CHAPTER SEVEN: GRAVITY MODELLING OF THE TAMWORTH BELT AND GUNNADEH BASIN

7.1 Introduction

The interpretation of gravity anomalies involves the construction of density models, which are consistent with the geology of the modelled area. Synthetic gravity anomalies are calculated from these models and matched with the observed gravity anomalies until a fit is obtained. The regional gravity anomalies over the Tamworth Belt and within the Gunnedah Basin provide an opportunity to construct structural models of the upper crust in this area. This chapter presents modelling of the five east-west gravity profiles between Nundle in the south and Bingara in the north (Figure 7.1).

7.2 Previous Gravity models

Bramall and Qureshi (1984) modelled a gravity profile across the Tamworth Belt and Gunnedah Basin and suggested that the Namoi High over the Tamworth Belt is of shallow origin and that the folded Palaeozoic sedimentary rocks of the Tamworth Belt mostly being products of mafic volcanism (Chappell, 1961), are denser than the surrounding rocks, hence generate the gravity high. The Peel Fault was modelled as a steep east dipping fault. To date this is the only gravity model developed for the Namoi High over the Tamworth Belt.

In contrast, several gravity models have been constructed for the gravity high within the Gunnedah Basin, which is known as the Meandarra Gravity Ridge (Longsdale, 1965). To the south of the Gunnedah Basin, Qureshi (1984), modelled the southern part of the Meandarra Gravity Ridge along a gravity profile from Bathurst to Mona Vale in the Sydney Basin, and suggested that the gravity ridge is produced by a north-south trending mafic body triangular in cross section (narrow at the bottom and broad at the top) of 12 km thickness beneath the basin but within the upper crust. A density of $2.9 tm^{-3}$ was assigned to the constructed mafic body, a density of 2.45 $t\ m^{-3}$ was assumed for the Sydney Basin rocks and a density of 2.7 $t\ m^{-3}$ was adopted for the Lachlan Fold Belt rocks. The base of the best fit modelled mafic body has an eastward dip of 53° on the western side, and a westward dip of 21°-33° on the eastern side. Later Qureshi (1989) updated his model and extended the mafic body to a depth of 13.5 km beneath the basin. A 12 km wide zone with a density contrast of $0.1 tm^{-3}$ against the lower crust was introduced within the lower crust to link the mafic body to a mantle source.

The Bathurst-Mona Vale gravity profile of Qureshi (1984) was re-modelled by Leaman (1990, 1994), who suggested the Meandarra Gravity Ridge is simply due to the absence of granite in the basement to the east of Bathurst Batholith. This model involved the density contrast produced by large low-density granite batholiths in the east and west compared to slightly higher density metamorphic country rocks in the middle.

Krassay et al. (in press) have extensively modelled the Meandarra Gravity Ridge from 26° to 32° latitude and suggested that the anomaly is produced by an underlying mafic source in the upper crust with the geometry proposed initially by Qureshi (1984). The maximum thickness of the modelled mafic body ranges from 9 km in the north to about 4.5 km in the south. The width ranges from about 65 km to over 200 km with the narrower segments in the central part of the north-south ridge.

Krassay et al. (in press), on the basis of their model, suggested that Leaman's model does not explain the entire Meandarra Gravity Ridge as the granite of the region to the west of Sydney (Bathurst Batholith) do not occur along the rest of the ridge. Krassay et al. (in press) concluded "the model requires two granite batholiths separated by a thin strip of denser rock, of a constant 50 km width, over the total length of the anomaly of more than 1200 km. The model may be possible for a single profile but is not feasible for the whole of the Meandarra Gravity Ridge".

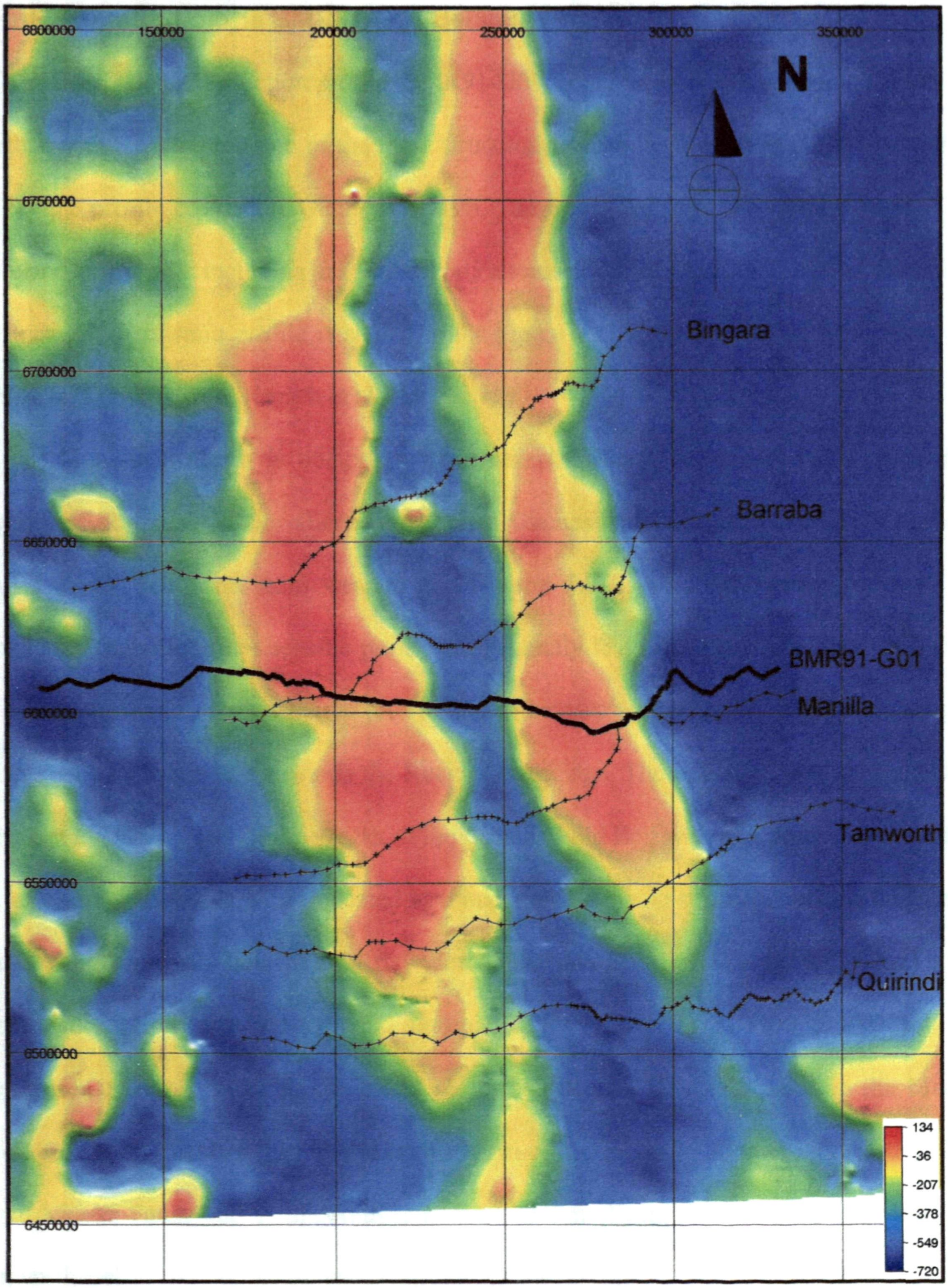

Figure 7.1 The location of the gravity profiles surveyed in this study, shown on the regional Bouguer gravity map. From south to north, the gravity profiles are named Quirindi, Tamworth, Manilla, Barraba and Bingara. The profiles are approximately normal to the north-north-west trending Meandarra Gravity Ridge to the west and Namoi Gravity High to the east. Also shown is the position of the deep reflection seismic line BMR91-G01.

7.3 Interpretation of the BMR91-G01 Seismic Profile

The deep seismic reflection profile, BMR91-G01, acquired by GA is shown in Figure 7.2, together with an interpretation of the main structural features by Korsch et al (1993a, 1993b, 1997). The profile covers the Gunnedah Basin, Tamworth Belt, and the western edge of the Tablelands Complex including the Bundarra Plutonic Suite of the New England Batholith. The location of seismic profile is shown in the Figure 7.1. The following interpretation was summarised mainly from Korsch et al. (1993a, 1997).

The Gunnedah Basin is composed of three sub-basins separated by two ridges (the Gilgandra Sub-basin, Rocky Glen Ridge, West Gunnedah Sub-basin, Boggabri Ridge and Maules Creek Sub-basin from west to east (Figure 2.8)). The sedimentary rocks of the Gunnedah Basin along the seismic profile are generally less than 1000 m in total thickness. On the western end of the seismic profile, a sedimentary succession of 400m was imaged, which shallows to the east towards the Rocky Glen Ridge. The basement was interpreted by Korsch et al (1993a, 1997) to be rocks of the Lachlan Fold Belt with a thickness of at least 10 km, extending eastwards until truncated by a major west-dipping structure beneath the eastern part of the Tamworth Belt. Within the West Gunnedah Sub-Basin, a thick (3+ km) well-layered succession was imaged, and interpreted by Korsch et al (1993a, 1997) to be interlayered Early Permian volcanic and sedimentary rocks. The succession in the Maules Creek Sub-basin thickens from the eastern margin of the Boggabri Ridge to the eastern limit of the Mooki Fault, and is underthrust at least 15 km (Korsch et al., 1993a) beneath the Tamworth Belt.

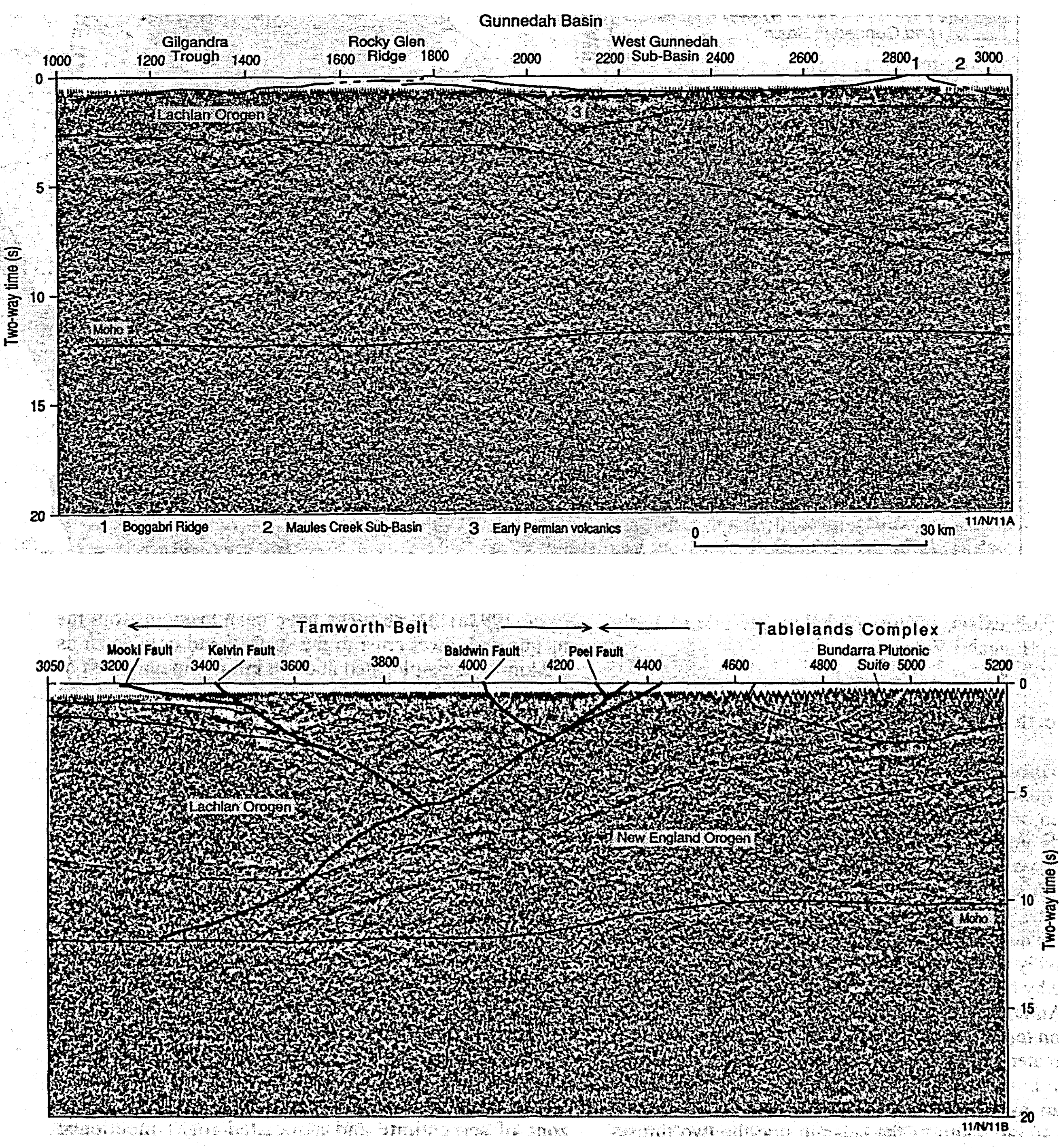

Figure 7.2 Interpretation of un-migrated deep seismic profile BMR91.G01 across the Gunnedah Basin and the Tamworth Belt and the Tablelands Complex. Western half on the top and eastern half on the bottom. An average crustal velocity of 6000 ms^{-1} is assumed. Horizontal numbers represent the shot points from 1000 to 5200 and vertical numbers represent two way travel time. (After Korsch et al, 1997)

The Mooki Fault forming the boundary between the Gunnedah Basin and Tamworth Belt was imaged to have a shallow eastward dip of less than 30° (Glen and Brown, 1993; Glen et al, 1993; Korsch et al, 1993a, b, 1997). To the east of the Mooki Fault, the Tamworth Belt was interpreted as a group of thin-skinned, west-directed thrust sheets (Korsch et al. 1993a, 1997; Glen et al., 1993; Glen and Brown, 1993). The Tamworth Belt was inferred to be mainly composed of volcanic-rich lithologies on the basis of the excellent correlation between a prominent reflector and volcanic units such as the mafic volcanics mapped in the Mostyn Vale Formation (Glen and Brown, 1993; Glen et al., 1993). The Kelvin Fault that lies just east of the Mooki Fault thrusts Late Devonian rocks over Late Carboniferous rocks and has a greater displacement than the Mooki Fault (Korsch et al, 1997).

The Peel Fault separating the Tamworth Belt from the Tablelands Complex was not imaged seismically due to its steep dip. A moderately west-dipping reflector at a depth of about 1 km, however, was imaged just beneath the surface position of the Peel Fault, placing significant constraints on the geometry of the Peel Fault at depth (Korsch et al, 1993a, 1997). Korsch et al (1993a, 1997) suggested that the Peel Fault is a high level splay fault off the west-dipping fault, and the Peel Fault and the west-dipping fault are associated with a melange zone of serpentinite and related rocks.

To the east of the Peel Fault, a series of moderately west-dipping reflections were imaged within the Tablelands Complex. Korsch et al (1993a, 1997) suggested that the west-dipping reflections either represent thrust faults developed during the subduction accretion event in the Late Devonian to Carboniferous or latest Carboniferous-Early Permian extensional faults forming part of a more widespread extensional event that led to the initiation of the Sydney-Gunnedah Basin. Further east, the Bundarra Plutonic Suite was imaged as a pancake shaped body, which extends to a depth of 6-9 km, and extends about 12 km further west of its outcrop position beneath a thin roof of Tablelands Complex metasedimentary rocks (Korsch et al, 1993a, 1997).

7.4 Density Data

Density data for the rock samples collected within the area of the gravity surveys were determined to provide some constraints on the modelling of the gravity data. To this end, a total of 148 rock samples were collected in the field within the study area. The density measurements were conducted at the geophysics laboratory at Macquarie University in Sydney using a Mettler Toledo AG204 balance. Sample locations were determined using a Garmin12XL hand-held GPS. In addition, eight drill cores within the study area were sampled for density measurements. Six of these are located within the Tamworth Belt, one within the Gunnedah Basin, and one within the Bundarra plutonic suite. The summary of the results from the density measurements of this study is shown in Table 7.1 and detailed data is provided in Appendix II.

Table 7.1 shows that the Tamworth belt rocks have a relatively high density compared to the Gunnedah Basin and Tablelands Complex rocks. Within the Tamworth Belt, the measured density of hand samples shows that the Devonian dolerite immediately west of the Peel Fault has the highest density of 2.81-3.26 tm^{-3}, and the Devonian volcanic breccia and mudstone has a relatively high density of 2.68-2.83 tm^{-3} and 2.66-2.76 tm^{-3}, respectively. The density measured on the surface samples is generally lower than those from drill-hole samples due to some weathering on the rock outcrops. Seven dill-cores within the Tamworth Belt were sampled to get fresh specimens for density measurement, including Wallabadah No.1, Wallabadah No.2 and Nundle NRC01, 02, 04, 06. Both Wallabadah No.1 and No.2 were drilled into the Carboniferous Namoi Formation at approximately 10 km north of Wallabadah at longitude 150.85°, latitude -31.42° and 150.91°, -31.43°. Wallabadah No.1 drilled to a depth of 1100 feet and Wallabadah No.2 to 723 feet. Both drill cores are composed mainly of shale which has a relatively low measured density of 2.61 and 2.66tm^{-3}, reflecting a Carboniferous silicic volcanic source (Mcphie et al, 1987). NRC01-06 of Nundle are all close to each other and drilled into the Devonian Tamworth group at approximate longitude 151.13°, latitude -31.41° all with a depth of about 150 m. Both siltstone and mudstone of the NRC cores have a relatively high measured density of 2.70-2.80 tm^{-3} and 2.71-2.79 tm^{-3}. The dolerite from the NRC drill core has a density of 2.94tm^{-3}.

