CHAPTER 2

Methodology/ Experimental design

2.1 Dataset

The study utilizes the 3D-Seismic Survey (Parihaka), covers an area of 1520 km^2. Total recorded length is 6 seconds with sample interval at 2 ms. Arawa-1 well final report PPL 38436 was published by Ministry of Economic Development Mantau Ohanga Crown minerals in Petroleum report series PR 1824. Three wells are located in the study area namely Witiora-1, Taimana-1 and Arawa-1 (Table 2.1) but only Arawa-1was incorporated into the study.

Table 2.1 The well log information

No	Well Name	Coordinates		Operator	Total Depth	Kelly Bushing	Inline-Crossline
		x	y				
1	Arawa-1	1661747.15	5704931.12	ARCO Petroleum	3055	17	4541-8654
2	Taimana-1	1646775.42	5699124.59	Dinamond Shamrock Exploration	4199	26	4809-6139
3	Witiora-1	1641083.80	5670734.11	NZ Oil and Gas (NZOG)	4229	26	3148-2897

2.2 Seismic Acquisition and Processing

The 3-D Parihaka survey was acquired in the Taranaki basin in 2004 by Veritas Viking II. It covers a total length of 1735.32 prime square kilometers (full fold). Eight Streamers, each having a length of 4500 meters separated by 100 meters were used in combination with alternating dual sources, laterally spaced at 50 meters. A 60-fold subsurface illumination area of 400 meters by 2250 meters is associated with each shot. This Survey was processed in Veritas DGC'Singapore processing center. A brief summary of the processing flow is given below obtained from Petroleum Report Series (PR3460) published by " Ministry of Economic Development Mantau Ohanga Crown Minerals".

1. Reformat
2. Merge of seismic and navigation data (Bin-size 6.25 x 25 m)

3. Source de-signature to minimum phase
4. Resample to 4 ms sample rate
5. Shot and channel trace editing
6. Low-cut filter
7. Spherical divergence correction (V^2T correction)
8. Automatic de-spiking (HFDESPIKE)
9. Swell noise attenuation (FXEDIT)
10. Linear noise attenuation using high-resolution radon transform (XRLIN)
11. Gain correction
12. Predictive deconvolution in tau-p domain
13. Freesurf demultiple
14. K-spatial anti-alias filter
15. Alternate trace drop (bin-size 12.5 x 25m
16. Tidal statics correction
17. Binning into common offset volumes
18. Initial velocity analyses (at 1.0 x 1.0 km grid) – guided by interpreted horizons
19. NMO correction using first pass velocity functions
20. Offset regularization and bin centering (FROID)
21. High-resolution radon de-multiple (XRMULT)
22. Acquisition footprint removal
23. Reverse NMO correction
24. Remove spherical divergence
25. Preliminary Pre-STM on velocity lines at 1km intervals.
26. Velocity analyses (at 1.0 x 1.0 km grid) – guided by interpreted horizons
27. Post-stack time migration (preliminary volume delivered to POGO)
28. Full 3D Kirchhoff pre-stack time migration (Pre-STM)
29. 3rd pass residual velocity analysis at 500 x 500 m grid – guided by interpreted horizons
30. AOK velocity analysis and application (AVO compliant)
31. Flat (event flattening) – Opunake survey only
32. 2nd pass high-resolution radon de-multiple (XRMULT)
33. Mute

34. Stack: full-fold and near / mid / far angle stacks
35. 2^{nd} pass acquisition footprint removal (post–stack)
36. Trace interpolation from 12.5 m x 25 to 12.5 m x 12.5 m bins
37. Gain compensation (on raw stack only)
38. Q compensation (on full and angle stack volumes)
39. Signal enhancement (on full stack volume only)
40. Zero-phase conversion
41. Source/Cable static correction
42. SEGY output (Final and Raw Stacks)
43. SEGY output (Well Tie Lines)

