3D Seismic Reflection Interpretation of Igneous Features in Parihaka-3D, Taranaki Basin, New Zealand
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Abstract:

Parihaka 3D is a seismic survey within Taranaki Basin, off the west coast of the North Island of New Zealand. Parihaka is a highly faulted region which contains a buried, submarine, startovolcanic complex. This means that any research in this area must be completed using only seismic data and core samples from wells. In order to discuss the architectural elements of this volcanic complex, the area has been separated into syn- and post- eruptive sequences. Within the syn-eruptive period the architectural elements include channels, parasitic vents, and sills. The post-eruptive period has channels (of differing morphologies) and seamounts. There is also a large amount of faulting which has formed a basin to the north of the volcanic complex. This basin has caused a channel running north-south along the western edge of the volcanic complex to incise more deeply than the others. Channel morphologies differ based on proximity to the volcanic complex. Those nearby are affected by the presence of a volcanic edifice and have become narrow, straight, deeper channels. Those that are further from the volcanic edifice do not appear to be influenced, and follow meandering wide paths while remaining shallow. The volcanic complex has altered not only the pre-existing sedimentary strata, but also the ongoing processes that occurred after the end of the eruptions.

Introduction:

This research aims to study one specific area in Taranaki Basin, with the data from Parihaka 2D and 3D seismic. From this point on the area will be referred to as Parihaka (Figure 1).

Taranaki Basin is located on the western side of the north island of New Zealand. It is up to ~60km wide and ~350km long. It is well known for its almost complete Miocene-Recent record of normal
faulting and volcanism, making it a popular area for research to occur. There are more than 25 buried volcanic complexes in the northern graben of Taranaki Basin. These volcanoes are NW-SE aligned, forming a belt of more than 100 km. They become younger to the SE due to the rotation of the slab and the steepening of the subducting pacific plate beneath the Australian plate (Giba et al., 2012). The volcanics within the basin are buried, submarine, andesitic stratovolcanoes (Bischoff et al., in press).

The present project’s aim is to characterize in detail the fundamental building blocks of volcanic systems. These are 3D elements formed during eruptions, magma emplacement, deformation, and sedimentation.

One major challenge for this project is the high degree of brittle deformation that has disturbed the igneous and sedimentary sequences due to normal faulting and rifting. Giba et al. (2010) studied the faulting and volcanism in the whole of Taranaki Basin, but did not focus into a smaller area of study.

The research will map architectural elements of the volcanic features present by locating them systematically and placing them into pre-, syn-, and post-eruptive stages during the evolution of the magmatic system and host sedimentary basin.

Features to be mapped are top of volcanics, dikes, sills, vents, and channels. The mapping of this area will provide a better understanding of the way different architectural elements of volcanics and channels interact.

In order to do so, mapping of the top of the volcanics was conducted on 2D seismic slices while correlating the seismic cube with wells present within the mapping area. Next, two 3D seismic cubes were constructed, one using the attribute of amplitude, and the other with dip of maximum similarity. These were used to better visualize the elements within the volcanic system and surrounding sedimentary strata. By using the seismic cube and manipulating the spectrum of the seismic reflectors, high resolution images of the architectural elements were taken.

**Methods:**

Research was conducted using Kingdom software, a program used for seismic and geological interpretation. Research was based on 2D and 3D seismic data as well as data correlated with three nearby wells. Research was conducted using two screens in order to simultaneously look at 2D and 3D data (Figure 2).
The first step in the process was to look through all of the data in a broad scale, looking for features that stood out and taking note of their locations. This was primarily done with the use of a 3D seismic cube created with amplitude as the attribute.

The next step was to begin separating the data into pre-, syn-, and post-eruptive periods. This started with mapping the top of the volcanics. This was done using the 2D inline and crossline data. Mapping was done every 10 lines, with each line being 12.5m apart. On each 125 spaced slice a horizon was mapped to represent the top of volcanics. The top volcanics horizon was initially identified by a combination of comparison with similar volcanics (i.e. Kora volcanics, Bischoff et al, in press), well data, and knowledge of age relations between Kora and this location.

Once horizon mapping of the top of the volcanics was completed, we could create a grid that separated the syn- and post-eruptive periods, with a resolution of 12.5m. The next stage was to locate architectural elements systematically with pre- syn and post- eruptive stages during the evolution of the system was applied.

2D seismic was used to locate sills. They appeared primarily as saucer shaped sills, with a distinct morphology. These fall into the syn-eruptive period. The 3D amplitude cube was used to look for the vents on the volcanic feature. They presented as circles on the top view of the cube. These are also part of the syn-eruptive period.

Another 3D cube was created with dip of maximum similarity as the attribute. This was used for locating and mapping structural and sedimentary features such as faults and channels. There were channels present in all three periods. By looking at the migration of the meanders of the channels a flow direction was estimated.

The final stage of research was to draw up a schematic representation of Parihaka Architectural Elements. This is intended to present the elements and show which period each one is in, as well as how they interact with the system as a whole.

Results: Mapping of the top of volcanics was partially successful. Due to the highly faulted nature of the region it was decided that the horizon mapping would be limited to the central region where the volcanics were located and end along the faults bounding it to the north, south, and east. The west edge was decided base on the west most extent of the northern fault. This horizon was then turned into a grid which
could be viewed as both a 2D map (Figure 3) and a 3D figure (Figure 4).