Within the Tablelands Complex, the chert/jasper of the Woolomin Association has a high density with a range of 2.65-2.78 tm^{-3} compared to those of the Sandon Association (2.61-2.68 tm^{-3}). The serpentinite along the Peel Fault has an average density of 2.52 tm^{-3}. The Tertiary basalt east of Nundle has a high density of 2.77-2.94 tm^{-3}. The Permian Bundarra Plutonic suite has a density of 2.64 tm^{-3} from hand samples and 2.63 tm^{-3} from the Den Mountain drill core samples. The Den Mountain drill-core drilled at the southwest edge of the Bundarra Plutonic Suite with a depth of 733 feet. The Moonbi Adamellite has a density of 2.66tm^{-3} as determined from hand samples, which is consistent with the value determined by Bailey (2002). The Walcha Road Adamellite has a density of 2.63 tm^{-3} as determined from hand samples.

Within the Gunnedah Basin, sandstone hand samples have a relative low density of 2.01-2.52 tm^{-3} with an average of 2.38 tm^{-3}. The sandstone from drill core (Quirindi No.1) has a measured average density of 2.41 tm^{-3}, the siltstone of 2.54 tm^{-3} and the shale of 2.48 tm^{-3}. All density measurement of siltstone, sandstone and shale samples from Quirindi No.1 have an average density of 2.46 tm^{-3}, which is consistent with the value of 2.45 tm^{-3} used for the Sydney and Gunnedah Basin by Qureshi (1984, 1989) and Krassay (in press). A density of 2.45 tm^{-3} for Gunnedah basin rocks is realistic, incorporating surface and drill hole density measurements.

Table 7.1 Summary of density data from the Tamworth Belt, Gunnedah Basin and Tablelands Complex.

Tamworth Belt	Rock description	Density (tm^{-3})	Mean	Std	Number of readings	Comments
	Devonian Mudstone	2.66-2.76	2.70	0.03	9	Hand samples
	Carboniferous Mudstone	2.63-2.70	2.67	0.05	2	Hand samples
	Devonian Volcanic Breccia	2.68-2.83	2.75	0.05	6	Hand samples
	Devonian Dolerite	2.81-3.26	2.99	0.17	5	Hand samples
	Devonian Sandstone/siltstone	2.51-2.64	2.57	0.05	7	Hand samples
	Carboniferous Sandstone	2.43-2.59	2.53	0.06	5	Hand samples
	Devonian Siltstone	2.57-2.68	2.63	0.05	4	Hand samples
	Devonian Slate	2.62-2.71	2.67	0.06	2	Hand samples
	Siltstone	2.70-2.80	2.73	0.03	9	NRC drill core
	Mudstone	2.71-2.79	2.75	0.06	2	NRC drill core
	Dolerite	2.81-3.1	2.94	0.06	29	NRC drill core
	Shale	2.26-2.67	2.61	0.07	32	Wallabadah1 drill core
	Shale/mudstone	2.59-2.72	2.66	0.02	36	Wallabadah2 drill core
Tablelands Complex	**Rock description**	**Density (tm^{-3})**	**Mean**	**Std**	**Number of readings**	**Comments**
	Serpentinite	2.36-2.64	2.52	0.12	9	Hand samples
	Tertiary volcanic rocks	2.77-2.94	2.82	0.07	5	Hand samples
	Woolomin Chert/Jasper	2.65-2.78	2.71	0.06	5	Hand samples
	Sandon Chert	2.61-2.68	2.65	0.03	4	Hand samples
	Woolomin sandstone/mudstone	2.60-2.70	2.64	0.04	4	Hand samples
	Sandon Sandstone/mudstone	2.46-2.62	2.52	0.09	3	Hand samples
	Bundarra Plutonic Suite	2. 60-2.68	2.64	0.03	4	Hand samples
	Bundarra Plutonic Suite	2.59-2.77	2.63	0.03	12	Den Mountain hole
	Moonbi Adamellite	2.65-2.67	2.66	0.01	2	Hand samples
	Walcha Road Adamellite	2.60-2.66	2.63	0.04	2	Hand samples

Table 7.1, continued.

Gunnedah Basin	Rock description	Density (tm^{-3})	Mean	Std	Number of readings	Comments
	Sandstone	2.01-2.52	2.38	0.16	6	Hand samples
	Sandstone	2.13-2.57	2.41	0.13	17	Quirindi drill hole
	Siltstone	2.43-2.61	2.54	0.1	3	Quirindi drill hole
	Shale	2.18-2.66	2.48	0.14	29	Quirindi drill hole
	All Sandstone/siltstone/shale	2.13-2.66	2.46	0.16	49	Quirindi drill hole

7.5 Gravity Models

The north-south elongation of the Meandarra Gravity Ridge and the Namoi Gravity High makes them well suited for two dimensional gravity modelling. Model responses were calculated using an interactive potential field modelling package supplied by Encom Technology®. The program calculates and compares the theoretical gravity response of a constructed structural model with the profile of observed data. The degree of misfit is expressed by the calculated root-mean-square (rms) error, and the model can be interactively modified to reduce the error. A rms of three was aimed for and was achieved in all best-fit models. Models were constructed as an assembly of polygon prisms, forming a two dimension model. Density contrasts were referenced to the reduction density of 2.67 g/cm^3, which is equivalent to Bouguer reduction density used to correct the observed gravity readings. This program features an ability to calculate regional anomalies due to very deep and broad scale structures. The regional lines in the modelled data were calculated using a superposed line of data extracted from the regional gravity dataset, which extends 50 km beyond the end points of the observed gravity data. The modelling of the profiles proceeded in three phases. First, a preliminary model was constructed for Manilla profile that runs close to the BMR 91G-01 seismic reflection line, which provides a well-constrained upper crustal model. Next, a secondary model was developed to satisfy the near-surface features. Third, alternative models were developed to test the dip of the Peel Fault. All the profile models were calculated to provide an insight into the regional structure.

7.5.1 Manilla Profile

Profile Manilla being close to the previous geophysical surveys (Ramsay and Stanley, 1976; Korsch et al, 1997) was first modelled using the geometry obtained primarily from the interpretation of seismic data (Korsch et al, 1997). Following that, the Peel Fault was modelled as a deep eastwards dipping fault to test the alternative model proposed by Bramall and Qureshi (1984).

In order to construct the basic gravity model, the interpretation of the 5s TWT seismic data was converted to depth using a constant velocity of $6000ms^{-1}$. This may have introduced errors in the depth estimation in the upper parts of the models where velocities may be up to $1000ms^{-1}$ less (e.g. Direen et al., 2001). The depth converted interpretation was subsequently imported into the potential modeling package ModelVision Pro as a background image and major structural features were duplicated in the modelling window. The constructed model is shown in Figure 7.3a. The densities of established polygon bodies were based mainly on measurements of samples obtained in this study, incorporating the density values used in previous gravity modelling where no outcrop surface were observed (e.g. the Lachlan Fold Belt) and the published interpretation of the seismic data. The Lachlan Fold Belt is assumed to have a density of 2.7 tm^{-3} as proposed by Qureshi (1984, 1989) and Krassay et al. (in press). This density value is consistent with the upper crustal rocks below the Sydney Basin being dominantly quartz greywackes on the basis a study of xenoliths from Mogo Hill diatreme (Emerson and Wass, 1980). A slightly higher density of 2.72 tm^{-3} was assigned to the polygon body beneath the Lachlan Fold Belt, because it represents a more reflective lower crust (Korsch et al., 1993). The average density of the Gunnedah Basin rocks, on the basis of the density measurements in this study (Table 7.1), is assigned to be 2.45 tm^{-3}, which is the value of sedimentary succession in the Gunnedah Basin used by Krassay et al. (in press) and the value of Sydney Basin rocks proposed by Qureshi (1984, 1989). The Early Permian volcanic succession beneath the Gunnedah Basin rocks is assumed to be 2.95 t m^{-3} (Krassay, in press).

The Tamworth Belt representing folded Palaeozoic strata consists of a succession of mainly forearc and volcanic arc rocks. Measured density values of hand samples collected within the Tamworth Belt range from 2.43-3.26 tm^{-3}. The Devonian dolerite just west of the Peel Fault has a highest density of 2.81-3.26 tm^{-3}. The Devonian volcanic breccia and mudstone of have a relatively high density of 2.68-2.83 tm^{-3} and 2.66-2.76 tm^{-3}, respectively. Measurements of the samples from a drill-hole from Nundle NRC01-06 and Wallabadah No.1 and 2 in Tamworth Belt show that Devonian mudstone and siltstone of the Tamworth Group have a density 2.70-2.80 tm^{-3}, and the Carboniferous shale of the Namoi Formation has a relatively low density of 2.61 and 2.66 tm^{-3} for Wallabadah No.1 and No.2 respectively. The belt was inferred to be largely the products of mafic and intermediate volcanism (Chappell, 1961, White 1964; Cawood and Flood, 1989; Greentree and Flood, 1999), which is supported by Glen et al (1993), and Glen and Brown (1993), on the basis of the excellent correlation between the prominent seismic reflector and mafic volcanics mapped in the Mostyn Vale Formation. Therefore in consideration that the belt is composed of mainly the high density Devonian mafic volcanic materials, the Tamworth Belt rocks are assumed to be 2.77 tm^{-3} and indeed this value gave a good match between the observed data and calculated profile.

To the east, measured densities of the main rocks of the Tablelands Complex have a range of 2.6-2.78 tm^{-3} (excludes serpentinite). Finlayson and Collins (1993) suggested that rocks of granitic composition make up a large part of the crust of the Tablelands Complex on the basis of wide-angle reflection and refraction seismic data north-south through the New England Fold Belt. The average density of 2.67 tm^{-3} is adopted for the upper part of the Tablelands complex. The Bundarra Plutonic Suite is assumed to be 2.64 tm^{-3} based on the density measurements in this study (Table 7.1). A slightly higher density of 2.72 tm^{-3} was assigned to the lower part of the Tablelands Complex beneath the Bundarra Plutonic Suite due to the increase of the seismic velocity with depth (Finlayson and Collins (1993). The misfit between the observed and calculated gravity anomalies is obvious (Figure 7.3a), including an excess of mass in the Boggabri Ridge within the Gunnedah Basin, and a small mass deficiency beneath the Tamworth Belt.

In the following modelling stage, the geometry of constructed polygon components was slightly modified, incorporating surface geology and previous gravity models (e.g. Qureshi 1984; Krassay et al., in press) to fit the observed gravity profile. The final derived structural model for the Manilla Profile is shown in figure 7.3b. The model has three main components: the accretionary complex, the uplifted Tamworth Belt, and the Gunnedah Basin. The gravity anomaly curve lies above the constructed model. The observed values, denoted by crisscross symbols, are compared with the calculated solid line curve, and the correspondence between them is good. However, no efforts were made to develop the other geometry for the shape of the constructed polygon bodies because it is not realistic to create highly detailed bodies at depth when there is no direct control on shapes of the bodies and because of the ambiguity in potential filed modelling, no comparison between such detail could be successfully achieved. The modelled result of the anomaly within Gunnedah Basin is consistent with those produced by Qureshi (1984) and Krassay et al. (in press).

The Manilla Profile was alternatively modelled with the Bramall-Type east-dipping Peel Fault model (Bramall and Qureshi, 1984), i.e. the Peel fault is modelled as a deep steeply east-dipping fault, to show any differences from the model developed from the seismic data and to address the dip and depth of the Peel fault within the upper crustal scale. The east-dipping Peel Fault is supported by geological evidence (e.g. Benson 1913, 1915; Crook, 1963) and interpretation of the magnetic data obtained in this study (e.g. Figure 5.8) although the depth extent of the fault is not well constrained. Figure 7.3c shows the calculated anomaly with an east-dipping Peel Fault. The same densities as used in the previous models are used with this model. There is a big difference between the calculated anomaly and measured one, indicating an excess of mass in the Tamworth region. Constructed models with a steeply east-dipping Peel Fault within the upper crust could not produce an anomaly to match the observed gravity data.

The gravity data is modelled more successfully with an introduction of a low-density unit (granite?) beneath the Tamworth Belt (Figure 7.3d, e, f). A steeply east-dipping Peel Fault was arrived at by trial and error, and is very similar to the bodies in the model of Bramall and Qureshi (1984). Such bodies give an approximate match of the calculated and observed gravity data. The low-density body which was developed by trial and error, probably represents a granite pluton intruded into the folded Palaeozoic forearc deposits of the Tamworth Belt during the Late Carboniferous –Early Permian extensional event in the New England region (Flood and Shaw, 1977; Allan and Leitch, 1990) that produced the Bundarra Plutonic Suite or in the Late Permian as part of the Moonbi or Clarence River Suites. The modelled granite pluton is supported by a gravity low on the Bouguer gravity map (Figure 7.4). Figure 7.4 indicates a half-circle gravity low on the regional bouguer gravity map, which could correspond to a low density unit (granite) at depth. The low density unit and the east-dipping Peel Fault were not imaged on the seismic section of Korsch et al (1997). This possiblly resulted from either the poor quality of the seismic data near the Peel Fault or the steep deep of the Peel Fault. Because of the steep dip of the fault, it is unlikely that the Peel fault would be imaged seismically (Korsch et al., 1997). On the other hand, seismic and gravity surveys measure contrasts in different physical properties of materials beneath the surface of the earth. A seismic survey measures variations in elastic moduli and density, while gravity surveys measure only variations in density and thus it is possible that a density variation like a low density unit or east-dipping Peel Fault may not be imaged seismically. The west-dipping feature imaged on the seismic section was modelled on the gravity profile with a density contrast of 0.1 g/cm^3 in Figure 7.3a. However, the feature was not modelled in Figure 7.3d, instead this model showed a steep east-dipping Peel Fault. The west-dipping feature imaged seismically reflects a combination of variation in elastic moduli and density of the upper crust rock, which may have a same density on both sides of the feature.

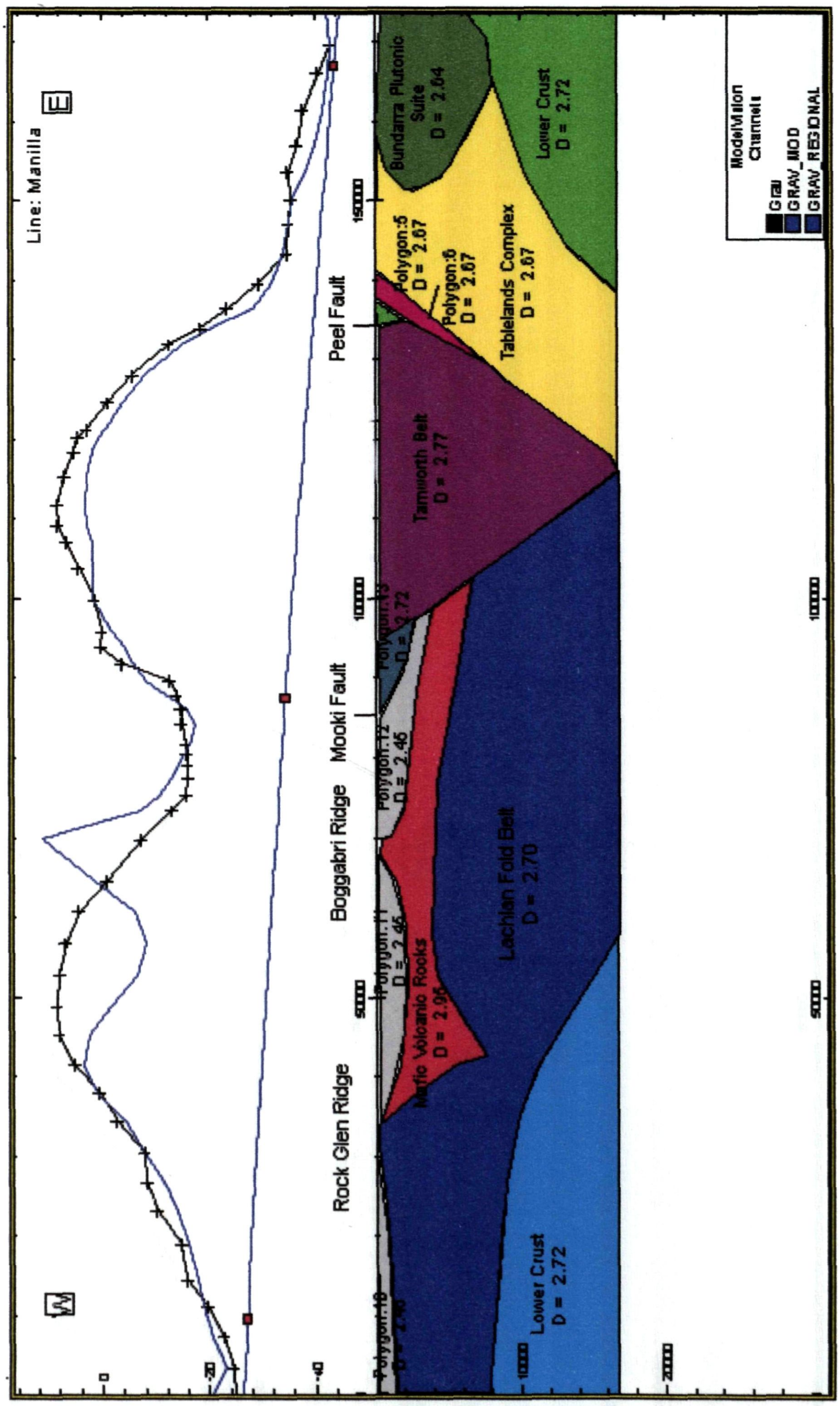

Figure 7.3a. 2D gravity model along the Manilla Profile (cross-section view). The reflection seismic model by Korsch et al. (1997) was used as background to constrain the subsurface geometry of the structural units along the Manilla profile. The modelled response indicates a misfit in the Boggabri Ridge within the Gunnedah Basin and a small mass deficiency beneath the Tamworth Belt. Polygons 10, 11, 12 represent the Gunnedah Basin, 13 the Tamworth Belt between the Mooki and Kelvin Faults, 5 and 6 the Woolomin Association. Symbols represent observed data and solid line is the calculated anomaly, Strait line with squares represents regional gravity trend, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