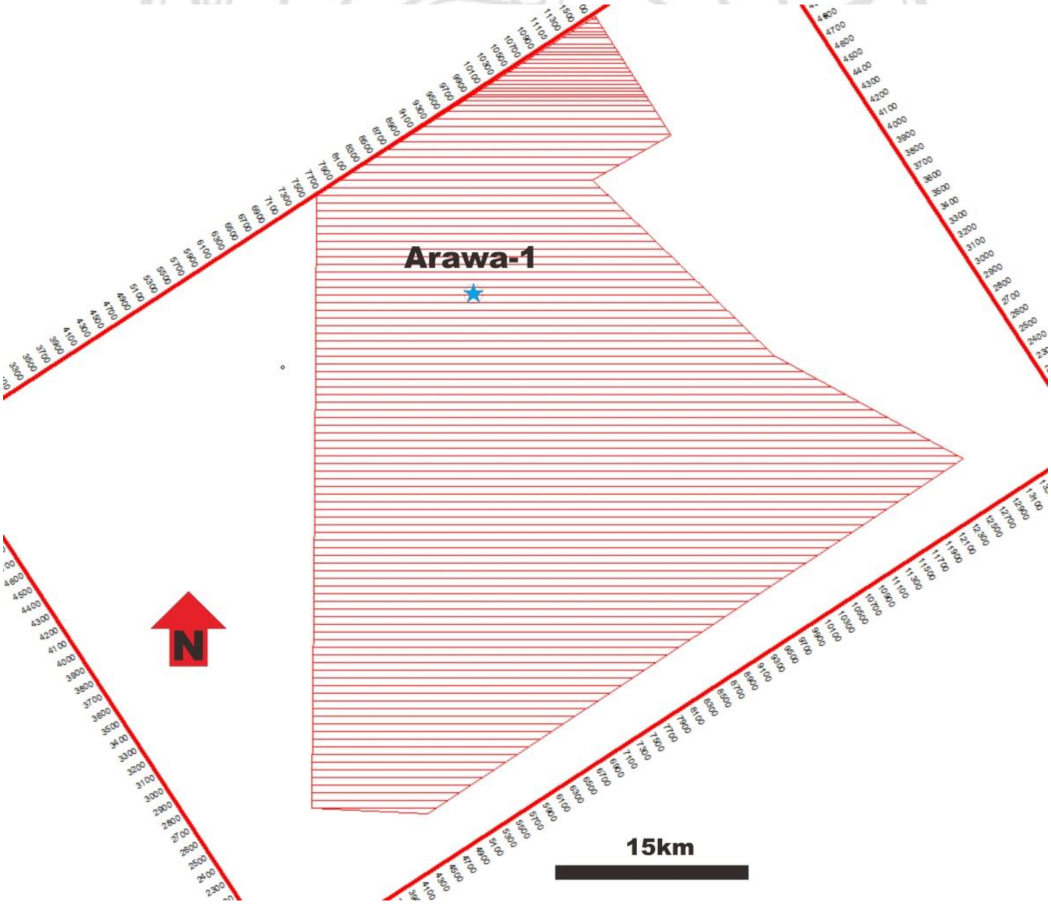

Figure 2.1 Location map for Arawa-1 well

2.3 Seismic Interpretation

Seismic interpretation is the most reliable technique to explore the geological history of a basin from the medium scale of 10's of kms to large scale up to100's of kms (Bacon, Simm & Redshaw, 2003). It has been widely used by the oil and gas explorers and earth scientists because of the high level detail of sub-surface which can't cannot be provided by any other means. Seismic interpretation provides a great insight for the geoscientists to the structural and sedimentary evolution of an area. Well data incorporation into the process gives information about the sediment age, depositional environment, and local physical properties such as porosity, permeability and fluid type and saturation. Interpretation was done using Kingdom Suite 8.8. The Variance variance attribute was incorporated to aid in the fault interpretation. To map and characterize volcanic intrusions and other geological facies, seismic facies analysis was performed, based on Vail and Mitchum (1977). Initially used for the sedimentary rocks, seismic facies is now also applied to volcanic rocks (Planke et al., 2005).

