Abstract

The Foulden Maar is part of the latest Oligocene - early Miocene Waipiata Volcanic Field and is located about 10 km to the southeast of Middlemarch, Central Otago, New Zealand. Its sediment-filled crater is approximately 1 km in diameter and includes laminites, debris flows and volcaniclastics. Three geophysical surveys of the Foulden Maar have been undertaken and these include seismic reflection, gravity and a magnetic investigation. Two boreholes have also been drilled at the site (FH1 and FH2) and the location of these was selected with the aid of the geophysical surveys.

The seismic reflection study entailed the collection of four profiles across the diameter of the Foulden Maar. Explosive sources (150 g Pentex boosters) were used as the source, and 48×40 Hz geophones at a 5 m spacing were used to record the reflections. Signal within the data was optimised using a commercial seismic processing package by removing noisy traces, attenuating the airwave, applying refraction static corrections, deconvolving the waveforms, and applying automatic gain. Six facies were characterised in the stacked reflections based on dip direction, velocity, and depth (time). The sedimentary facies were the most well defined, with debris flows at the edges (marginal facies) and laminites filling the remaining accommodation space in the crater. The diatreme facies had a low reflectivity because it probably has a density which is similar to the Otago Schist (∼2.67 g/cm³). Reflections from a deep antiformal structure (∼2 km) were identified and are likely to be from an old magma chamber or sill. A normal fault structure was also identified toward the west of the Maar, and this has an offset between 10 and 30 m.

The FH2 borehole was drilled at 5516263N, 2292728E (NZGD1949) and 183.88 m of core was recovered with a diamond drill rig between the 23rd of June and the 3rd of July, 2009. FH2 contained four significant facies related to maar sedimentation. These were laminated diatomite, non-laminated diatomite, sandstone debris and a schist breccia. The facies were grouped into four stages of sedimentation (A-D) based on their succession. Whole core densities and P-wave velocities were measured for FH2 with a Multi Sensor Core Logger. These data sets were analysed in a geophysical interpretation package to generate a synthetic seismogram for the well location. The synthetic seismogram allowed for a detailed re-interpretation of seismic profiles based on the four stages of sedimentation.

A gravity survey over the Foulden Maar involved the observation of 356 stations over eight profiles. Observations were made at 20 m intervals and accurate height information was gathered by differential GPS. Raw gravity data were corrected for drift and reduced to the Bouguer Anomaly (BA). The residual gravity field was exposed by occupation of 22 stations around Foulden Hills. This was extracted from the BA to give an oblate residual anomaly of -6.2 mGal centred toward the middle of the mapped diatomite deposit. The crater sediments were modelled in 2D for each of the eight profiles. Two bodies were used in the modelling; a diatomaceous body (1.27 g/cm³); and a sandstone body (2.22 g/cm³). A 3D model was created using an original method. The basal 3D surface of the modelled diatomaceous body has a maximum depth of 118 m while the sandstone body has a maximum depth of 194 m.

The total field strength of 2011 magnetic stations were measured with a proton magnetometer during November, 2008. Data was processed to extract the effects of diurnal variation, account for magnetic infrastructure, and transform data to the pole, where the inducing
field is vertical. Two high intensity, short wavelength trends were identified in the southwest, while longer wavelengths were also identified there (242 nT) and toward the centre of the mapped diatomite deposit (84 nT). Computer models were developed with basalt bodies, assigned a magnetic susceptibility of 0.0043 c.g.s. The models reveal that short wavelength trends are related to outcrops of basalt at the surface which penetrate to a depth of 600 m. The long wavelength trend in the southwest may be caused by an eroded basalt body while a feeder vent is probably the cause of the 84 nT intensity toward the centre of the Maar.

Overall, the Foulden Maar conforms with the general maar model which was postulated by Lorenz (2003). The crater sediments have a bowl like shape, whereas the diatreme facies probably have a funnel shape. The Maar walls are steep sided within the diatreme breccia because the Foulden Maar is situated in a hard rock environment, and a diatreme depth of 1500 m is proposed, giving a ratio of about 4:7, for crater width to diatreme depth. There is a possibility that two maar craters exist at Foulden Hills, and evidence for this is found in the gravity and magnetic data. However, further investigations are needed to prove the theory. Therefore, the Foulden Maar is likely to have a similar structure to the Baruth and Messel maars in Germany, which have been defined by Schulz et al. (2005).