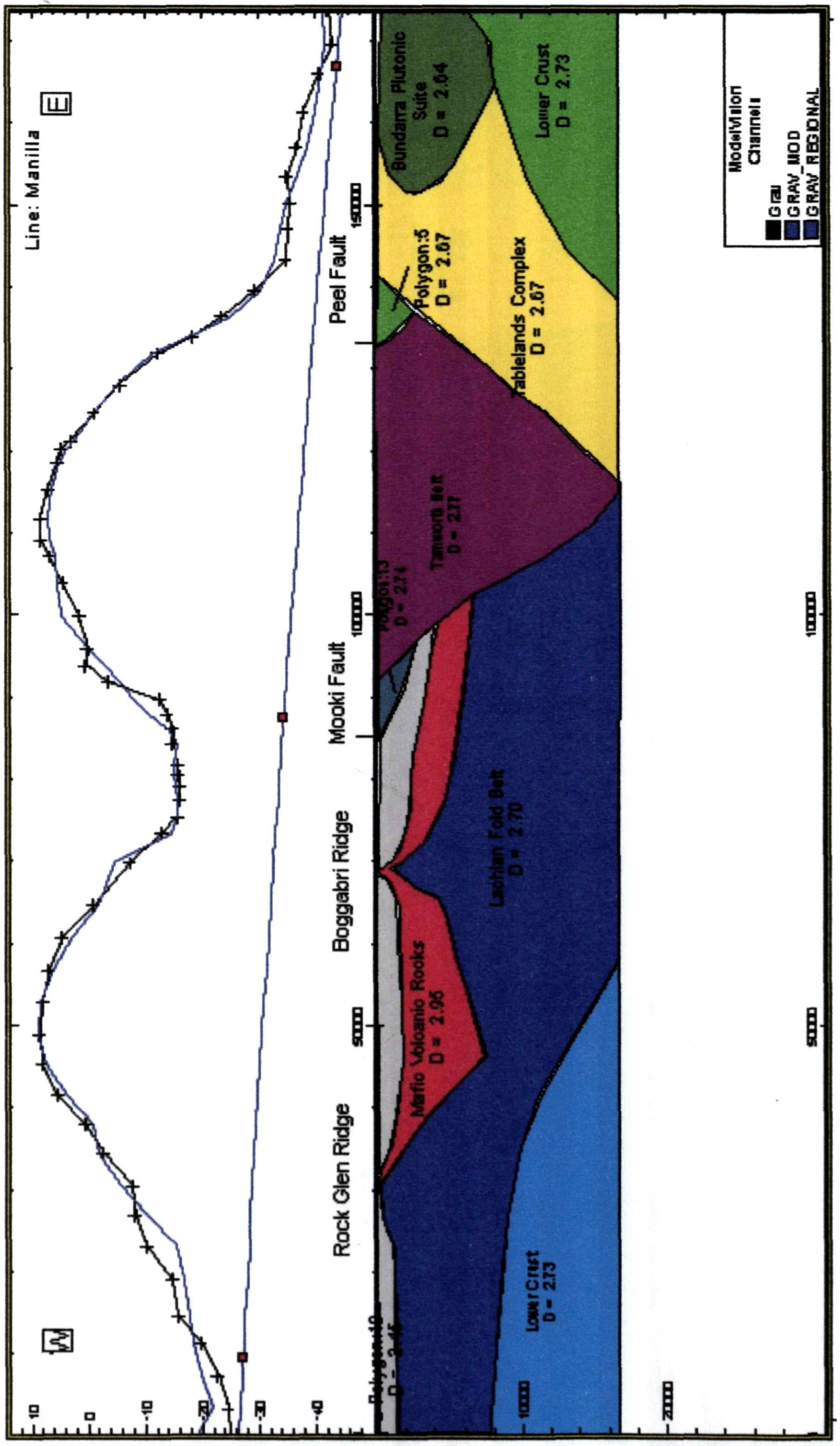

Figure 7.3b. 2D gravity model along the Manilla Profile (cross-section view). The reflection seismic model by Korsch et al. (1997) was slightly adjusted to constrain the subsurface geometry of the structural units along the Manilla profile. The Peel Fault was modelled as an east-dipping fault truncated by a west-dipping structure. Polygon 10 represents the Gunnedah Basin, 13 the Tamworth Belt between the Mooki and Kelvin Faults, 5 the Woolomin Association. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

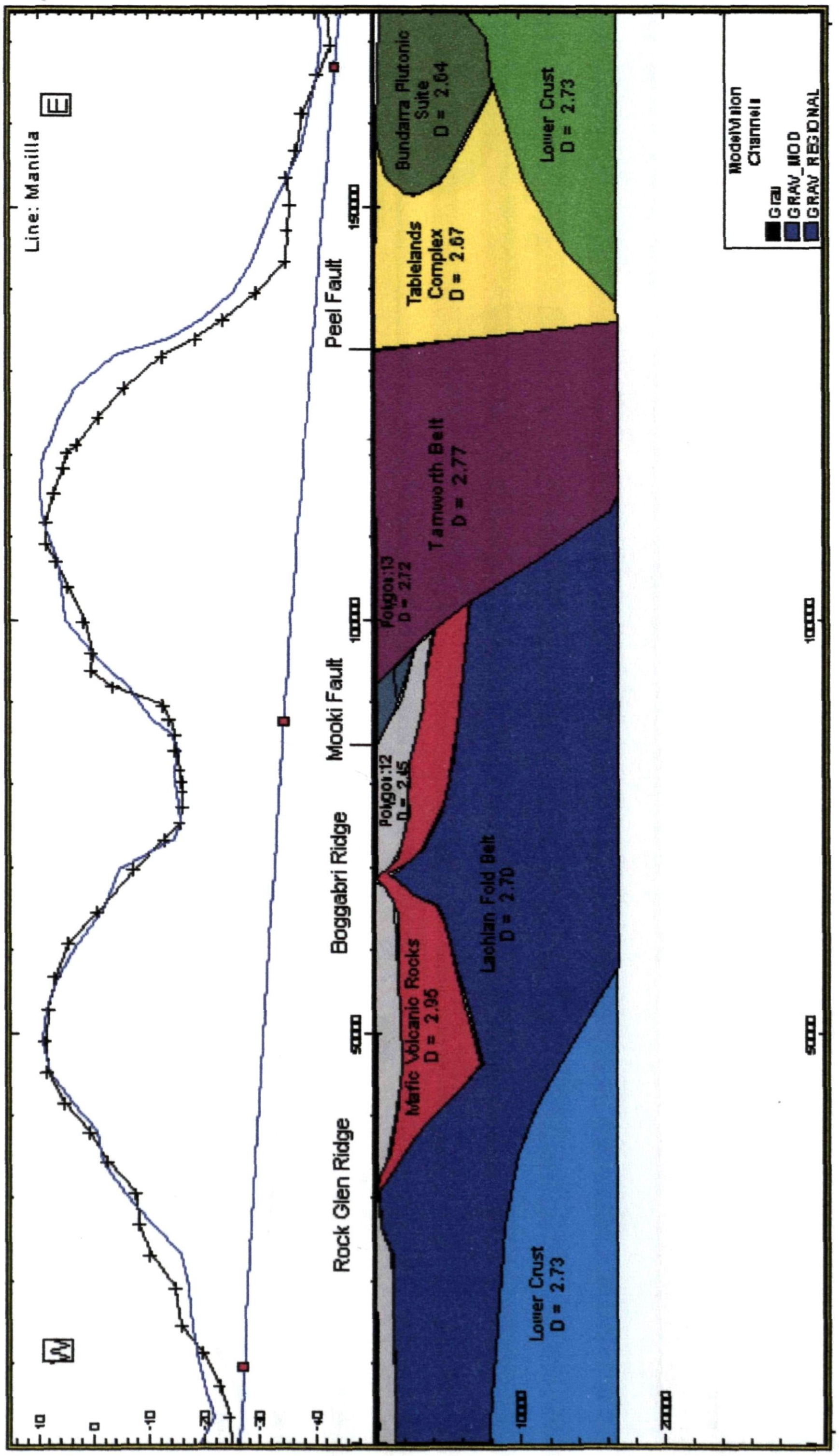

Figure 7.3c. 2D gravity model along the Manilla Profile (cross-section view). The configuration of Bramall and Qureshi (1984) was used to constrain the subsurface geometry of the structural units along the Manilla profile. The Peel Fault was modelled as east-dipping with a depth extent of 15 km. This model shows a mass excess over the Tamworth Belt. Polygon 12 represents the Gunnedah Basin, 13 the Tamworth Belt between the Mooki and Kelvin Faults. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

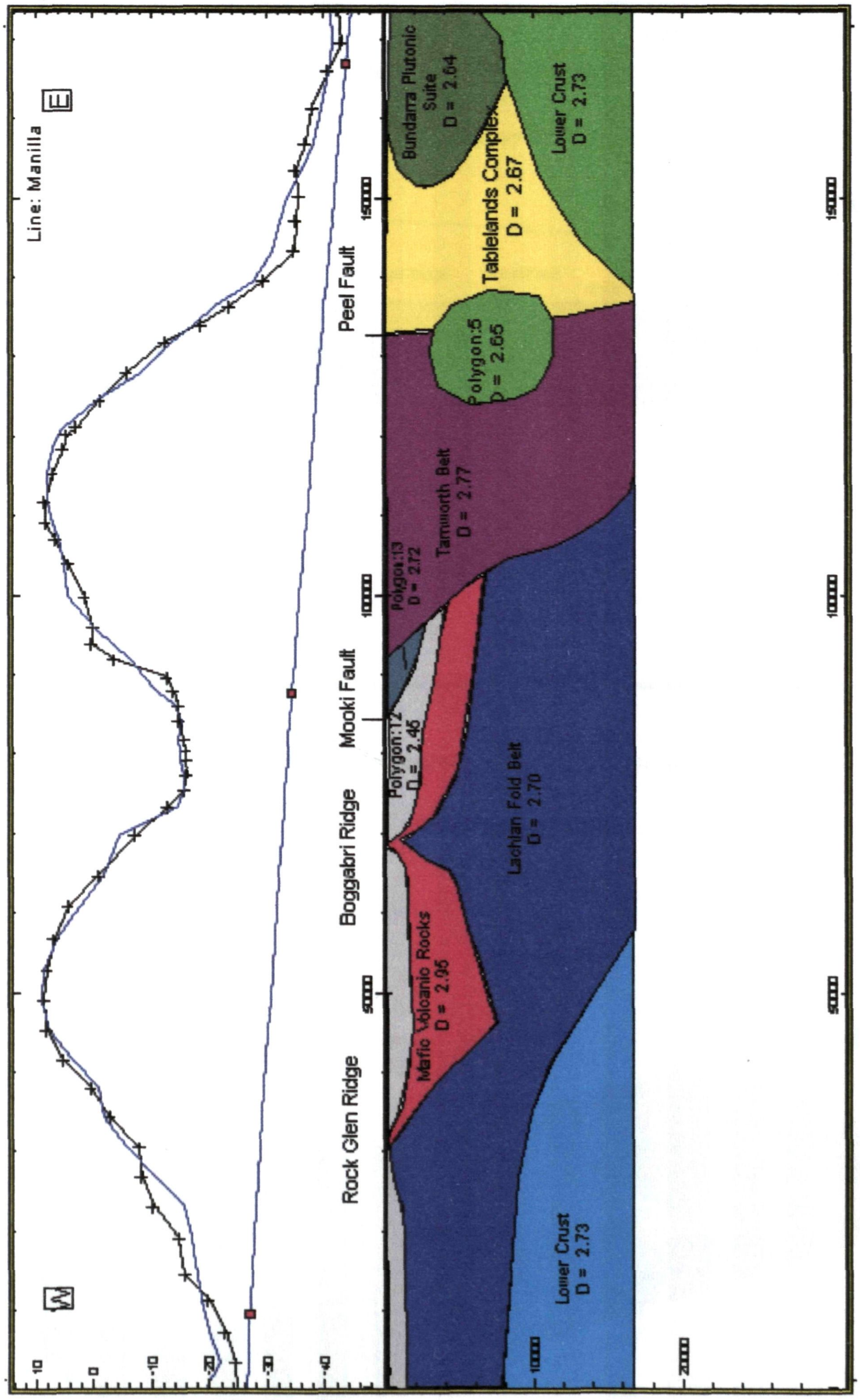

Figure 7.3d. 2D gravity model along the Manilla Profile (cross-section view). The configuration of Bramall and Qureshi (1984) was used to constrain the subsurface geometry of the structural units along the Manilla profile. A low-density unit (granite?) was introduced beneath the Tamworth Belt, showing a good fit between the observed data and the calculated profile. Polygon 12 represents the Gunnedah Basin, 13 part of the Tamworth Belt, 5 a low density unit. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

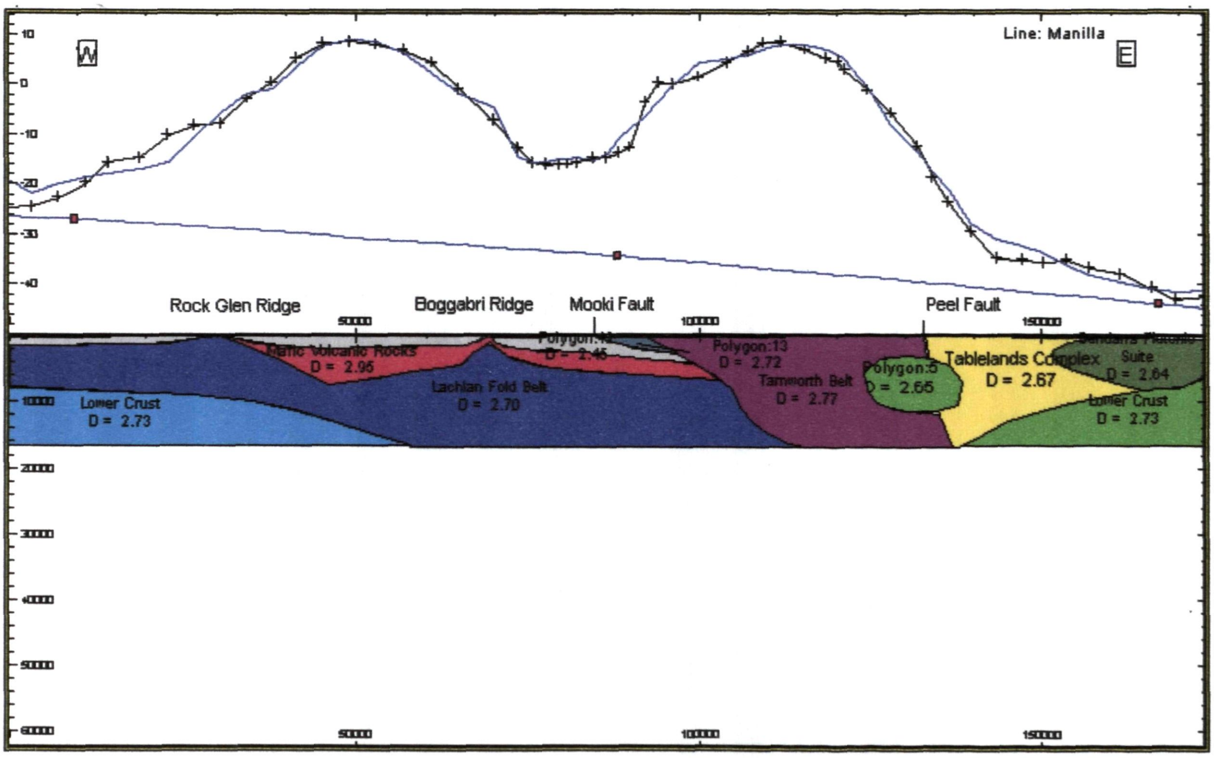

Figure 7.3e. Cross-section view on natural scale of Figure 7.3d.

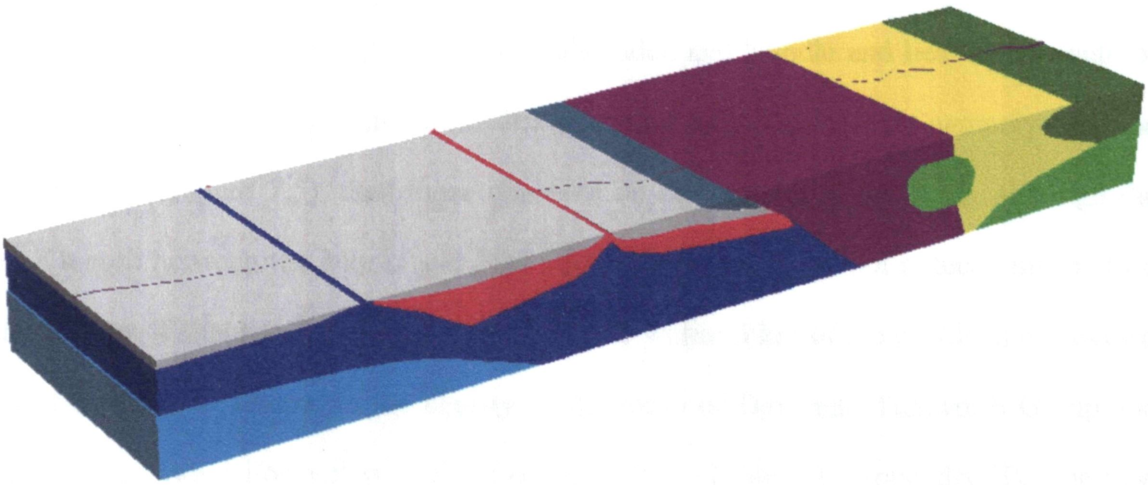

Figure 7.3f. 3D Perspective view of Figure 7.3d.

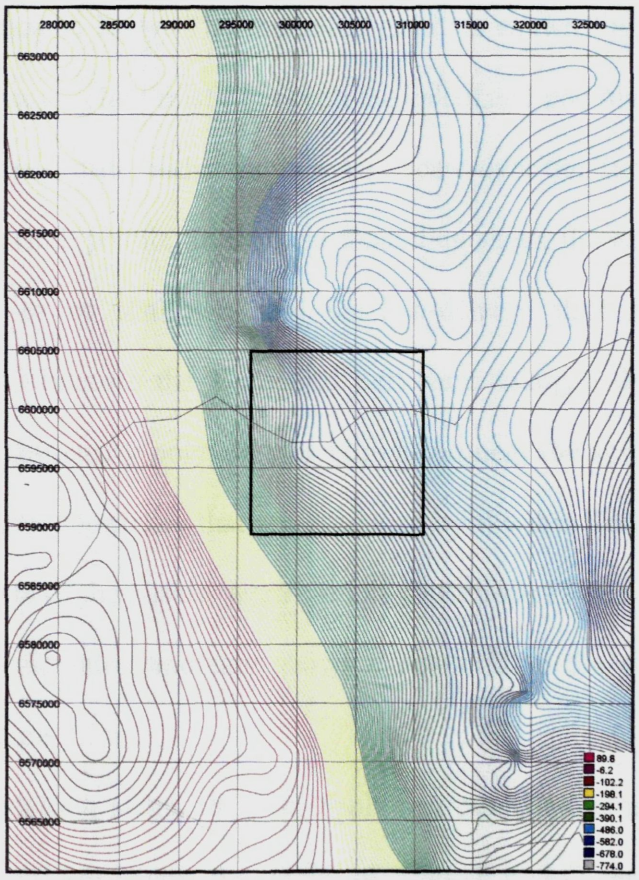

Figure 7.4 Bouguer Gravity map covering the Manilla area. The square shows half-circle gravity low indicating a possibly low density granite beneath.