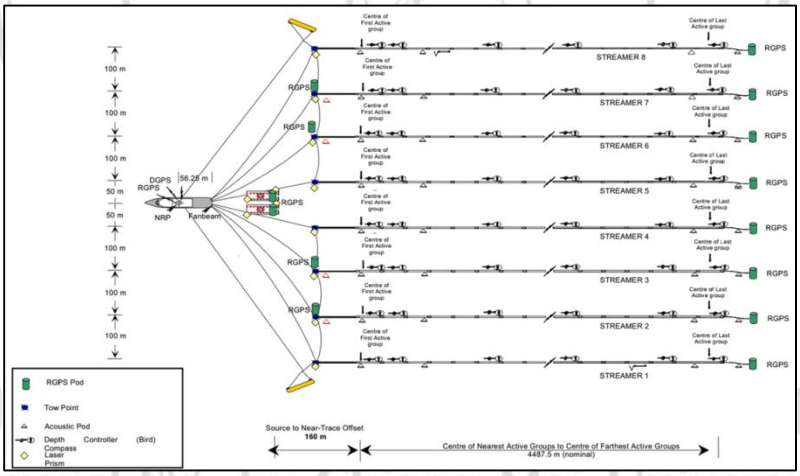

Figure 2.2 Diagram showing the Dual source and eight streamer combination diagram, figure used from processing report.

2.4 Attribute Analysis

Coherency data analysis is a comparatively a new development in seismic data interpretation. It has an advantage over conventional 2D and 3D seismic data as it is capable of highlighting very small scale features less than one km. Coherency data cube was incorporated into this study to validate and aid in the structural.

2.5 Quantification

The morphological characteristics of intrusive and extrusive features were quantified, and treated as mounds following Magee et al. (2013).

However, unlike Magee et al. (2013) the dip of these mounds were measured from eight sides and each side was considered as a separate triangle. The downlap point of mounds was considered as an outer limit of the volcano. Measurement of the dip from eight sides allowed the three dimensional geometry to be constrained.

2.6 Rose Diagram

To determine the dominant fault orientation length weighted rose diagrams were made and to avoid any misleading interpretation fault length was subdivided by applying 2×2 km grids (equation 2.1). Fault measurement and orientation data collection were conducted for each fault segment within selected areas

Length weighted; $$\boldsymbol{wl} = \frac{L}{l} \tag{2.1}$$

Total number of fault segments;

$$\boldsymbol{sf} = \sum_{i=1}^{n} wl\text{i} \tag{2.2}$$

where:

wl = *weighted length*
L = *length of each fault within the area*
l = *constant length of segment (2 km)*

2.7 Constraining of the Seismic Velocities of the Volcanogenic Mounds

To convert the summit height measurements from TWT to meters or kilometers Time-Depth curve from Arawa-1 well was used and it was extended with the same trend to the deeper section assuming that the volcanogenic mounds have approximately same velocities at the interface. This time-depth curve uses the average velocity of approximately 2100m/s.

2.8 Internal Architecture of the Volcanic Rocks

The internal Architecture of volcanic rock is a complex feature and there have been attempts in the past to define internal architecture of volcanic rocks. Ran et al., 2014 proposed the following division of volcanic rocks for the internal architecture from larger to smaller in the following order: Volcanic formation, volcanic edifice, volcanic massif, volcanic lithofacies and volcanic lithology (in terms of petrogenesis). Volcanic edifices are divided into three categories: centered type, fissured type, and combined type. They can be subdivided into various subtypes based on their various shapes and architectures. Volcanic rocks internal architecture is a multi-level feature as mentioned above starting from largest to smallest in the following order; volcanic formation, Volcanic edifice, volcanic massif, volcanic lithofacies and volcanic lithology.

2.8.1 Volcanic formation

The term volcanic formation according to Yuan et al., 1985 is a set of volcanic rock associations formed on the crustal surface of a given tectonic unit at a given evolving stage. Following Yuan and his colleagues in 1985 Sun et al regarded volcanic formation a regular and natural association of rocks closely associated in origin with close paragenetic relationships in a given tectonic environment and at a given geological evolution stage (Fig. 2.3).