The grid shows two volcanic features in the southeastern region. These are part of the same volcanic complex, which will now be called the Parihaka Volcanic Complex, or PVC (Figure 5). The volcanic features will now be referred to as the north and south volcanic edifices, respectively. To the north of the volcanics is a clear low elevation region. This basin like feature appears to be related to the major faults that borders it to the north and east. To the south of the volcanics is another relatively large fault. The fault to the north has the largest displacement of all the faults.

One very distinct feature on the grid is the deeply incised channel bordering the western side of the PVC (Figure 6). It appears to run south to north, feeding into the basin. The fact that the location and flow direction are influenced by the volcanics, and that it is incised into the volcanics, means that this feature falls into the post-eruptive period.

In addition to the major channel, there are channels throughout all the periods. Within the post-eruptive period, near the volcanic complex, are primarily low-sinuosity channels. They can distinctly be seen to be fed from sources on the volcanic feature (Figures 7a, 7b, 7c).

There are also high sinuosity channels, primarily on low incline areas. There are two distinct clusters proximal to the volcanic feature. One lies to the east and is cut by a fault (Figure 7d). It has a distinct meandering appearance with many oxbows. The other lies to the west on the other side of the valley. It has changed course frequently throughout time and has a harder to follow course (Figure 7).

In addition to the post-eruptive channels, there are some that are syn-eruptive. These are harder to recognize using 3D seismic (Figure 7e, 7f). The syn-eruptive channels are easiest to distinguish using 2D seismic in addition to the top volcanics horizon.

The pre-eruptive channels are the hardest to see. The seismic imaging is very poor the deeper it goes below the volcanics. There are a few channels visible in 2D seismic, and some things that might be channels in the 3D seismic (Figure 7f).

Another feature that was looked at were vents on the volcanic features. In addition to the one main vent present on each volcanic feature, there were a few parasitic vents as well. There were mainly visible from a top view of the 3D seismic
cube. They resembled circles of varying sizes. In 2D seismic there were two parasitic vents that were more prominent and could be seen in the deformation of the volcanic feature.

Part of the research was to look for sills and dikes. Unfortunately dikes are difficult to see since objects that are near vertical don’t produce clear images. The vents were the only signs of dikes found. There were a couple of places that had sill like features. They had the saucer shaped sill morphology, however they weren’t very clear. This limits the viability of the identifications.

All of the research was then used to create a representative schematic of the Parihaka Volcanic Complex (Figure 8). This schematic is meant to show the way each of the architectural elements relate to one another, as well as what period they are a part of. It is intended to show a general idea of all of the architectural elements. The schematic is drawn through one of the volcanic features and is separated into the pre-, syn-, and post-eruptive periods. As the bottom of volcanics was not mapped as a horizon there is not distinct horizon separating the pre- and syn-eruptive periods. The schematic shows elements such as channels, vents, the top of volcanics horizon, and the seamount.

**Discussion:**

Throughout the research process there were a number of difficulties. First, there was a high level of faulting covering almost the entire mapping area. In particular there were three major faults the bound the PVC to the north, east, and south. Attempts were made to determine the fault offset, however, the sheer number of faults made it unreasonable to accomplish with the limited available time. This made correlation of the top of volcanics difficult so the mapping area was limited to the areas inside of the faults.

In addition, this research took place during only a four month period. At the beginning of research I had no experience with Kingdom software, and had no familiarity with seismic interpretation. This meant that not all of the research goals were able to be accomplished. The biggest goal that could not be completed was the mapping of the bottom of volcanics. This means that some of the elements attributed to the syn-eruptive period might actually be part of the pre-eruptive period.

One part of the research that was interesting was the unusual channel that runs along the west side of the PVC. This
channel has such a vastly different morphology to the other channels due to its steep sides and deep incision into the volcanics. My current theory is that the channels location is the cause of its morphology. It seems to feed directly into the northern basin. It is possible that the channel formed along the edge of the PVC and when the faulting of the basin occurred the sudden drop in base level caused the channel to incise deeper than other channels. This could also be because it is so near the PVC and has a relatively straight profile as opposed to the meandering paths many others follow.

There is a clear relationship between the presence of the PVC and the morphology of the streams. The increased elevation means that the streams near volcanic edifice incise laterally rather than meandering horizontally. Those channels that are on the relatively flat distal areas don’t have the ability to incise, and thus meander through time.

The Parihaka Volcanic Complex is a good example of the ways in which volcanism not only affects the pre-existing strata through which it intrudes and erupts, it also affects the long term morphologies and processes that will occur.
Figures:

Fig. 1: Google Earth image of Taranaki Basin, New Zealand. Parihaka mapping area is outlined in red.

Fig. 2: Sample of working dual screen. Left is 2D seismic. Right is two 2D seismic slices over a 3D seismic (amplitude) cube.
Fig. 3: Map showing top volcanics grid.
Fig. 4: 3D top volcanics grid.
Fig. 5: Top view of 3D dip of maximum similarity cube. A. Time is 2.944. Shows single volcanic mass. B. Time-slice is 0.800. Shows separation into two volcanic features.

Fig. 6: Top view of 3D dip of maximum similarity cube with 3D top of volcanics grid overlay. Distinct deep channel is visible to the east of the PVC.
Fig. 7: Top view of 3D dip of maximum similarity cube. Each image shows the progression of channel morphology and how the PVC affected it through time. Times for each image: A. = 0.780, B. = 0.928, C. = 1.056, D. = 1.588, E. = 1.900, F. = 3.204

Fig. 8: 2D slice with amplitude as the attribute. A schematic diagram showing architectural elements separated into syn- and post- eruptive sequences. A. Reflectors were dimmed to allow sketches to show. B. Unedited image.
Works Cited