7.5.2 Quirindi Profile

Profile Quirindi runs through Quirindi, Wallabadah and Nundle and lies 75 km south of profile Manilla (Figure 7.1). This profile has a smaller amplitude gravity anomaly over the Tamworth Belt (Figure 7.5), than those observed on the profiles to the north, although the distance length between the Mooki and Peel Faults on the surface is not reduced much. Two boreholes near Wallabadah and four near Nundle lie within 5 km of the profile and provided excellent samples to determine the density of the rocks of Devonian Tamworth Group and Carboniferous Namoi Formation of the Tamworth Belt (Table 7.1, Appendix II). The new gravity data was initially modelled with the simplified geometry constructed from the interpretation of the BMR 91-G01 seismic data. Densities of the constructed polygon bodies were assumed to be similar with those used in modelling the Manilla profile. The western part of the gravity profile was first modelled to fit the observed data by adjusting the geometry of the high-density volcanic body. The modelled result is shown Figure 7.5a. The calculated gravity anomaly shows a clear misfit between the calculated and observed gravity profiles in the eastern part of the profile, indicating a mass excess over the Tamworth Belt. To obtain a better fit for the Quirindi profile, in the next modelling stage, the geometry of the Tamworth Belt was reshaped to be shallower and the low-density slabs (Lachlan Fold Belt and Tablelands Complex) beneath the Tamworth Belt were enlarged. Meanwhile, to the east of the Peel Fault, a high-density polygon was introduced near the surface to model adequately the small local gravity anomalies that are produced by the thin Tertiary basalts. The surface density measurements of the basalts were used as constraints (Table 7.1). As shown in Figure 7.5b the resulting calculated anomaly shows a better fit to the observed profile than the previous model (Figure 7.5 a).

In the third modelling stage, the Peel Fault was modelled as an east-dipping fault to a depth of more than 10 km to test the model of Bramall and Qureshi (1984). The modelled result is shown in Figure 7.5c; obviously the calculated anomaly did not match the observed data, showing a large mass excess over the Tamworth Belt. In order to match the observed data successfully, a low-density unit (granite?) was introduced underneath the Tamworth Belt using an assumed density of 2.64 tm^{-3}, and was developed to get a better fit by trial and error. As can be seen again in Figure 7.5d the calculated anomaly fits the observed profile quite well. The low-density body probably represents a granite pluton that is part of the Late Permian New England Batholith as used for the Manilla profile. The Permian Duncan's Creek Trondhjemite is exposed on the surface to the northeast of Nundle (Gilligan and Brownlow, 1987; Ashley and Hartshorn, 1988) and supports the likely presence of a low-density body at depth and shows that plutons do occur in the region. The Mt Ephraim Granodiorite to the west of the Peel Fault at Nundle (Offenberg, 1967; Gilligan and Brownlow, 1987) may represent the roof zone of the pluton inferred to be much large at depth. A large pluton at depth is also supported by a local gravity low corresponding to these two outcropping granites (Figure 7.5e).

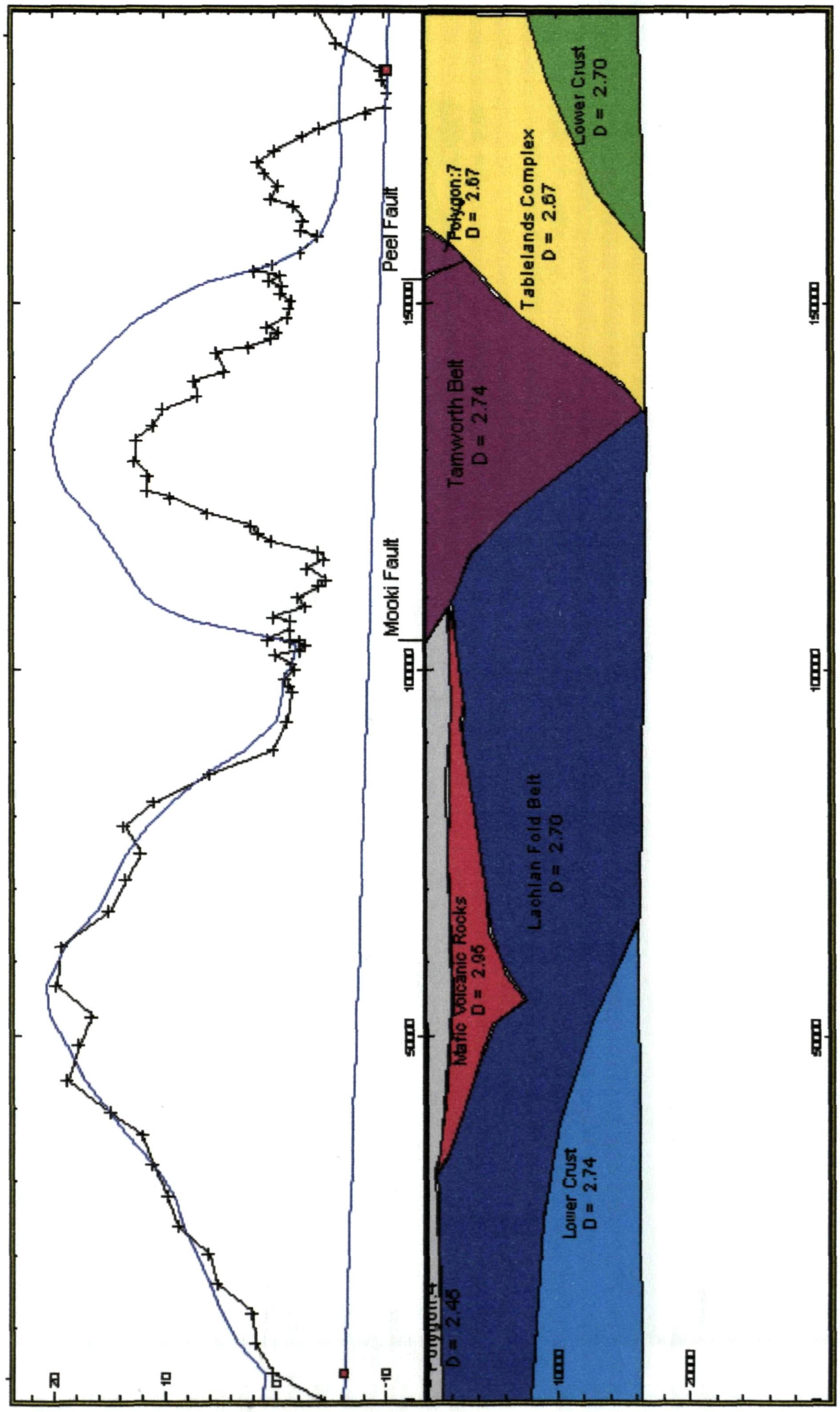

Figure 7.5a. 2D gravity model along the Quirindi Profile (cross-section view). The reflection seismic model by Korsch et al. (1997) was used as background to constrain the subsurface geometry of the structural units along the Quirindi profile. The Peel Fault was modelled as an east-dipping fault truncated by a west-dipping structure. Polygon 4 represents the Gunnedah Basin, 7 the Woolomin Association. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

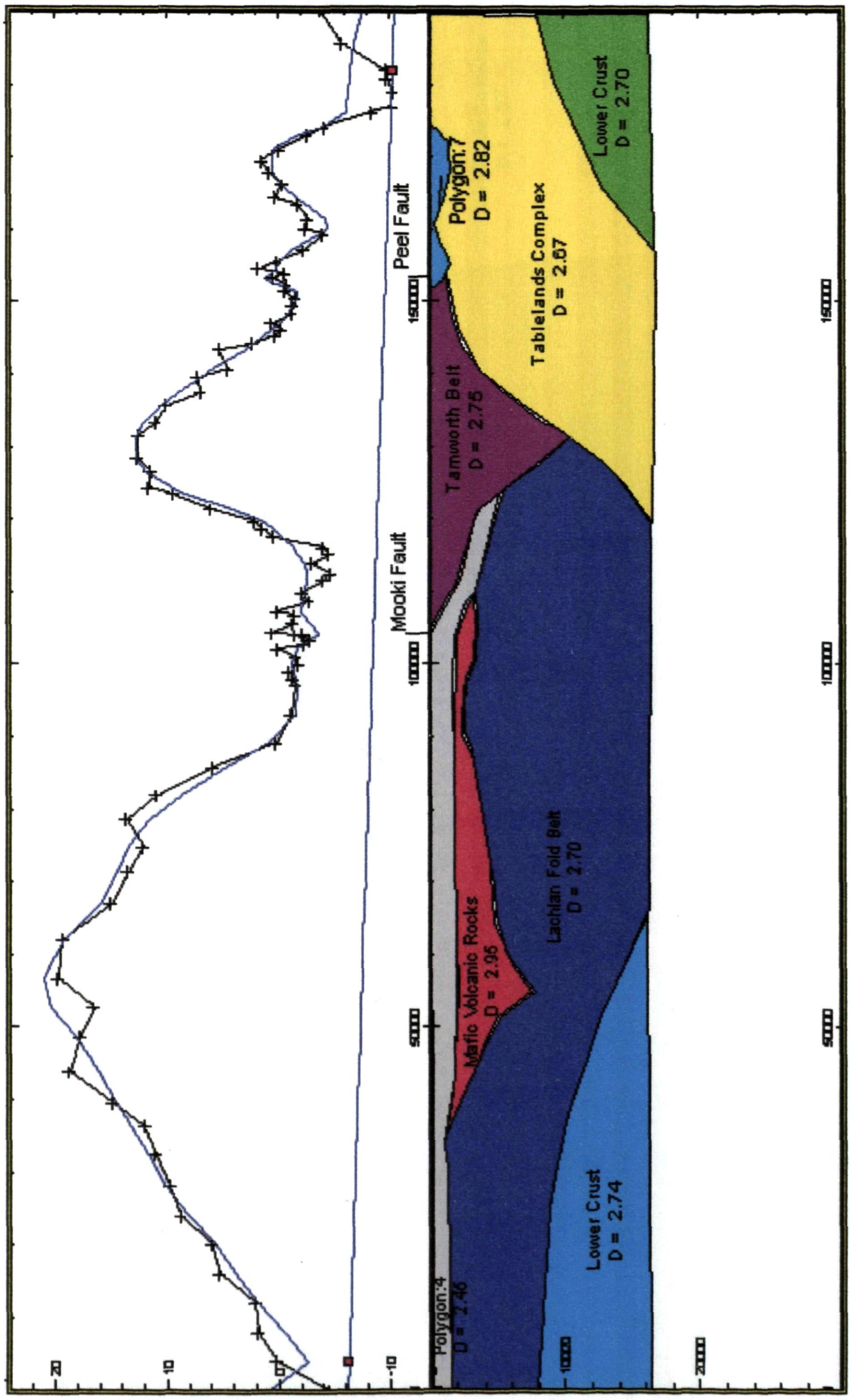

Figure 7.5b. 2D gravity model along the Quirindi Profile (cross-section view). The reflection seismic model by Korsch et al. (1997) was adjusted to constrain the subsurface geometry of the structural units along the Quirindi profile. The Peel Fault was modelled as an east-dipping fault truncated by a west-dipping structure. Polygon 4 represents the Gunnedah Basin, 7 the Tertiary volcanics. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

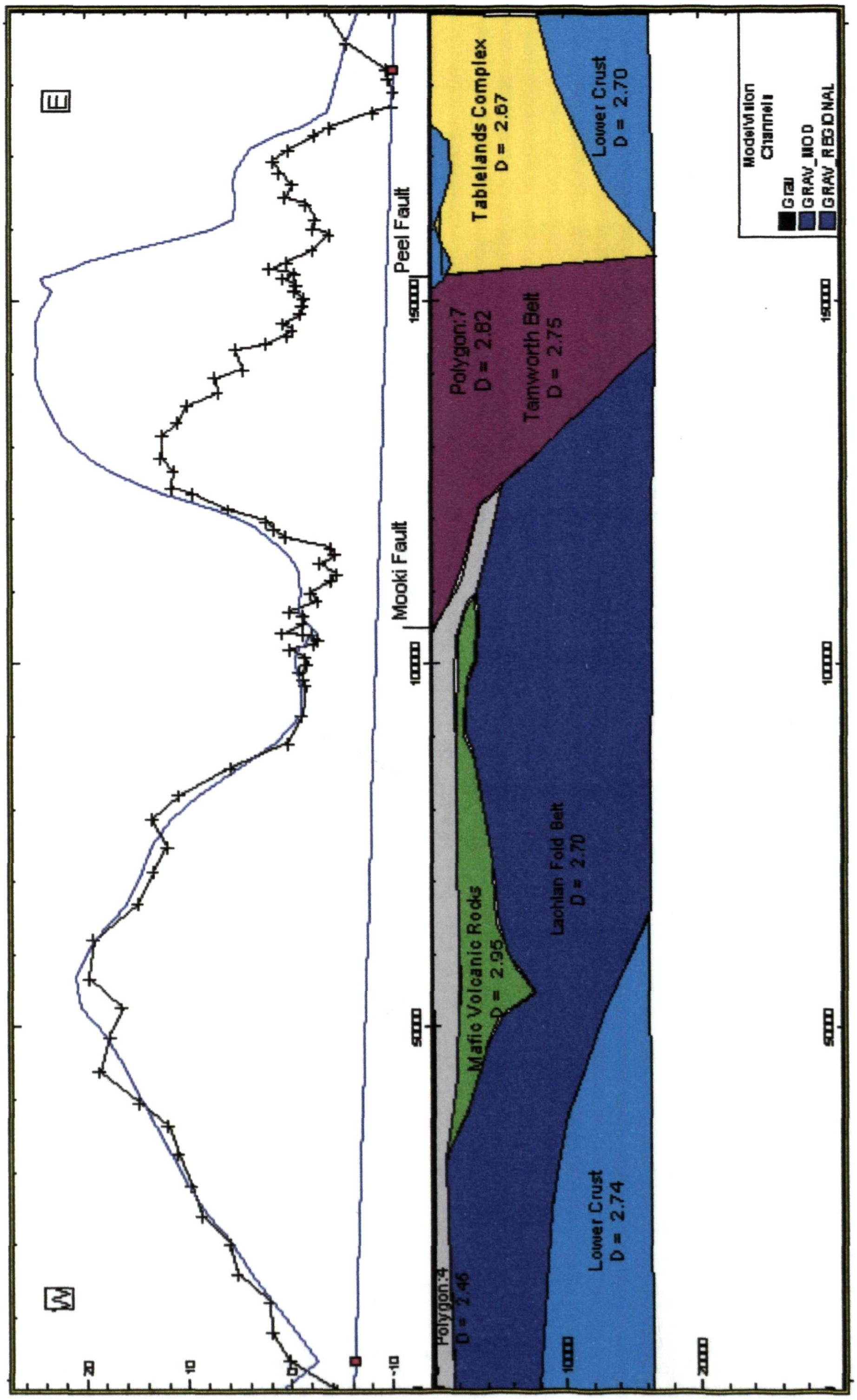

Figure 7.5c. 2D gravity model along the Quirindi Profile (cross-section view). The configuration of Bramall and Qureshi (1984) was used to constrain the subsurface geometry of the structural units along the Quirindi profile. The modelled response shows a mass excess for the Tamworth Belt. Polygon 4 represents the Gunnedah Basin, and 7 the Tertiary volcanics. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

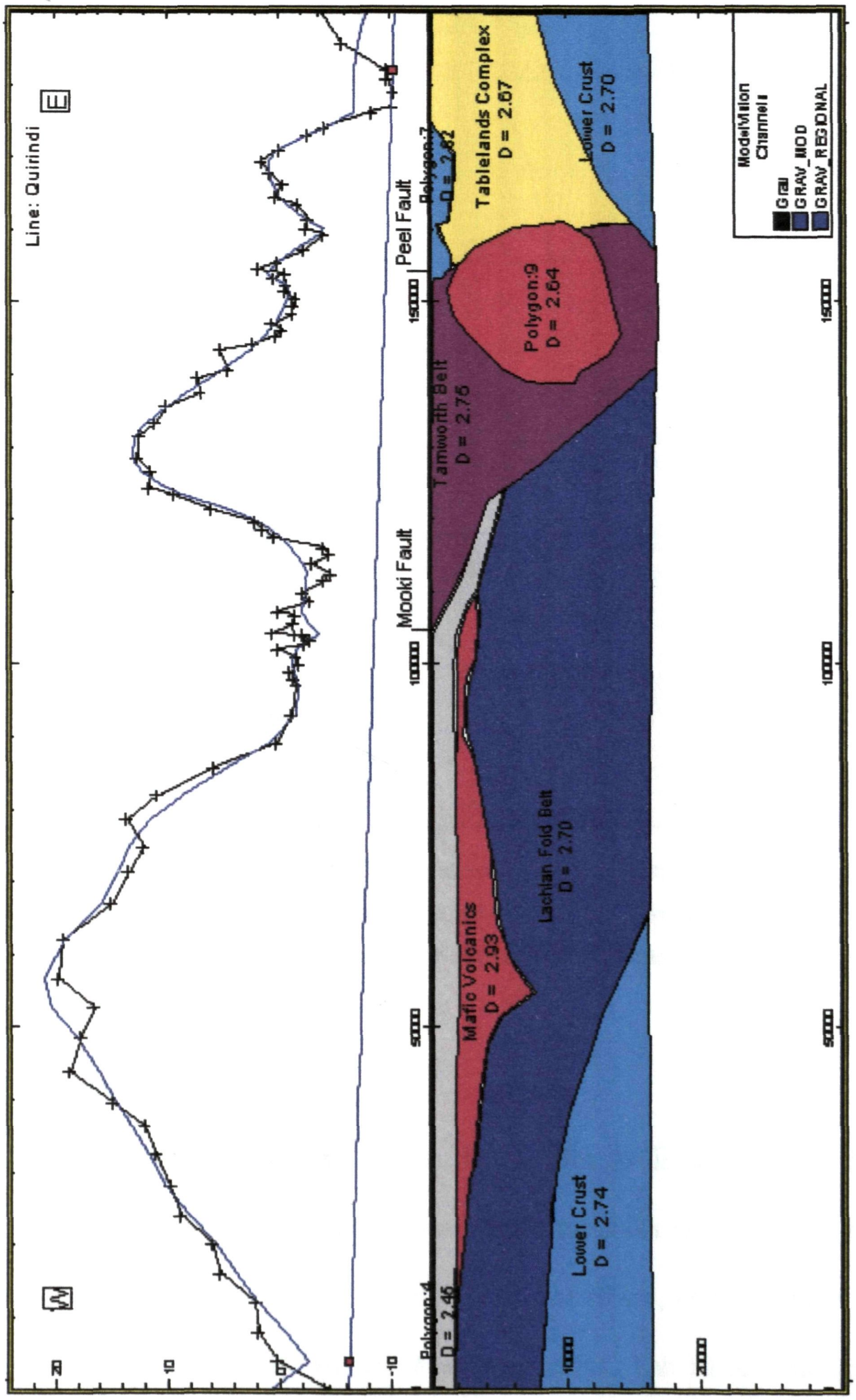

Figure 7.5d. 2D gravity model along the Quirindi Profile (cross-section view). The configuration of Bramall and Qureshi (1984) was used to constrain the subsurface geometry of the structural units along the Quirindi profile. A low-density unit (granite?) was introduced beneath the Tamworth Belt, which results in a good fit between the observed data and the calculated profile. Polygon 4 represents the Gunnedah Basin, and 7 the Tertiary volcanics and 9 the low density unit. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