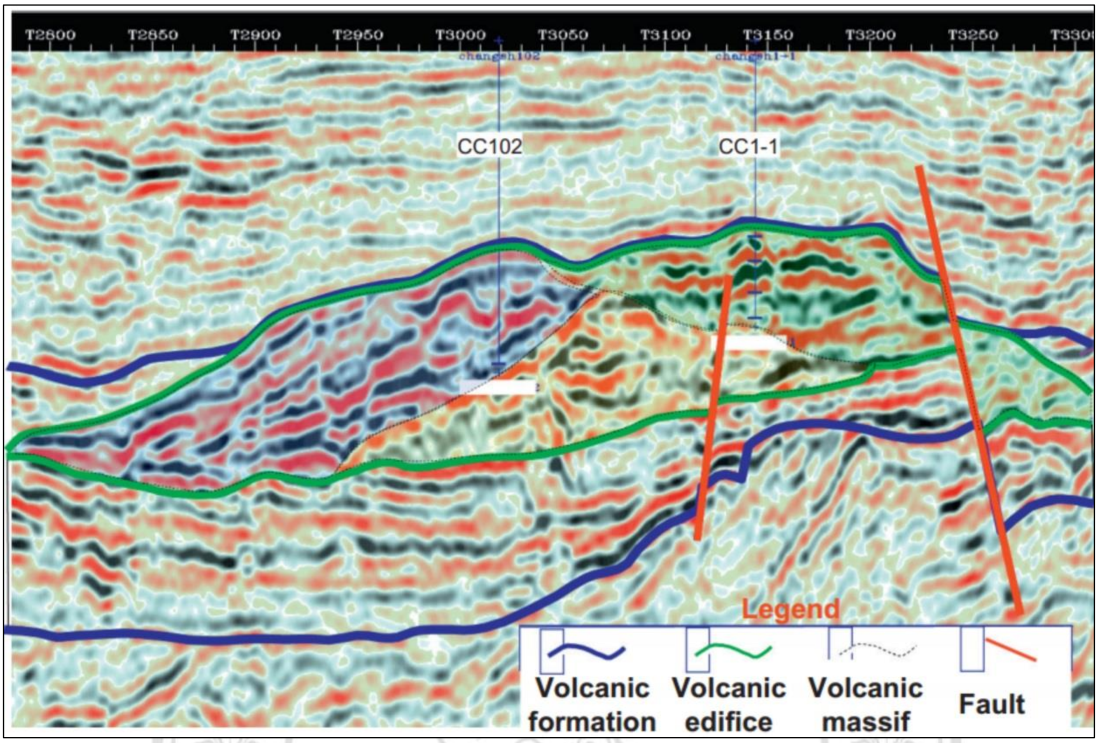

Figure 2.3 shows the volcanic formation, edifice, massif along with faults in Yingcheng Formation in the Songliao basin(Ran et al., 2014).

2.8.2 Volcanic Edifice

Volcanic edifice has been defined in various ways from (a) aggregate of the products derived directly from volcanic activity near the magmatic conduits; (b) residues of all volcanic and sub-volcanic rocks that fill the volcanic conduits is or associated with the same eruption period, and the residues of the rocks near the volcanic conduits; (c) an assemblage composed of various products derived from the volcanic activities within a given time unit (d) various extrusive-intrusive products near volcanic conduits formed in the same eruption period, as well as the overall shape of the products in a specific spatial and architectural relationship that reflects the eruption mechanism; and (e) the combination of various volcanic products, which, formed in a given geological time from the same eruption source, accumulated around the eruption point with a given shape and paragenetic association relationship by Qiu et al., 1996; Li et al., 1981; Hou et al., 2009;

wang et al., 2008, Translation of Anguita Volcanic geology of Canary Islands in Spain by Wu et al., 2009; and Wang et al., 1982 respectively.

Ran et al., 2014 defined volcanic edifice in the following ways; (a) eruption from the same magma source of same magma chamber (b) mutually associated petrogenesis, with magma migrating in an identical main conduit; eruption and effusion being the main volcanic process, with some shallow intrusion; (c) the rock body being continuous in time sequence, formed within a specific time interval; and (d) spatially related paragenesis, comprising rocks in the volcanic craters, conduits, eruption surfaces, and other associated volcanic deposits in the same assemblage. The volcanic crater acts as the gateway for magma eruption and volcanic conduit acts as the pathway for the movement of the magma to the surface. The major components of the volcanic edifice's rocks are the eruptive material derived from the accumulation of lava and volcaniclastic rocks.

