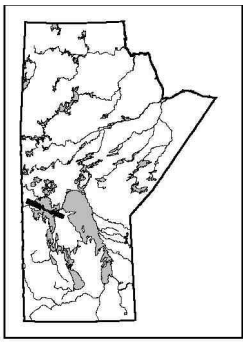
GRAVITY AND MAGNETIC PROFILE ALONG THE PAS MORAINE

by A.T. Surasky[1], I.T. Hosain and A.J. Letkemen[1]



Surasky, A.T., Hosain, I.T. and Letkemen, A.J. 2001: Gravity and magnetic profile along The Pas Moraine; *in* Report of Activities 2001, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 164-171.

SUMMARY

In June and July 2001, a gravity and magnetic survey was completed along The Pas Moraine. The survey was completed along Provincial highways 6, 60 and 10. The survey crossed the Superior Boundary Zone almost 90 degrees from strike. The purpose of this survey was to investigate the gravity and magnetic field of the Superior Boundary Zone in this region, and to obtain more information on the possible southern extension of the Thompson Nickel Belt.

INTRODUCTION

Gravity and magnetic surveys were completed during an eight-day survey starting June 26 along The Pas Moraine in central Manitoba in order to obtain a more detailed view of the gravity and magnetic field in the area. Of particular interest in the survey is the response from the Superior Boundary Zone, with possible implications for the extension of the Thompson Nickel Belt beneath the Paleozoic cover. The surveys were carried out along Provincial Highway 6, Provincial Highway 60, and Provincial Highway 10, from south of Grand Rapids to Westray. The survey area is illustrated in Figure GS-26-1.

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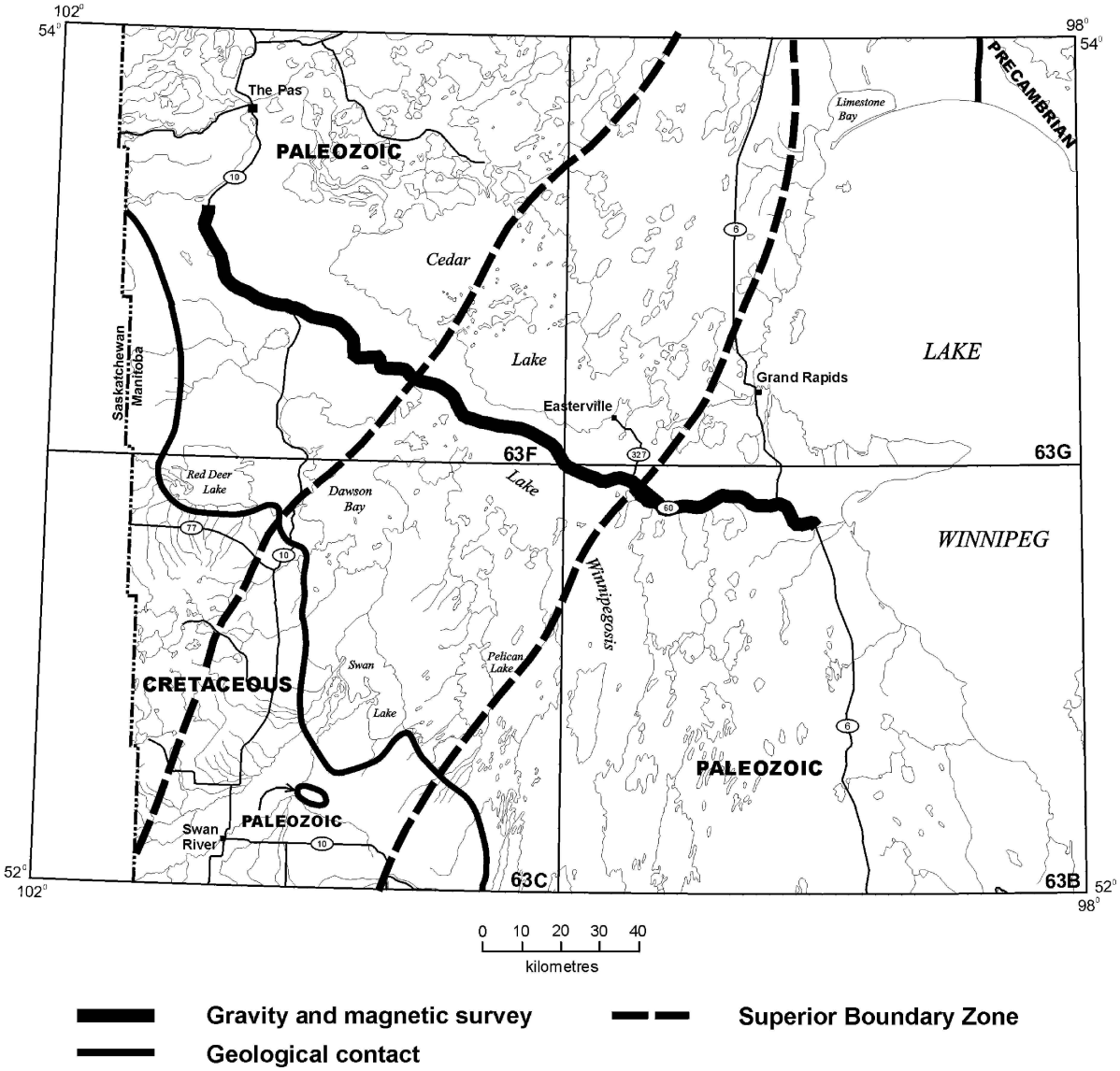