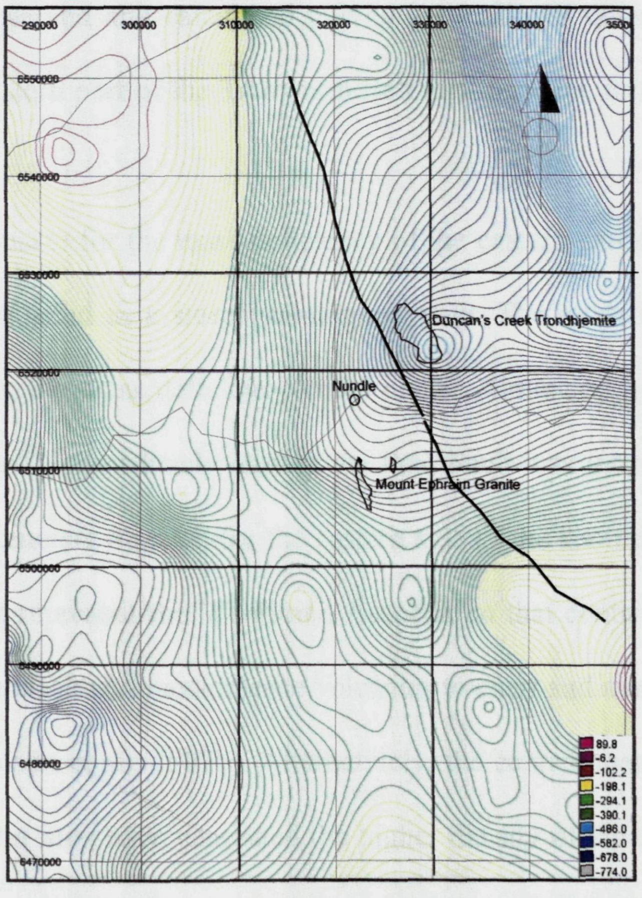

Figure 7.5e. Bouguer gravity map covering the Nundle area. The thick black line shows the location of the Peel Fault. The gravity low corresponding to the Duncans Creek Trondhjemite and Mount Ephraim Granite indicates a possibly large low-density pluton beneath.

7.5.3 Tamworth Profile

The Tamworth profile lies between the Manilla profile and the Quirindi profile (Figure 7.1). The profile passed through Tamworth, Currabubula and Breeza. The gravity anomaly corresponding to the Tamworth Belt has a width of 80 km, which is wider than the anomalies observed on both the Quirindi and Manilla profiles. The basic structure of this model is derived from those of Manilla and Quirindi profiles. The western part of this profile (Gunnedah Basin) was first modelled to match the observed data with only minor differences in geometry of the constructed bodies for the Manilla and Quirindi profile (Figure 7.6a). Values of density are the same as those used in Manilla and Quirindi profiles. To the east, the density of the Tamworth Belt needed to be reduced to match the observed data, however, the misfit between the observed and calculated gravity anomalies is considerable, indicating a mass excess in the western part of the Tamworth Belt of the model, and a mass deficiency in the eastern part.

In order to compensate for the mass deficiency of the eastern part of the Tamworth Belt, the Peel Fault was modelled as a steep east-dipping fault. The modelled result is shown in Figure 7.6b, indicating the mass deficiency could not be eliminated by this model. A high-density prism (2.75 tm^{-3}) immediately east of the Peel Fault was introduced to balance this mass deficiency and generate a match for the eastern side of the anomaly over the Tamworth Belt. The prism might represent the Woolomin Association that contains a larger proportion of higher density metabasalt and metadolerite volcanics to chert and mudstone (Crook, 1961a, b; Leitch, 1974; Aitchison et al., 1992b). Alternatively, the contact metamorphism associated with the Moonbi Pluton may have generated the higher density of the rocks in this area. The chert/jasper has a measured density ranging from 2.65 to 2.78 tm^{-3} (Table 7.1). In addition, Bailey (2002), on the basis of a gravity investigation of the Moonbi and Bendemeer Adamellites, reported a density of 2.77 tm^{-3} for the Woolomin Association 5 km away from the Moonbi Pluton. Therefore, a density of 2.75 was adopted for the Woolomin Association. To the east of the Woolomin Association, the Sandon Association composed chiefly of siltstone and sandstone with rare chert/jasper (Aitchison et al., 1992b) is assumed to have a low density of 2.67 tm^{-3}. That is not very different from granite composition inferred from the wide-angle seismic data (Finlayson and Collins, 1993).

The next modelling stage began by introducing the Moonbi and Walcha-Road Adamellites, to model the observed local gravity low to the east end of the profile. The density of the Moonbi Adamellite used is 2.66 tm^{-3}, which is the measured value in this study (Table 7.1) and that reported by Bailey (2002). A density of 2.63 $tm^{-3}$was adopted for the Walcha-Road Adamellite, which is the measured average value of samples. To the west of the

Namoi Gravity High, a relative low-density body just east of the Mooki Fault was introduced to fit the observed anomaly. This constructed polygon represents the Permian Werrie Basin. A density of 2.65 was adopted because the rock is composed of coherent dacitic and rhyolitic lavas with minor epiclastic, pyroclastic breccias and airfall tuffs (Preston, 1987). The final model is shown in Figure 7.6c. The resulting calculated anomaly shows a better fit to the observed profile than the previous model.

An alternative model for the Tamworth profile is shown in Figure 7.6d, the low-density Tablelands Complex extended to beneath the Tamworth Belt, indicating a similar crustal structure to the interpretation of the BMR91-G01 seismic data in the north. However, the depth of the Peel Fault could not be reduced to the 1 km proposed by Korsch et al. (1993a, 1997). Modelling of the magnetic data collected 3 km south of the profile indicated that the Peel Fault has a depth at least 2-3 km (Edwards, 1996). This models gives a fit that is as good as the previous model.

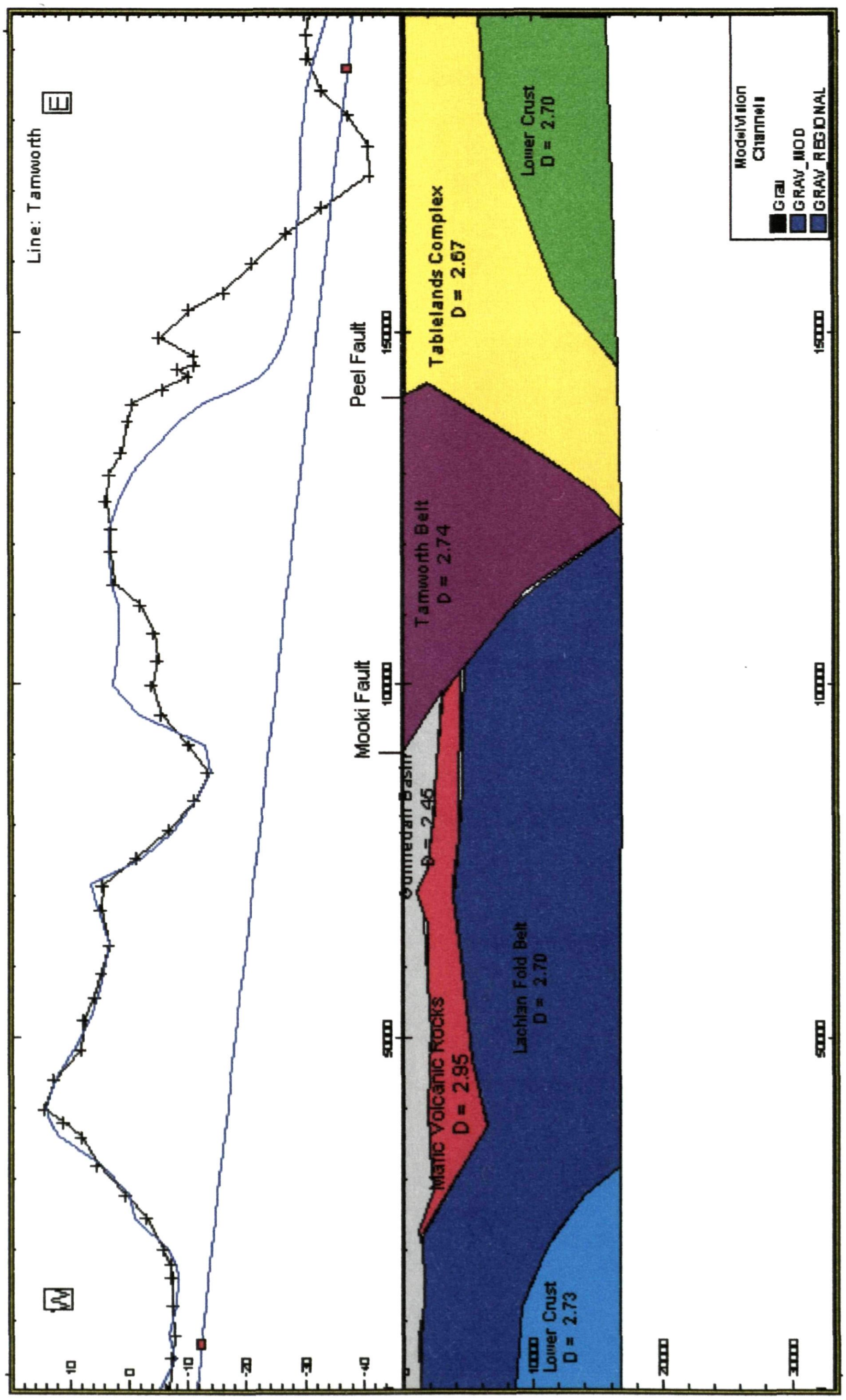

Figure 7.6a 2D gravity model along the Tamworth Profile (cross-section view). The reflection seismic model by Korsch et al. (1997) was used as background to constrain the subsurface geometry of the structural units along the Tamworth profile. The Peel Fault was modelled as an east-dipping fault truncated by a west-dipping structure. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

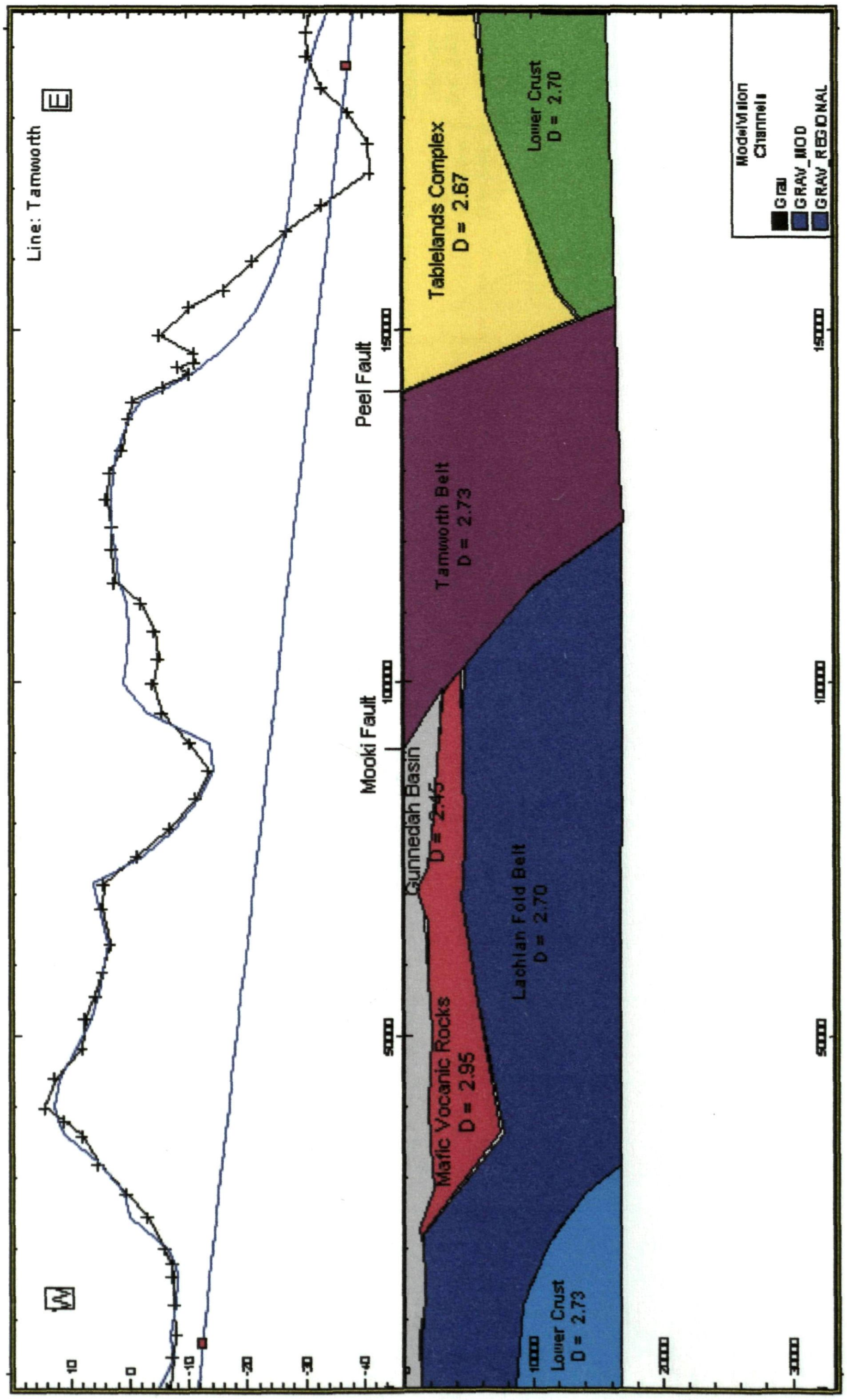

Figure 7.6b 2D gravity model along the Tamworth Profile (cross-section view). The configuration of Bramall and Qureshi (1984) was used to constraint the subsurface geometry of the structural units along the Tamworth profile. This model showed a mass deficiency to the east of the Tamworth Belt. Symbols represent observed data and solid line is calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

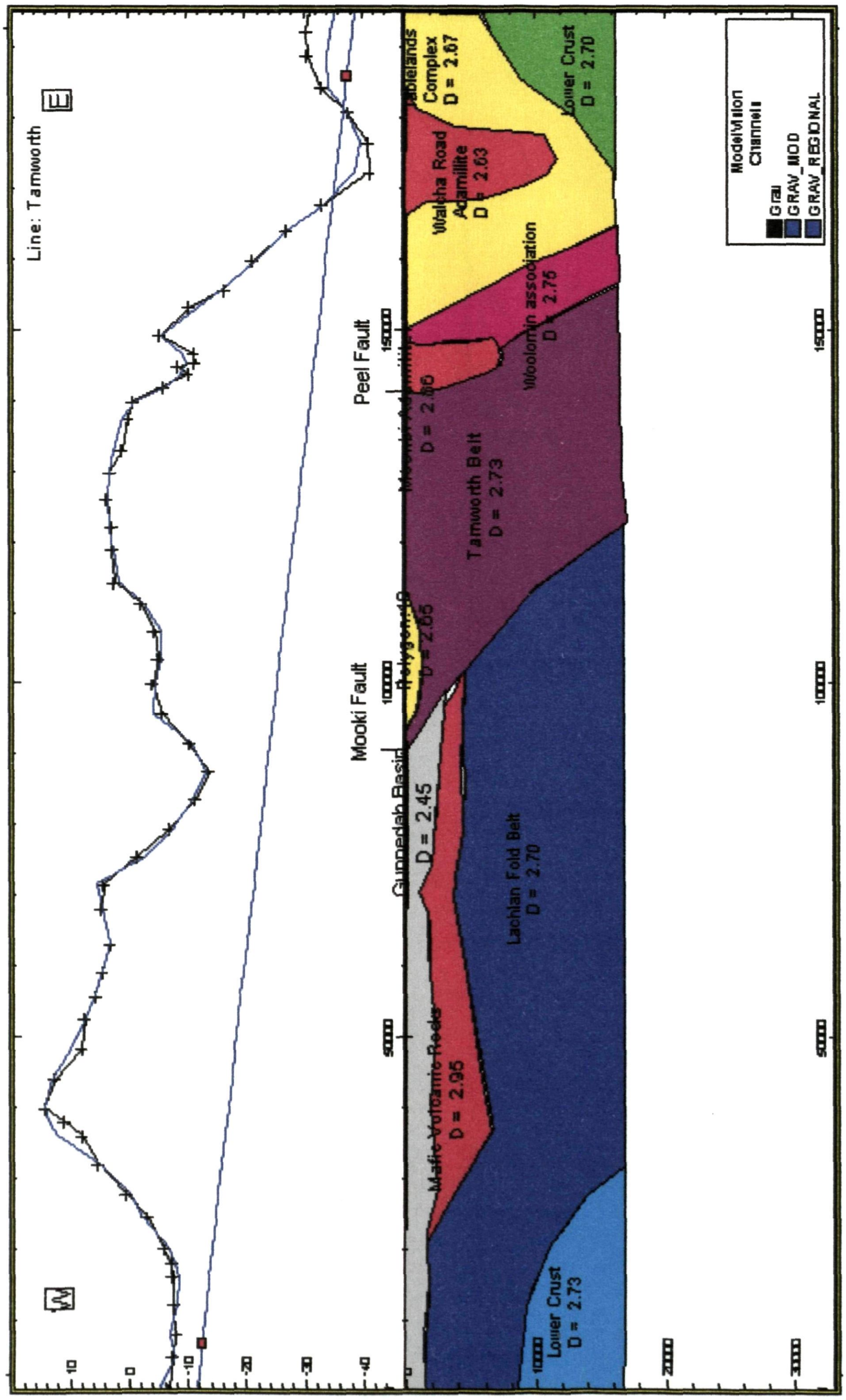

Figure 7.6c 2D gravity model along the Tamworth Profile (cross-section view). The configuration of Bramall and Qureshi (1984) was used to constrain the subsurface geometry of the structural units along the Tamworth profile, showing a good fit between the observed data and calculated profile. Polygon 10 represents the Werrie Basin. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