2.8.3 Volcanic Formation

A volcanic formation is a very large-scaled architectural unit. Shape of Volcanic formation based on eruption style:

2.8.3.1 Single Central Eruption

A volcanic formation derived from a single centrally eruptive volcanic edifice typically manifests as an uplifted mound, dome, or lens typically, being circular or elliptical in plan view and as a bead string along the fault zone.

2.8.3.2 Multiple combined central Eruption

A volcanic formation formed by multiply combined central volcanic edifices commonly manifests as an irregular mound with increased area, forming strips, ad bands or irregular elliptical patterns in plan view.

2.8.3.3 Eruption of Acidic Magma

A volcanic formation formed by eruption of acidic magma is mainly shaped as a steep-sloped mound and as small circular or elliptic bodies in plan view.

2.8.3.4 Eruption of basic magma

A volcanic formation formed by eruption of basic magma is usually shaped as a flat shield and as a large circular or elliptical body in plan view.

2.8.3.5 Fissure Eruption

Most of the volcanic formations produced by fissured eruption are irregularly laminar. The formations formed by effusion of acidic magma are thick, usually in the shape of a steep wedge, showing a strip like geometry with a small areal extent in plan view, whereas those formed by effusion of basic magma are mainly flat laminar, in the shapes bands or strips, with a large areal extent in plan view.

2.8.4 Size Characterization of volcanic formation

The size of a volcanic formation is associated with the volcanic eruption energy and duration, with great variation in thickness and area.

2.8.5 Distribution of volcanic formation

Vertically, the distribution of a volcanic formation is controlled by basin tectonic evolution, which is developed primarily during the faulting and depression episodes of the basin.

2.8.6 Volcanic Edifice

A volcanic edifice is a basic architectural subunit of volcanic formation, and it determines the distribution, type, and size of volcanic gas reservoirs.

2.8.7 Identification of Volcanic Edifice

The identification indicators for volcanic edifices are craters, conduits, and periclines (Ran et al., 2014). Out of the three mentioned before volcanic crater and conduit are the most important makers for the identification of a volcanic edifice.

2.8.7.1 Volcanic Craters

It is a circular depression formed around the bocca with the accumulation of volcanic ejecta(Ran et al., 2014).

2.8.7.2 Volcanic conduits

It is located below the crater and it acts as the pathway for the magma. Since it is too steep so seismic imaging techniques can’t image it so that is why it is not possible to see a volcanic conduit in the seismic data.

2.8.8 Seismic signature of a volcanic crater

The seismic reflection of a centered crater is an arclike depression with a strong amplitude, high frequency and a continuous pattern (Ran et al., 2014).

2.8.9 Classification of Volcanic edifice

Volcanic edifices are divided into three categories:

a) Centered type
b) Fissured type
c) Combined type

2.8.9.1 Centered type

A centered volcanic edifice is formed by the accumulation of magma erupted from one or several columnar conduits around the crater. Centered volcanic edifice can be further sub-divided into:

(a) Conic volcanic edifice
(b) Shield volcanic edifice
(c) Domed volcanic edifice

2.8.9.1.1 Conic volcanic edifice

A conic volcanic edifice has conic external morphology, composed mainly of volcanic clastic rocks derived from high-energy volcanic eruptions. This type of volcanic edifice is circular in plan view with good symmetry, a high primary dip angle, and a great thickness in the cone margin, but with a small diameter. It can be subdivided into following two types:

(a) Monoconic volcanic edifice

(b) Multiconic volcanic edifice

2.8.9.1.1 Monoconic volcanic edifice

It has a single crater with one conduit in a dotted, symmetrical distribution, with its strata inclined inward (Fig. 2.5).

