower frequency (Fig. 2.7). Simultaneously, RGB-blending, whereby three different frequency components decomposed from seismic data are assigned red, green, and blue colours and blended together (Fig. 2.8), highlight variation in frequency and amplitudes as variation in colour and intensity (McArdle and Ackers, 2012).

In the shallow part of the GFF unit, there is evidence of multiple stages of channel incisement within the study area. Colour-blended images of 14-, 32-, and 54-Hz spectral component and corresponding coherence images were used to map the channel features at different stages. Those frequencies were identified from the amplitude spectrum extracted from the seismic data by cropping the zone of interest (Fig. 2.9). Analysis of a suite of spectral components within a zone of interest can provide a more precise definition of a given geologic feature.

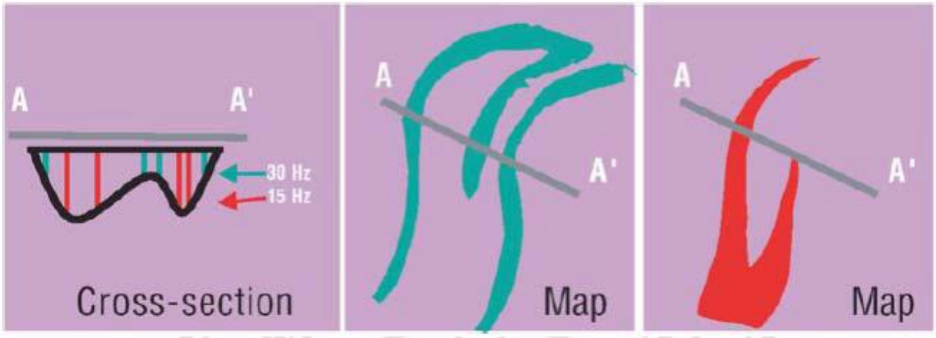

Figure 2.7: The effect of thin bed tuning in different frequencies (Laughlin et al., 2002)

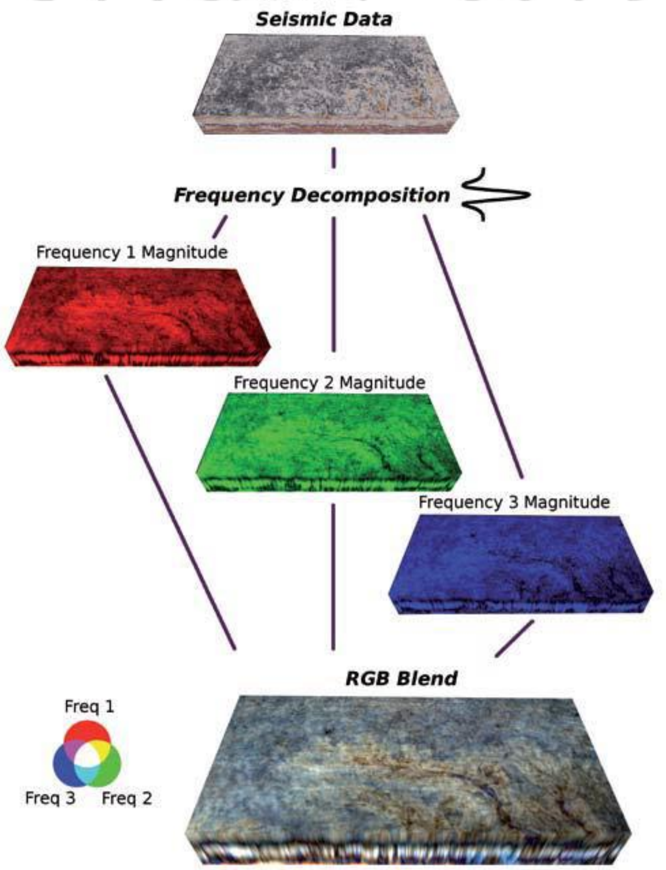

Figure 2.8: An example of frequency decomposition and RGB colour blending workflow, whereby three different frequencies are assigned red, green, and blue colour and blended together (McArdle and Ackers, 2012).

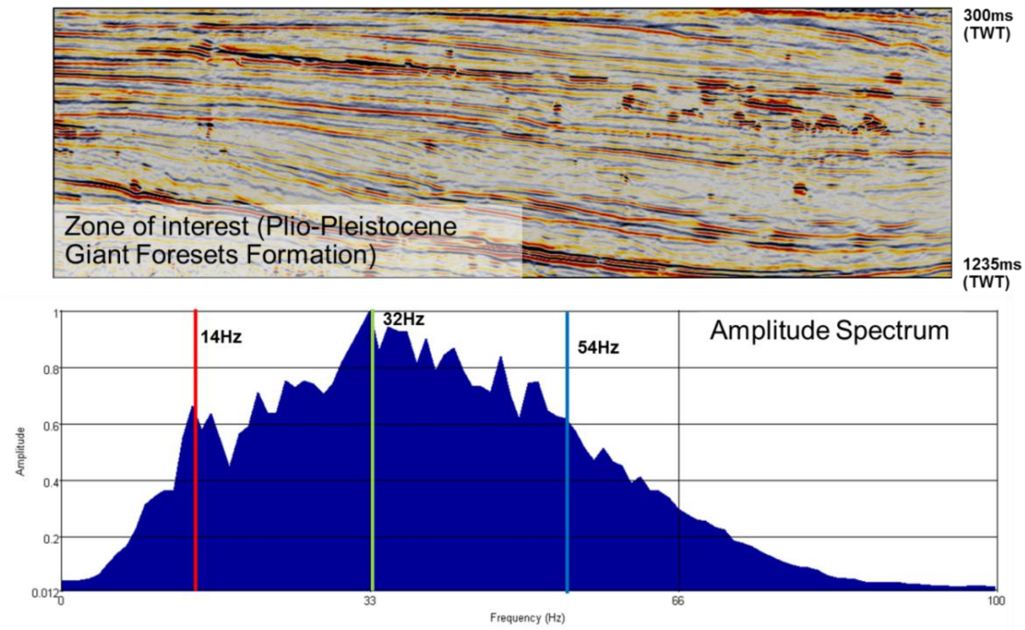

Figure 2.9: RGB frequencies are selected within the seismic bandwidth; minimum (red), middle (green), and maximum (blue) of the amplitude spectrum.