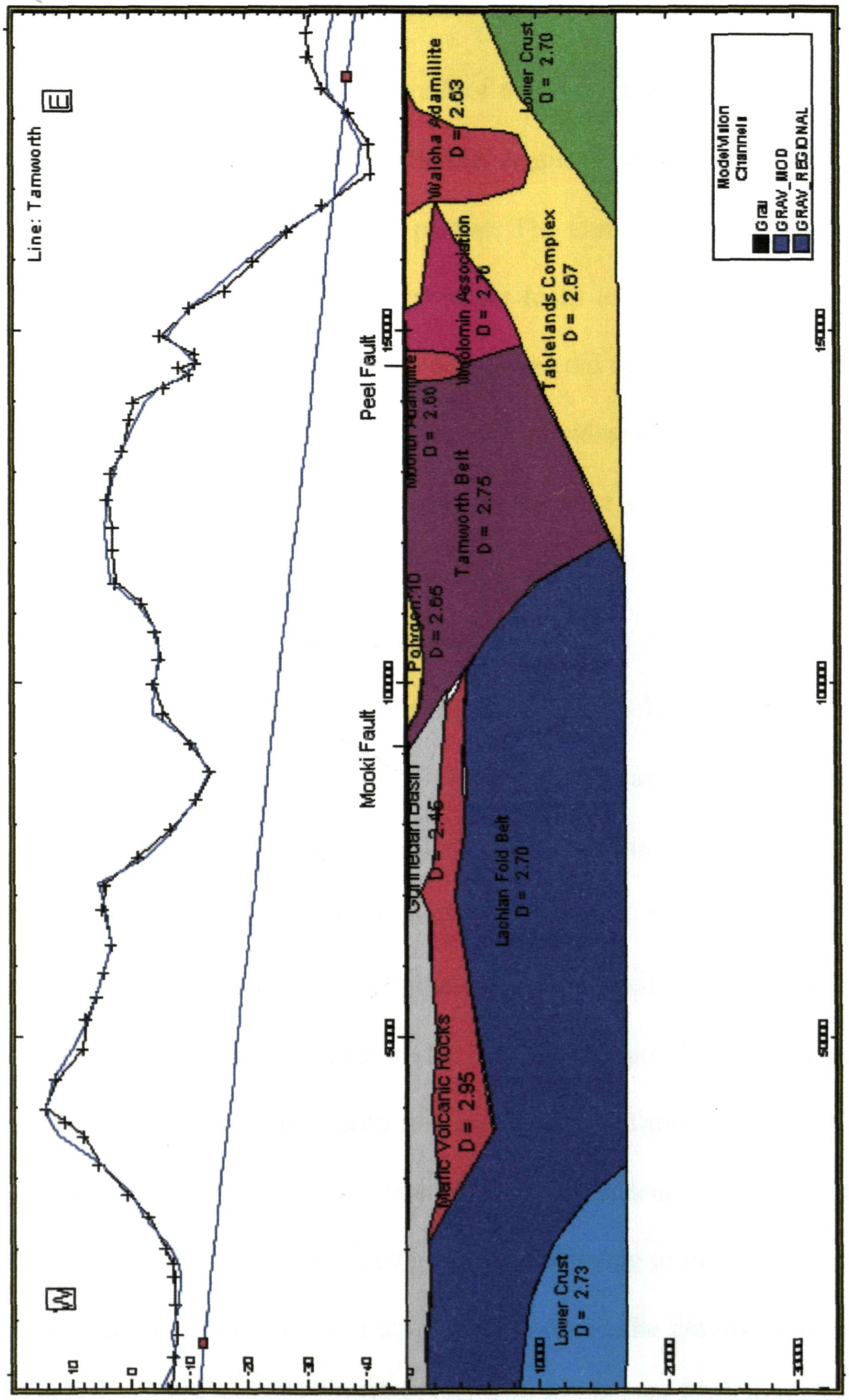

Figure 7.6d 2D gravity model along the Tamworth Profile (cross-section view). The low-density Tablelands Complex extended to beneath the Tamworth Belt, showing a good fit between the observed data and the calculated profile. Polygon 10 represents the Werrie Basin. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

7.5.4 Barraba Profile

The Barraba profile lies 35 km north of the Manilla profile (Figure 7.1). The profile runs through Baan Baa, Barraba and Woodsreef. Again the data was modelled with the simplified geometry derived from the Manilla profile. The Gunnedah basin was modelled as a rifted basin filled with high-density mafic volcanic rocks to match the observed anomaly. For the eastern part of the profile, the modelled response did not match the observed data. As can be seen in Figure 7.7a, the misfit between the calculated and observed gravity anomalies is significant, indicating an excess of mass on the west side of the eastern gravity high and a mass deficiency on the east side.

To obtain a better fit for the Barraba profile, in the follow modelling stage, the geometry of the Tamworth Belt was slightly adjusted and a high-density prism was introduced immediately east of the Peel Fault. The prism was assumed to represent the Woolomin Association composed chiefly of jasper, basalt, dolerite and metabasalts (Crook, 1961a, b; Aitchison et al., 1988, 1992b; Blake and Murchey, 1988a, b). The association has an anchizonal metamorphism with prehnite-pumpelyite facies (Offler and Hand, 1988). Again a density of 2.77 tm^{-3} was adopted for the Woolomin Association on the basis of the measurements of the samples collected in this study (Table 7.1) and Bailey's report (2002). The geometry of the Woolomin Association is consistent with that proposed by Blake and Murchey (1988), who did a detailed geological mapping in the Woodsreef area. In addition, a dyke-like high-density body was introduced to match the gravity high east of the Peel Fault, and a small low density unit was used just west of the Peel Fault to match a local gravity low. The dyke-like body is just east of the Peel Fault in Woodsreef area, may represent serpentinite-related gabbroic rock (Scheibner and Glen, 1972; Blake and Murchey, 1988a, b). The low density unit may be related to the outcrop of the Carboniferous and Early Permian sedimentary rocks along the Peel Fault (Table 7.1). The samples from the drill-hole northeast of Wallabadah within the Namoi Formation have an average density 2.61 and 2.66 tm^{-3} for Wallabadah No.1 and No.2. As shown in the final model (Figure 7.7b), the resulting calculated anomaly shows a better fit to the observed profile than the previous model (Figure 7.7 a). It is worth noting that the Peel Fault could not be modelled as a east-dipping fault with a depth of 1km, and that the best fit model has the Peel Fault extend to a depth of 7 km. Modelling of the ground magnetic data collected in this area only indicates that the Peel fault must have a minimum depth extension of 2.5 km (Figure 5.6) to the base of serpentinite bodies.

In the next modelling stage, the gravity data was modelled to show the alternative subsurface geometry of the Tamworth Belt being that of a deep east dipping Peel Fault (Figure 7.7c). Both the density of the Woolomin Association and Tamworth Belt were slightly reduced to provide a better fit to the observed gravity data. The geometry of the Bundarra Plutonic Suite was adjusted slightly to get a good match to the observed data. In this model the Peel Fault extends to a depth of 15 km, and the Woolomin Association steeply dips to west. A small low density unit was used just west of the Peel Fault to match a local gravity low. The calculated anomaly was a good match to the observed data, and no constraint was put for the depth of the Peel Fault.

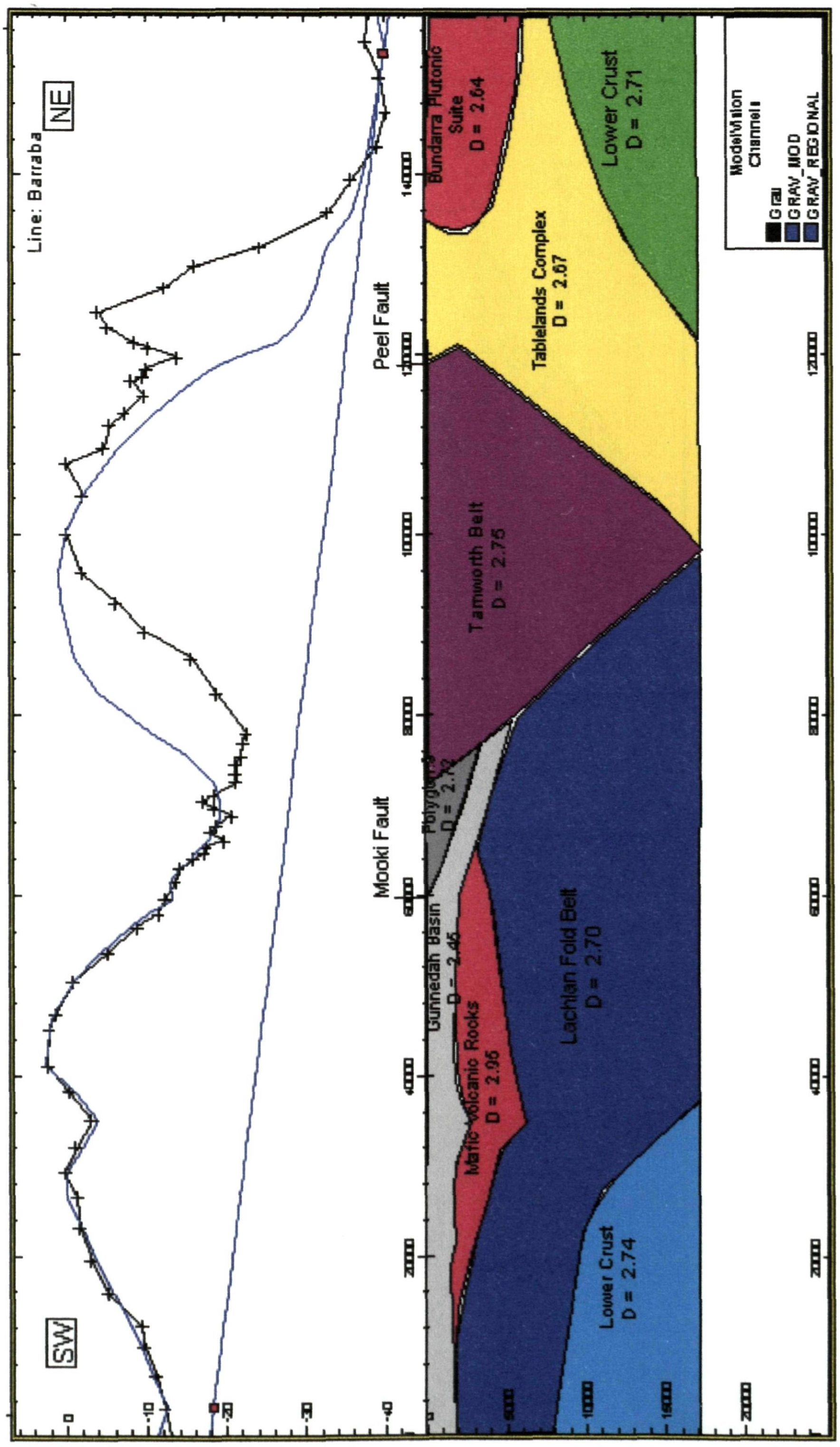

Figure 7.7a 2D gravity model along the Barraba Profile (cross-section view). The reflection seismic model by Korsch et al. (1997) was used as background to constrain the subsurface geometry of the structural units along the Barraba profile. The Peel Fault was modelled as an east-dipping fault truncated by a west-dipping structure. There is a mass deficiency over the east of the Tamworth Belt. Polygon 9 represents part of the Tamworth Belt. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

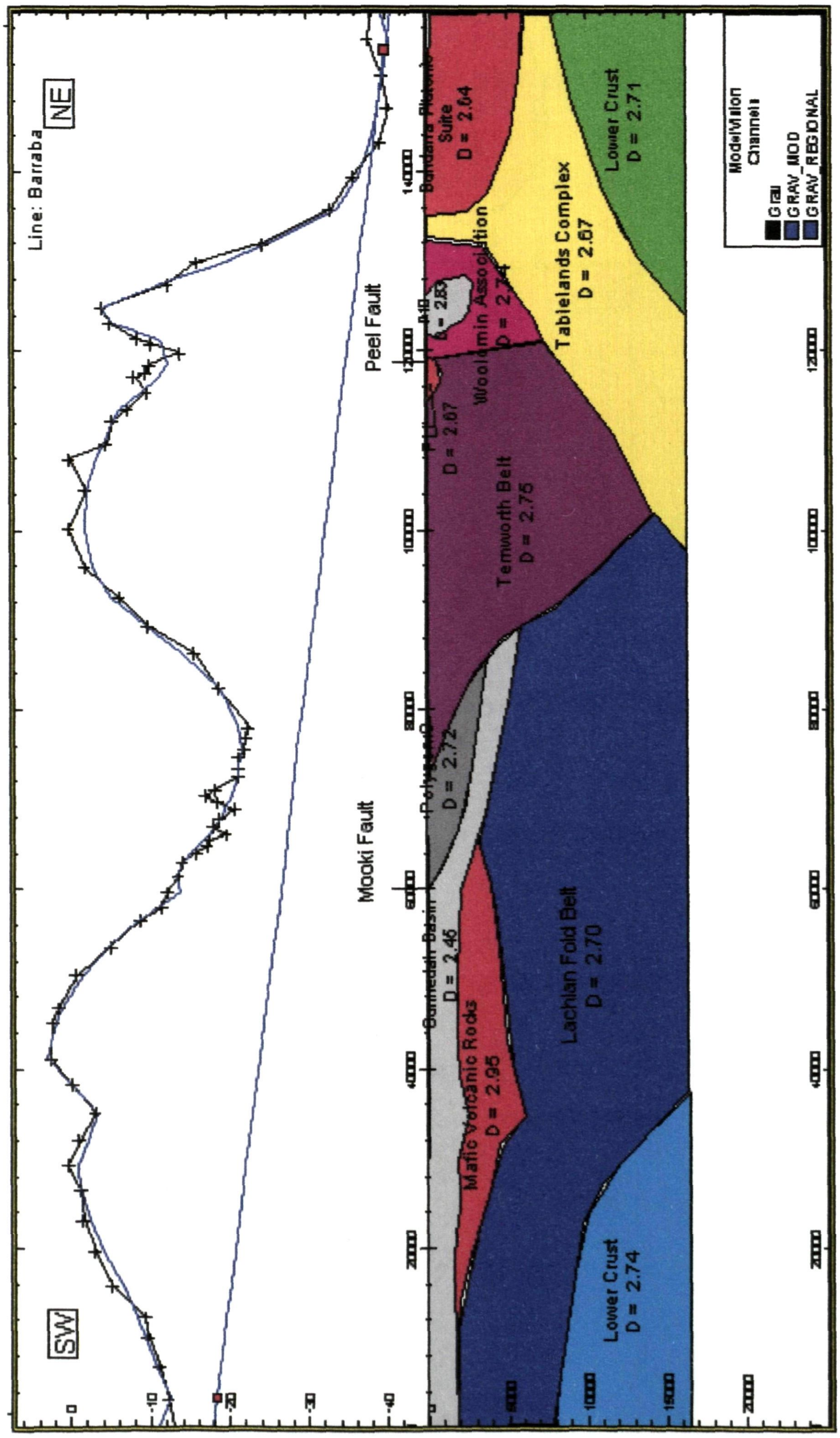

Figure 7.7b 2D gravity model along the Barraba Profile (cross-section view). The Peel Fault was modelled as an east-dipping fault truncated by a west-dipping structure. Polygon 9 represents part of the Tamworth Belt, 10 is a high-density unit in the Woolomin Association, 11 is a low density unit to the west of the Peel Fault. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