2.8.9.1.2 Multiconic volcanic edifice

It has multiple craters and volcanic conduits which are distributed in a bead-string pattern along a major fault with a linear symmetry and with many depressions developed between cones (Fig. 2.4)

2.8.9.1.2 Shield volcanic edifice

A shield volcanic edifice is formed by low-energy multiple effusions (occasionally weak explosion), characterized by the slow and gentle accumulation of basic magma in the form of a shield. The marginal rock layers of a shield volcanic edifice dip gently with a small thickness and large distribution diameter (Fig. 2.6)

2.8.9.1.3 Domes Volcanic Edifice

It is formed by slow extrusion of high-viscosity, acidic, neutral-acidic, or basic magma. It has steeply dipping margins, flat at the centre and bell-, mound-, or tabular-shaped rock bodies developed on its top(Fig. 2.7)

2.8.7.2 Fissured Volcanic Edifice

A fissured volcanic edifice is usually distributed in a strip along a fault or fissure. Its crater and volcanic conduit are not clearly defined. Its lithology is simple, consisting mainly of basic basalt and neutral andesite with some dacite or rhyolite. Horizontally, a fissured volcanic edifice is almost equiaxial with wide and broad top and gentle flanks, and the rock layers dip outward with a gentle curvature (Fig. 2.8)

2.8.7.3 Combined Volcanic Edifice

A combined volcanic edifice can be formed under three circumstances:

(a) the volcano remains unchanged but has migrating major volcanic conduits and craters, and the accumulated volcanic massifs shift with these conduits and craters and overlap on top of one other or extend in a given direction

(b) subsidiary volcanic massifs such as parasitic cone and volcanic domes occur above the parasitic or lateral volcanic conduits

(c) many large-scale lava domes occur within a caldera as a result of late volcanic activity

A schematic cross-section through combined volcanic edifice is given in Fig. 2.9 and a general cross-section through the volcanic edifice is given in 2.10.

Figure 2.4 Multiconic volcanic edifice(Ran et al., 2014)

Figure 2.5 Monoconic volcanic edifice(Ran et al., 2014)

Figure 2.6 Shield volcanic edifice (Ran et al., 2014)

Figure 2.7 Domed volcanic edifice (Ran et al., 2014)

Figure 2.8 Fissured volcanic edifice(Ran et al., 2014

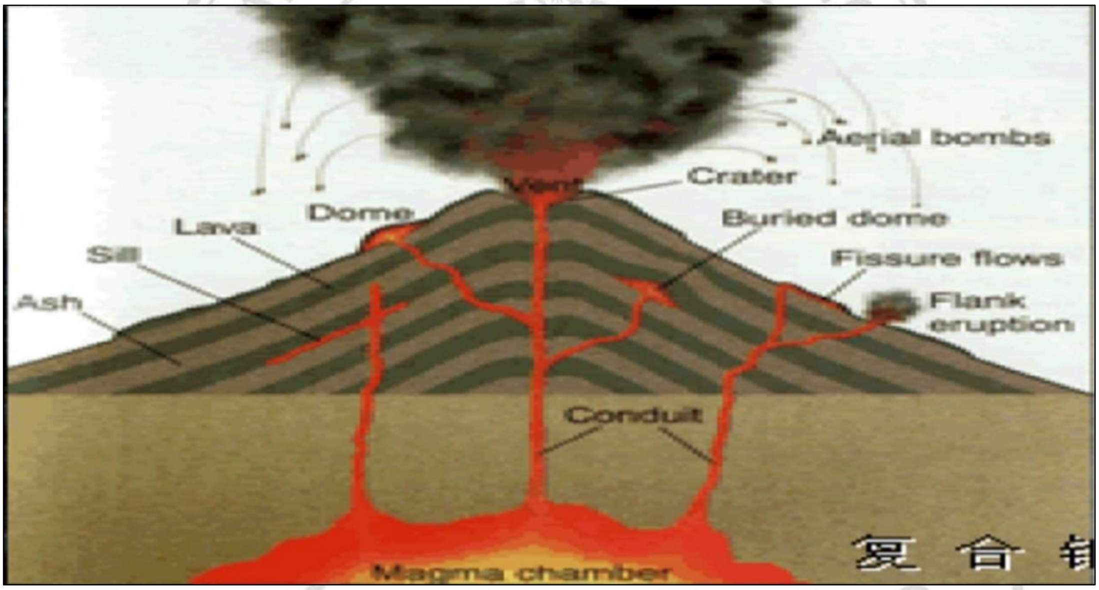

Figure 2.9 Schematic Illustration of a combined volcanic edifice(Ran et al., 2014)