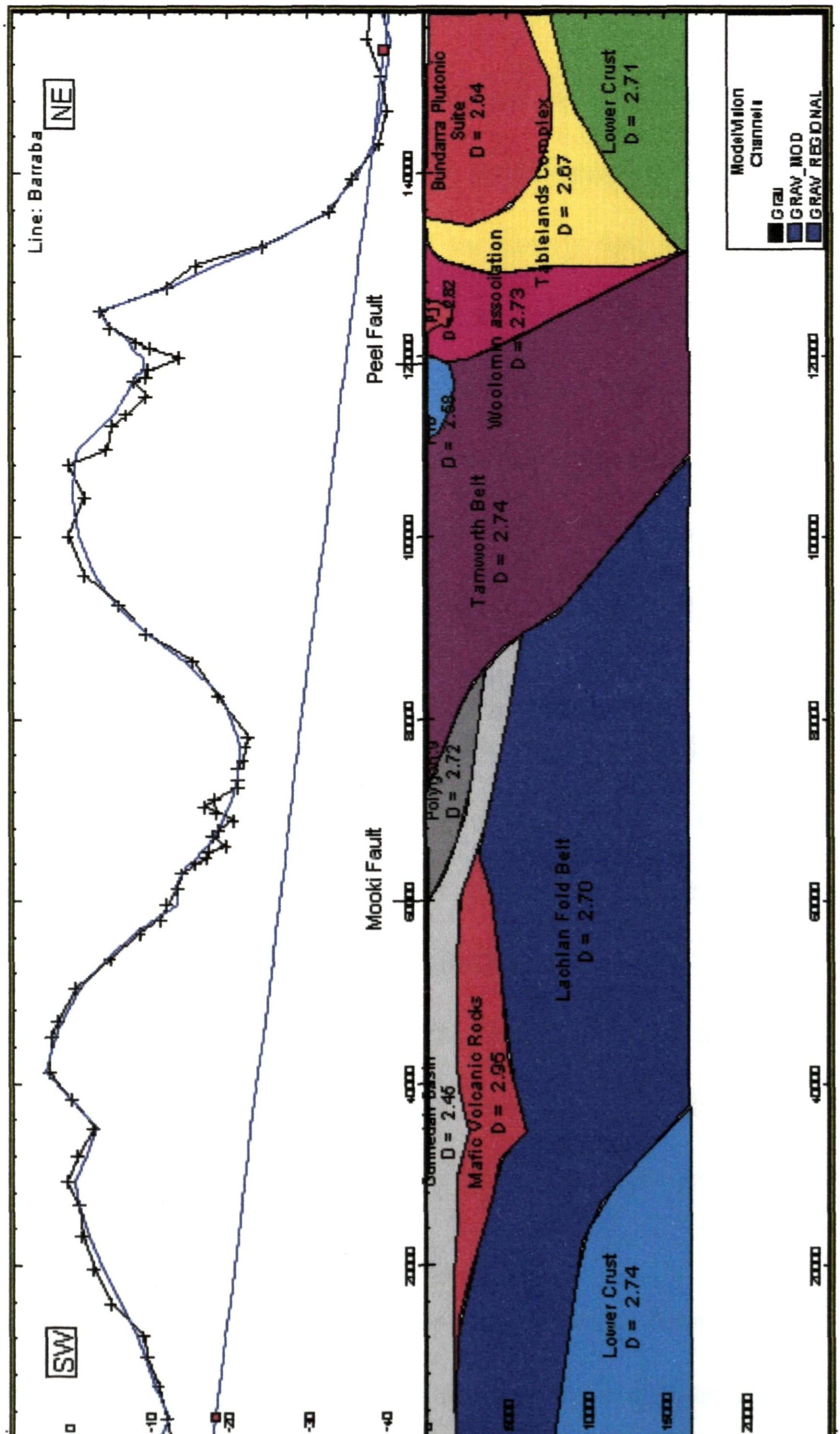

Figure 7.7c 2D gravity model along the Barraba Profile (cross-section view). The configuration of Bramall and Qureshi (1984) was used to constrain the subsurface geometry of the structural units along the Tamworth profile. This model showed a good fit between the observed data and the calculated profile. Polygon 9 represents part of the Tamworth Belt, 11 is a high-density unit in the Woolomin Association, 10 is a low density unit to the west of the Peel Fault. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

7.5.5 Bingara Profile

The Bingara profile is the most northern area surveyed in this study (Figure 7.1), and is 50 km north of the Barraba profile. The profile runs through Bingara and Narrabri, and has a total length of 190 km. Modelling of the gravity data was started with a geometry derived from the Barraba profile. After the western part of the profile was modelled to get a better match between the observed and calculated anomalies with high density volcanic rocks generated with a rift origin as used in the Barraba profile, the eastern part of the profile was modelled using two different configurations. Firstly, the eastern anomaly was modelled using the tectonic model proposed by Blake and Murchey (1988a, b). As can be seen in Figure 7.8a, the calculated anomaly matched the observed data quite well. The Woolomin Association composed chiefly of the chert/jasper, metabasalt and metadolerite (e.g. Crook, 1961a, b; Cuddy, 1978) was assumed to be a high-density unit, and the Sandon Association composed mainly of siltstone and sandstone with rare chert/jasper (e.g. Cuddy, 1978; Blake and Murchey, 1988a, b) extended underneath the Tamworth Belt and Woolomin Association units. The model indicates that the Peel Fault steeply dips to east and has a depth extent of 7 km. In order to match the small local anomaly, a high-density polygon was introduced to model the gravity high just west of the Peel Fault, representing the Tertiary volcanics 10 km west of the Bingara Town.

The gravity model was alternatively developed to determine the depth extent of the Peel Fault. In this model both the Peel Fault and the fault between the Woolomin and Sandon Associations dip to east. The final model is shown in Figure 7.8b, the calculated anomaly shows a good fit to the observed profile. Modelling results indicate that in both cases, the Peel Fault has a greater depth extent than 1 km as proposed by Korsch et al. (1993a, 1997).

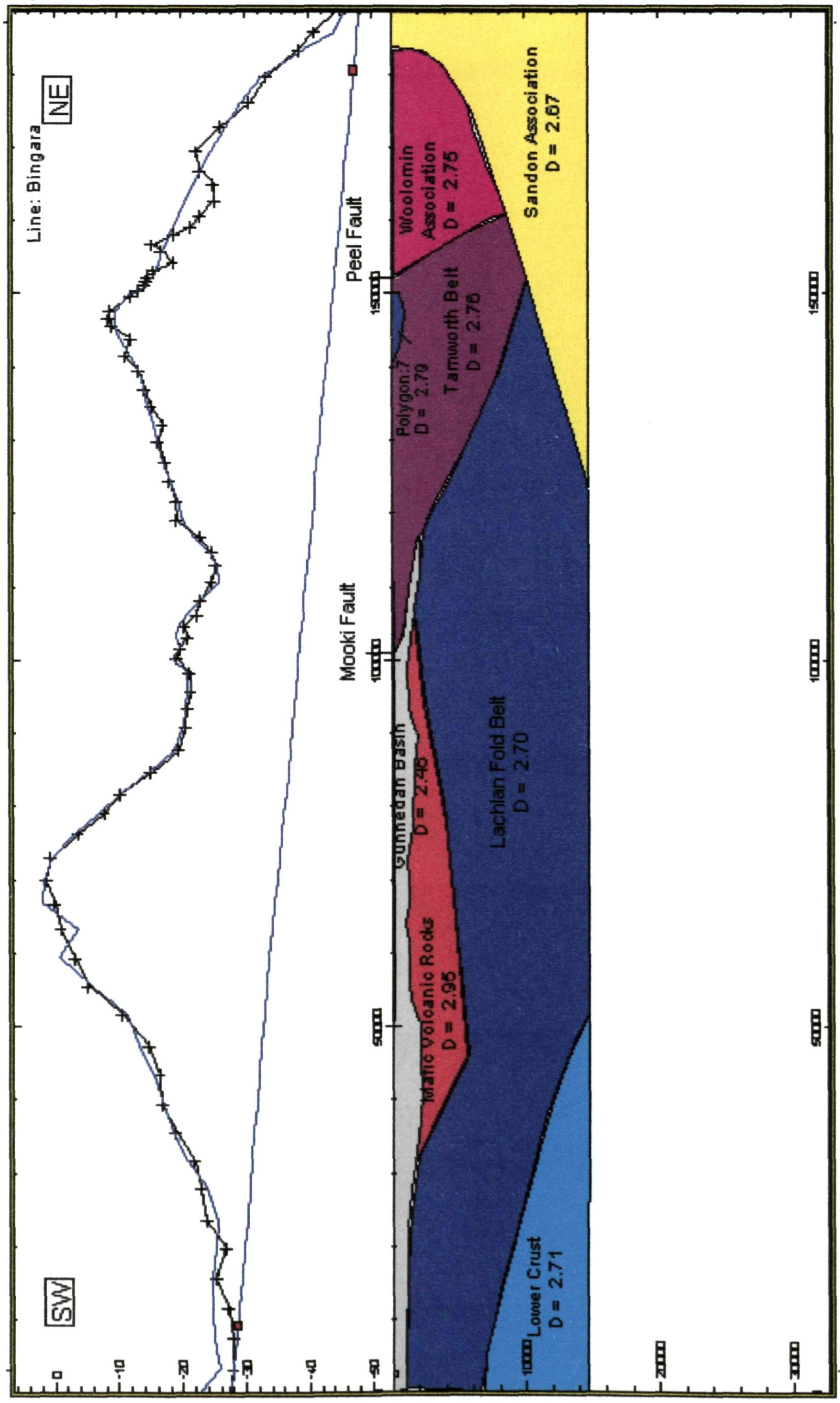

Figure 7.8a 2D gravity model along the Bingara Profile (cross-section view). The Peel Fault was modelled as an east-dipping fault truncated by a west-dipping structure. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Polygon 7 represents for a high density Tertiary volcanics. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

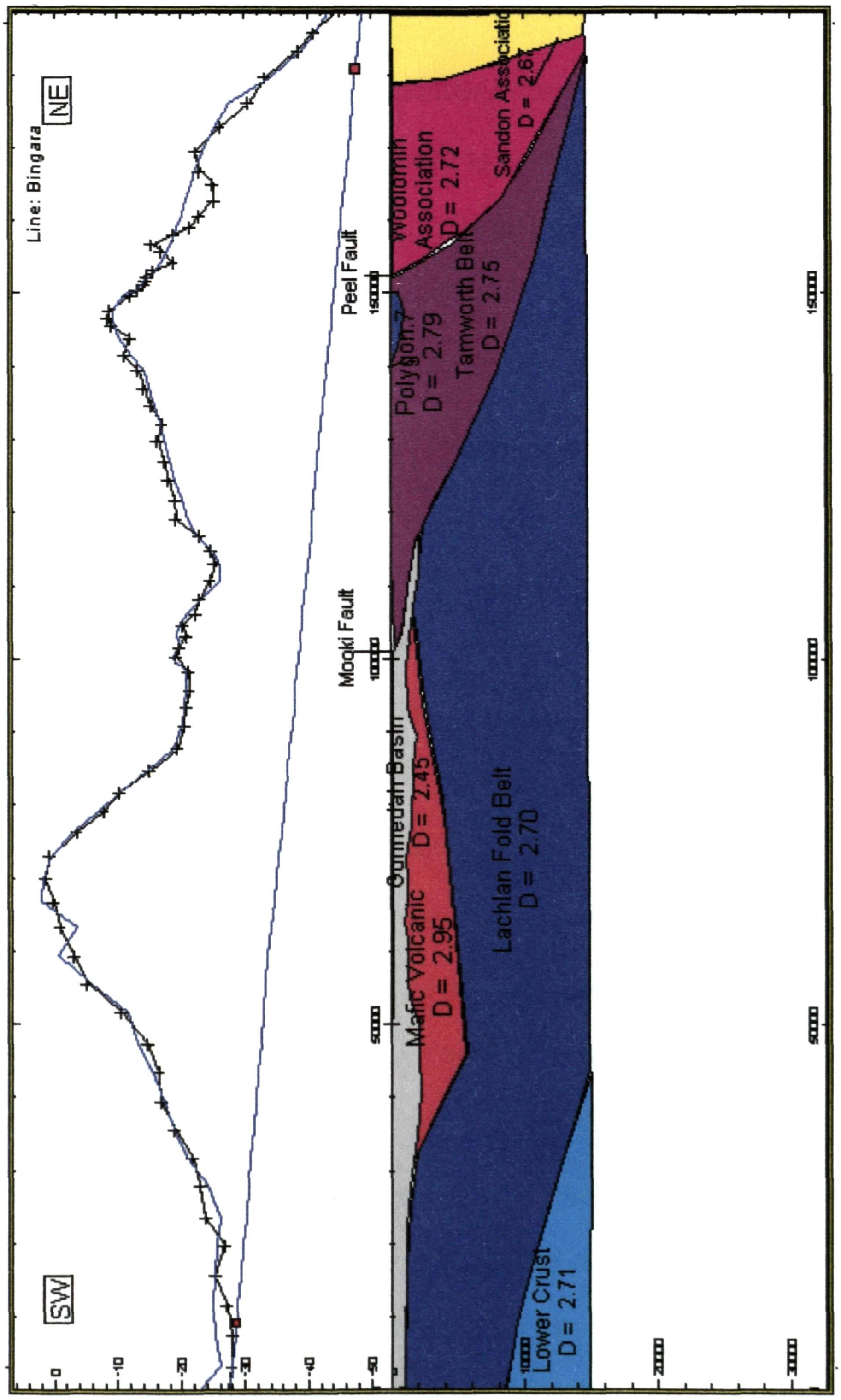

Figure 7.8b 2D gravity model along the Bingara Profile (cross-section view). The Peel Fault was modelled as an east-dipping fault with a depth extent of 15 km. Polygon 7 represents for a high density Tertiary volcanics. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre. See Figure 7.1 for location of cross-section.

7.6 DISCUSSION OF RESULTS

This study models five gravity profiles between Nundle in the south and Bingara in the north. A variety of models were tested to assess the possible subsurface geometry of the Tamworth Belt and Gunnedah Basin. The final models developed for each profile are not necessarily the only models that will fit the data satisfactorily but represent a reasonably successful match to the observed data along the gravity profile while satisfying the constraints posed by the other geophysical and geological data.

7.6.1 Evaluation of the modelling result

The densities of the structural units in gravity models are key factors to the response of the calculated gravity profile. On the basis of an inversion of the gravity data of the Tamworth profile, a higher density Woolomin Association was used to match to the observed data, and was applied to the Barraba and Bingara profiles. Therefore, it is necessary to evaluate the modelling results of the Manilla and Quirindi profiles with a high density Woolomin Association. Figure 7.9 shows the re-modelled Manilla profile, in which the Woolomin Association (2.72 tm^{-3}) was used to match the observed data. Both models by Korsch et al. (1993a, 1997) and Bramall and Qureshi (1984) can produce a good fit to the observed data by slightly changing the shape of the Tamworth Belt and introducing a low density granite body as previously discussed. The re-modelled Quirindi profile also shows that both configurations can produce a good match to observed gravity data (*Figures not shown here*). The remodelling of the Manilla and Quirindi profiles indicated that the higher density adopted for Woolomin Association can be used to produce good fit to all gravity profiles.

Alternatively, if the Woolomin Association was assumed to have the same density of 2.67 tm^{-3} as the Sandon Association to the east. The Tamworth, Barraba and Bingara profiles were remodelled to construct a subsurface geometry of the Tamworth Belt incorporating the lower density. Figure 7.10 shows the modelling result of the Tamworth Profile. In this model the Peel Fault shallowly dips to the east, and the Woolomin Association has a thickness of 500-1000 m. Remodelling of the Barraba and Bingara profiles shows similar results as the Tamworth profile (*Figures not shown here*). No geological observations suggest that the Woolomin Association is so thin or that the Peel Fault dips shallowly to the east.

The Woolomin Association was inferred to have a high density on the basis of the measured density of 2.66-2.78 tm^{-3} for chert/jasper and 2.81-3.26 tm^{-3} for dolerite (Table 7.1). Theoretical calculation, based on the quartz density of 2.65 tm^{-3} and hematite density of 5.2 tm^{-3}, assuming that the chert contains 0-5% hematite, the density of the chert would be in a range of 2.65-2.78tm^{-3}, consistent with the measured value of the chert sample collected within the Woolomin Association. It is usually accepted that the Woolomin Association consists mainly of high density red ribbon-bedded chert/jasper, basalt, dolerite and metabasalt with rare low density volcanic sandstone and argillite (Crook, 1961a, b; Leitch, 1974; Cawood, 1980; Korsch, 1977; Aitchison et al., 1992b). In addition regional anchizonal metamorphism on the Woolomin Association (Offler and Hand, 1988) will have led to a slightly increase of the density. Thus it is reasonable to use a high density when modelling the Woolomin Association.

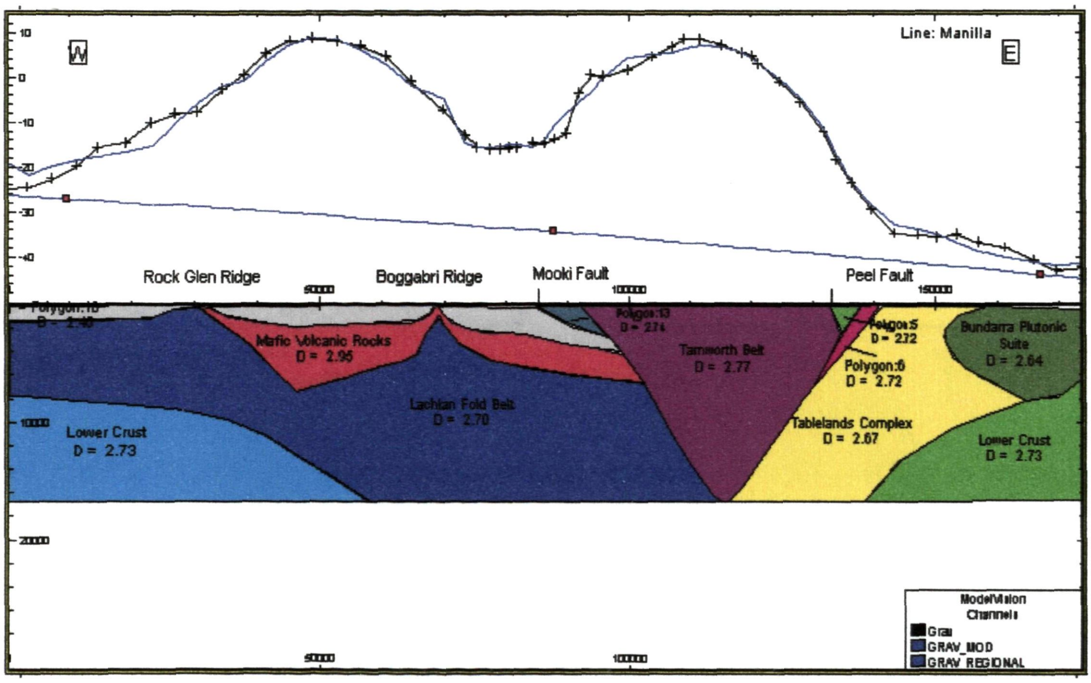

Figure 7.9a 2D gravity model along the Manilla Profile (cross-section view). The reflection seismic model by Korsch et al. (1997) was used to constrain the subsurface geometry of the structural units along the Manilla profile. Polygons 5, 6 represent the high density Woolomin Association, 10 the Gunnedah Basin, and 13 the Tamworth belt Between the Mooki and Kelvin Faults.

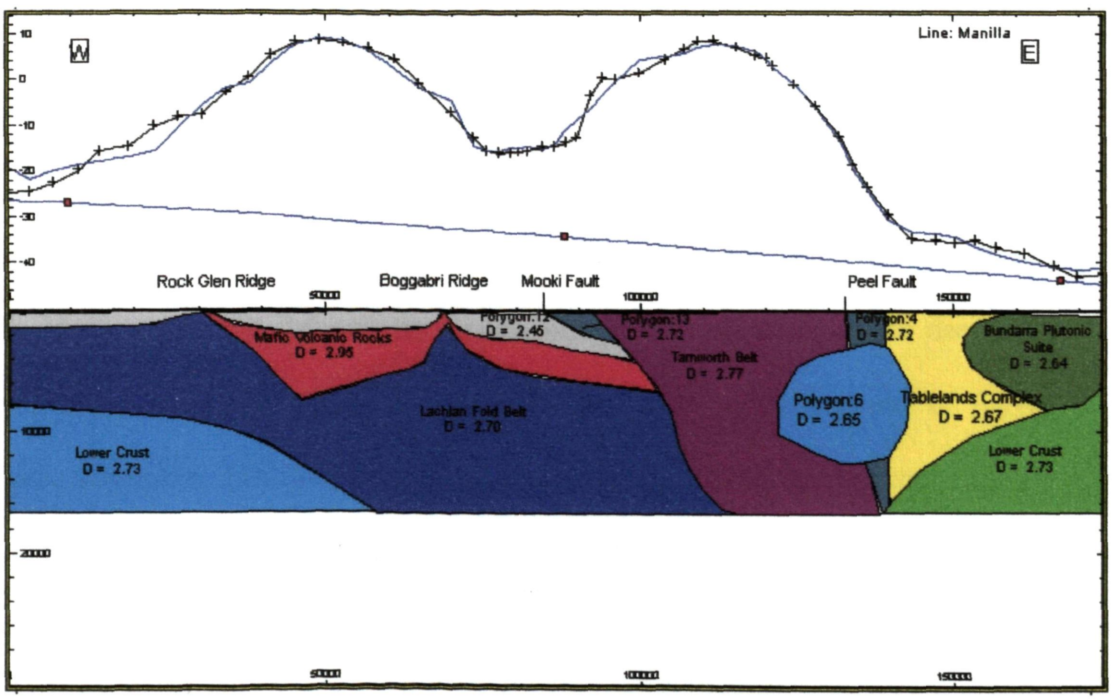

Figure 7.9b 2D gravity model along the Manilla Profile (cross-section view). The Peel Fault was modelled as an east-dipping fault with a depth extent of 15 km. Polygon 4 represents the high density Woolomin Association, 6 a low density unit, 13 the Tamworth belt Between the Mooki and Kelvin Faults and 12 the Gunnedah Basin. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre.

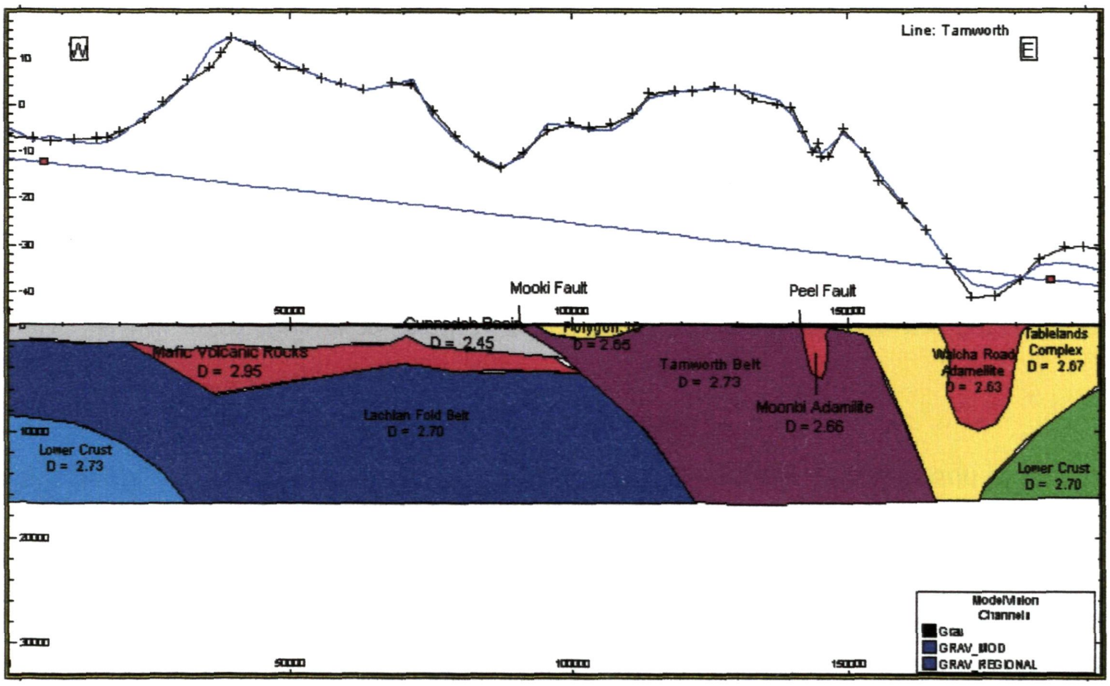

Figure 7.10 2D gravity model along the Tamworth Profile (cross-section view). The Peel Fault was modelled as a shallow east-dipping fault with a low density Woolomin Association. Polygon 10 represents the Werrie Basin. Symbols represent observed data and solid line is the calculated anomaly, V/H=2. Density in tm^{-3}, scale in metre.

7.6.2 Modelling results of the Gunnedah Basin

The Gunnedah Basin in northern NSW forms part of the Early Permian-Triassic Sydney-Gunnedah-Bowen basin system in eastern Australia. The prominent gravity feature within the basin is a gravity high (Meandarra Gravity Ridge) corresponding to the deepest part of the basin. The sedimentary succession of the basin is mainly composed of Early Permian-Triassic sandstone, siltstone, claystone and conglomerate with rare tuff and mudstone (Figure 2.10, Tadros, 1993) and has a relatively low measured density of 2.45 tm^{-3}. The succession is inferred to be relatively thin, usually less than 1000m to the top of the basement that is deformed Lachlan Fold Belt to the west and a thick volcanic succession to the east (e.g. Tadros, 1988; Korsch et al., 1993b; Leitch, 1993; Martin, 1993). It is generally accepted that the Gunnedah Bain formed during an Early Permian extension event during which the westward subduction ceased and the arc was replaced by mafic volcanic rocks of a rift origin (e.g. Murray, 1990; Scheibner, 1993;). The fill of the rift is mafic volcanics that have a high density (2.95 tm^{-3}) (Krassay et al, in press) and are inferred to produce the Meandarra Gravity Ridge (Qureshi, 1984, 1989; Murray et al., 1989; Korsch et al, 1993a, 1997; Krassay et al, in press). This model was supported by Krassay et al (in press) because the alternative model by Leaman (1991) involving local granite bodies could not be applied to the entire Meandarra Gravity Ridge.

All five gravity profiles in this study were modelled with the configuration of the volcanic rift and no alternative modelling was attempted for the Gunnedah Basin. Modelling results indicate that it is possible to produce a good match between the observed gravity data and calculated gravity profile with this configuration. However, the shape of the mafic volcanic body and thickness of the sediments need to be adjusted slightly to get the best fit for each profile. The volcanic bodies show a half-graben shape in all models with a steep dip on its west side and gentle dip on its eastside. For the Manilla and Tamworth profiles, the modelled volcanic bodies (Figure 7.3d, 7.6c) extend eastwards until they are truncated by the east-dipping Mooki-Kelvin fault system. For the rest of the gravity profiles, the modelled volcanic bodies do not extend far enough to reach the Mooki-Kelvin fault system (Figure 7.5c, 7.7c, 7.8b). The maximum thickness of the modelled mafic bodies is variable, ranging from 4.5 to 6 km. Although combining gravity and magnetic models would potentially reduce the ambiguity in the interpretation of the gravity data, there was no attempt to model the magnetic anomalies along the gravity profiles due to an unavailability of a high resolution aeromagnetic dataset.

The model developed by this study has broad similarity with those proposed by Qureshi (1984, 1989, Figure 7.11) and Krassay et al (in press). However, the thickness of the modelled volcanic bodies in this study is much less than the thickness of 12 km inferred by Qureshi (1984), who used a density contrast of 0.2 tm^{-3} between modelled volcanic rocks and Lachlan

Fold Belt. A contrast compared to the Lachlan Fold Belt rocks of 0.25 tm^{-3} is supported by a possible local analogue, the Ben Bullen mafic plutons to the west of Sydney basin, for the likely composition of the mafic volcanic at depth, which has density contrast of 0.2-0.3 tm^{-3} (Qureshi, 1984). The modelled thickness of the mafic unit is less than 4.5-9 km proposed by Krassay et al (in press) and is thicker than the thickness of 3 km inferred by Korsch et al (1993a, b, 1997) from the BMR91-G01 seismic data.

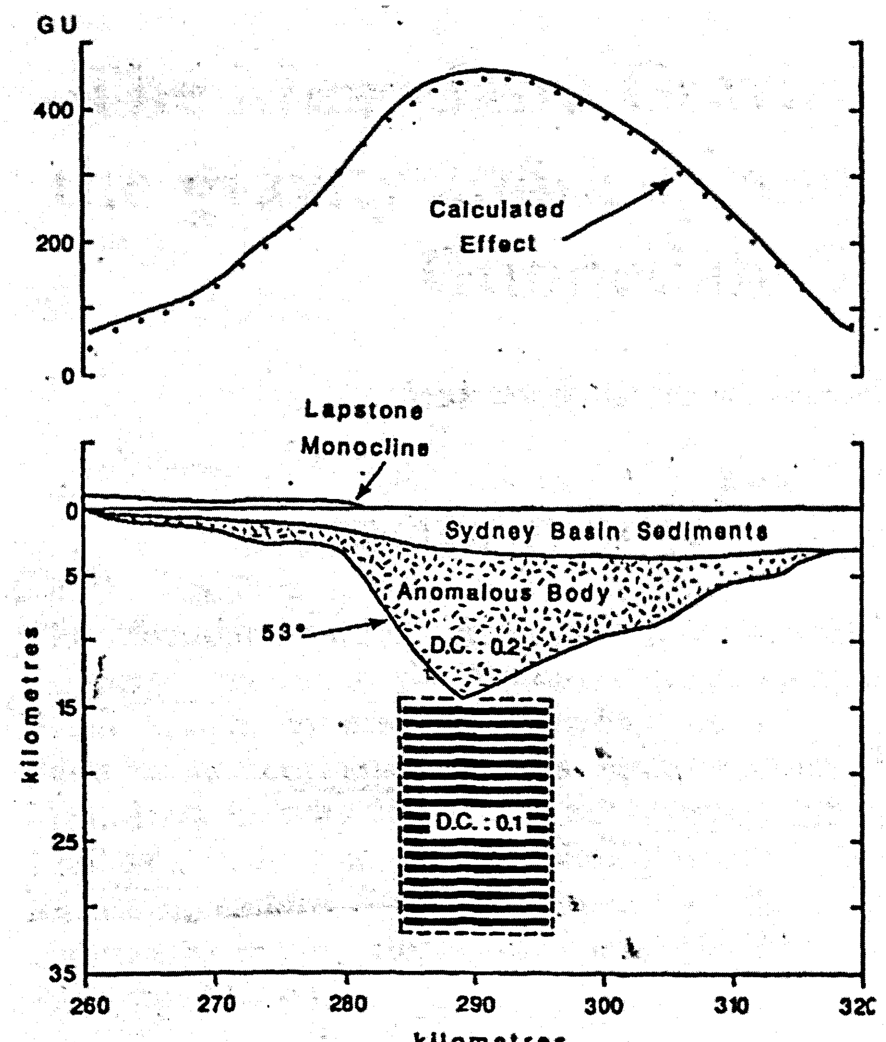

Figure 7.11 The Meandarra Gravity Ridge within the Sydney Basin and its interpretated source by (Qureshi, 1989) on natural scale along the Bathurst and Mona Vale profile. Dots represent the calculated effect of the source underlying the Sydney Basin. The western boundary of the source in the upper crust dips at 53° and marks a major basement fault. A zone of sills with a density contrast of 0.1 tm-3 forms a link to mantle.

7.6.3 Modelling Results of the Tamworth Belt, Mooki and Peel Faults

Modelling of the gravity data collected in this study mainly focused on the gravity high over the Tamworth Belt, and evaluating the dip and depth of the Mooki and Peel faults. The Mooki Fault that forms the boundary between the Gunnedah basin and Tamworth Belt, has been inferred to dip shallowly to the east at 40°-50° (Carey, 1934a, b) and 30° (Liang, 1991). It is also inferred that the Mooki Fault shallowly dips to east at 25°-30° from both modelling of ground magnetic data north of Gunnedah (Ramsay and Stanley, 1976) and interpretation of the seismic data east of Boggabri (Korsch et al., 1993a, 1997). Interpretation of the magnetic data from this study also fit this geometry. Modelling results of the five gravity profiles show that on each, the Mooki Fault can be modelled having a similar shallow east-dipping orientation, where the Late Carboniferous and Early Permian Rocks of the Tamworth Belt were thrust over Permian rocks of the eastern margin of the Early Permian-Triassic Sydney-Gunnedah Basin for 15-30 km. The displacement of the Mooki Fault is consistent with the 10 km suggested by Korsch et al (1997) and 25 km by Glen and Brown (1993). It is different to the work of Woodward (1995), who indicated 45-58 km of combined displacement on the Mooki and Kelvin thrust system. The difference in part may be due to the fact that Woodward included a displacement of the Kelvin Fault to the Mooki Fault. The displacement of the Kelvin Fault could not be estimated from this gravity model. On the other hand, the study of Woodward (1995) was also questioned by Korsch et al. (1997) and Roberts et al. (2004) due to his assumption that the NEFB extended westward beneath Lower Permian volcanic and sediments of the Gunnedah Basin.

To the east of the Mooki Fault, the Tamworth Belt represents the Palaeozoic forearc basin and produces a prominent gravity high. The mainly sedimentary rocks of the belt are inferred to be the weathered products of mafic volcanism (Chappell, 1961, 1968). Glen et al (1993) also suggested that the Tamworth Belt was mainly composed of volcanic-rich lithologies on the basis of the excellent correlation between the prominent seismic reflector and mafic volcanics mapped in the Mostyn Vale Formation (Glen and Brown, 1993; Glen et al., 1993, Greentree and Flood, 1999). The gravity anomaly of four out of five of the profiles is a broad high characterised by a gradual reduction on the west side and a sharp reduction on the east side over the Tamworth Belt. The exception is the Quirindi Profile that has a sharp western boundary and gradual eastern boundary. Modelling of the gravity data indicates that the width of the Tamworth Belt ranges from 49 to 59 km with the Barraba profile being the longest (~59 km) and the Nundle profile being the shortest (~49 km) at the surface in all gravity profiles. Modelling results confirmed that the Tamworth Belt must have a relatively high density (2.74-2.77 tm^{-3}) compared to the rocks of both the Tablelands Complex to the east and the Sydney-Gunnedah Basin and Lachlan Fold Belt rocks to the west. It is noteworthy that the gravity anomaly over the Tamworth Belt is not only produced by the Tamworth Belt but also by a narrow belt of rocks just east of the Peel Fault, the Woolomin Association as well. The Woolomin Association, the most western part of the accretionary wedge, also has a high density of 2.72-2.75 tm^{-3} immediately east of the Peel Fault and contributes to the Tamworth Belt gravity anomaly. To the east of the Woolomin Association the Sandon Association of the Tablelands Complex that joins the Woolomin Association to the west, and consists of low density greywackes, sandstone and mudstones with minor chert and jasper (Crook, 1961a, b; Leitch 1974; Cawood, 1980; Korsch, 1977; Aitchison et al., 1992b). The Sandon Association has been intruded by granitic rocks of the Bundarra Plutonic and the Moonbi Plutonic Suites of the New England Batholith (Shaw and Flood, 1981), representing a low-density unit and producing a gravity low.

The Peel Fault forming the boundary between the Tamworth Belt and the Tablelands Complex is a key structural component of east Australia. All gravity profiles could be modelled to get a good fit for the observed gravity anomalies using either the configuration of

Korsch et al. (1997), that has the Tablelands Complex extend westward under the Tamworth Belt, or the configuration of Bramall and Qureshi (1984) who has the Tablelands Complex thrust over the Tamworth Belt. Modelling of the Manilla and Quirindi Profiles indicate that the Peel Fault could be either modelled as an east-dipping fault with a cut off at a depth of around 1 km by a westward underthrust Tablelands Complex, or modelled as an east-dipping fault to a depth of more than 1 km with an introduction of low-density unit (granite) beneath the Tamworth Belt. Both low density units for the Quirindi and Manilla profiles may represent blind granitoid plutons emplaced beneath the Tamworth Belt during Late Carboniferous to earliest Permian extension event (Korsch, 1982; Leitch, 1988; Allan and Leitch, 1990) or the Late Permian (Flood and Shaw, 1977; Shaw and Flood, 1981).

Modelling results from this study do not fully support the previous seismic model by Korsch et al (1993a, 1997) on a broad regional scale. The results from this study indicate the very limited depth extension of the Peel Fault proposed by Korsch is only applicable for the Manilla and Quirindi profiles. Korsch et al. (1993a, 1997) point out that the Peel Fault is unlikely to be imaged because of its steep dip. It should be noted that the seismic data is of poor quality in the vicinity of the Peel Fault where the surface dips are much steeper (Korsch et al. 1993a, 1997; Edwards, 1996), and where the moderately west-dipping structure just beneath the Peel Fault at a shallow depth is accepted. The east-dipping Peel Fault extending to a great depth of more than 15 km can be modelled for all five gravity profiles with an introduction of two low-density granites for the Manilla and Quirindi profiles. Modelling results support the previous geological and geophysical work on the east-dipping Peel Fault (e.g. Benson, 1913; Crook, 1963; Ramsay and Stanley, 1976; Edwards, 1996). The key point to be stressed is that modelling of the five gravity profiles does not exclude the possibility that the Peel Fault is truncated by a westward underthrust low density Tablelands Complex but this must occur at depth of 7 km or more (Figure 7.6d, 7.7b, 7.8a).