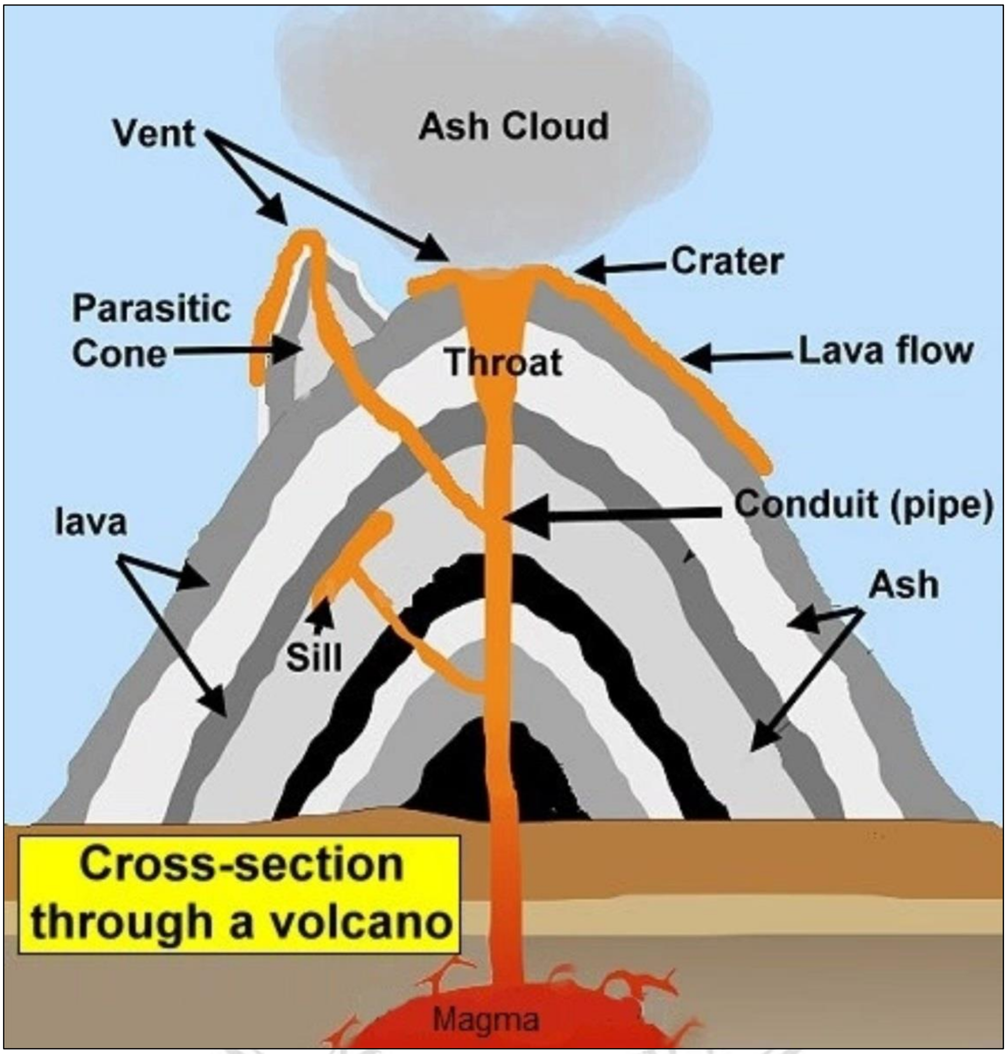

Figure 2.10 A cross-section through volcano. Figure retrieved from https://bio4esobil2011.wordpress.com/2011/11/28/parts-of-a-volcano-and-materials/