Figure GS-26-1: Location of survey area.

GEOPHYSICAL SURVEYS

Gravity Survey

The gravity survey was completed using a Worden Gravity Meter, no. 543, model III, built by Texas Instruments, with a sensitivity of 0.04 mgal, belonging to the Department of Geological Sciences, University of Manitoba. Readings were taken along the highways at 1 km intervals. The readings were taken in the ditch adjacent to the highway. Two readings were taken at each station location; the results were then averaged. The gravity meter was placed on a tripod approximately 50 cm off the ground when the readings were taken. The gravity survey used a base station in order to correct for drift. The base station was visited approximately every two hours.

The site position was recorded using a Garmin 12 XL global positioning system (GPS). As the elevation data from the GPS is not sufficiently accurate for gravity surveying, station heights relative to the centre of the highway were recorded.

The elevation data was obtained using highway profile maps from the Manitoba Department of Transportation and Government Services. The station location was found on the highway profile and the elevation was read off the profile. The difference between the height of the highway centreline and the station was subtracted from the highway profile elevation, to result in the actual station elevation. Using this procedure, the elevation information is accurate to approximately 50 cm.

Data Reductions

Gravity data needs to be reduced so that only lateral subsurface density variations are represented by the data (Reynolds, 1997). In the processing of the gravity data, the following corrections were made in order to reduce the data to the Bouguer anomaly:

- drift correction (using repeat base-station readings)
- free-air correction

$$dg_F = 0.3086h$$

where h is the height differential between stations and δg_F is in mgal

- Bouguer correction

$$dg_B = 2pGrh$$

where G = 6.67 x 10^{-8} $m^3 \cdot Mg^{-1} \cdot s^{-2}$, ρ = density (a density of 2.67 $Mg \cdot m^{-3}$ [2670 $kg \cdot m^{-3}$] was assumed) and δg_B is in mgal

- latitude correction

$$dg_L = -0.8108\sin(2f)$$

where ϕ is degrees latitude, δg_L is in mgal/km north

The terrain correction was not applied because the survey area had limited relief, and with the assumed density, the correction was negligible. The final reduced data are shown in Table GS-26-1.

Results

The Bouguer gravity anomaly profile is displayed in Figure GS-26-2. There are two definite high areas in the response with a trough in the middle. These spikes are of the order of 60 mgal in amplitude. There are also shorter wavelength (<10 km) and smaller amplitude variations (<3 mgal) toward the eastern end of the survey.

Modelling

Some preliminary two-dimensional modelling of the gravity data was done using the computer program Potent (version 2.0), produced by PC Potentials. A linear regional trend was removed from the data, such that the east and west ends of the survey had a constant value. The bodies in the model were given a strike of 040 degrees, which is consistent with strike of the gravity trends in this region of the province (Geological Survey of Canada, 1995). The aim of the modelling was to combine other geophysical and geological data with the gravity data to derive a model that fit the data. The auxiliary data came from Lucas et al. (1996) and their interpretation of the LITHOPROBE seismic line S3B (Fig. GS-26-3 and -4). The interpreted contacts from the seismic data were used to form lithological bodies, which comprise the bodies in the model. The model consists of 10 two-dimensional polygonal prisms located within the crust. A flat Moho at 40 km depth was used in the modelling. The gravity data were fitted by iteratively adjusting the density of the bodies. The final model is shown in Figure GS-26-5. The data fits fairly well into the model that consists of 10 bodies. The final characteristics of the bodies in the gravity model are shown in Table GS-26-2. The lithological units in the table are from Lucas et al. (1996). The density of the Archean granitoid can be taken as the background density because this rock unit has a density contrast of zero with respect to the actual background density.

This gravity model is only preliminary but shows that the interpreted contacts from LITHOPROBE seismic data agree with the gravity data.

Table GS-26-1: Final reduced data collected along The Pas Moraine.

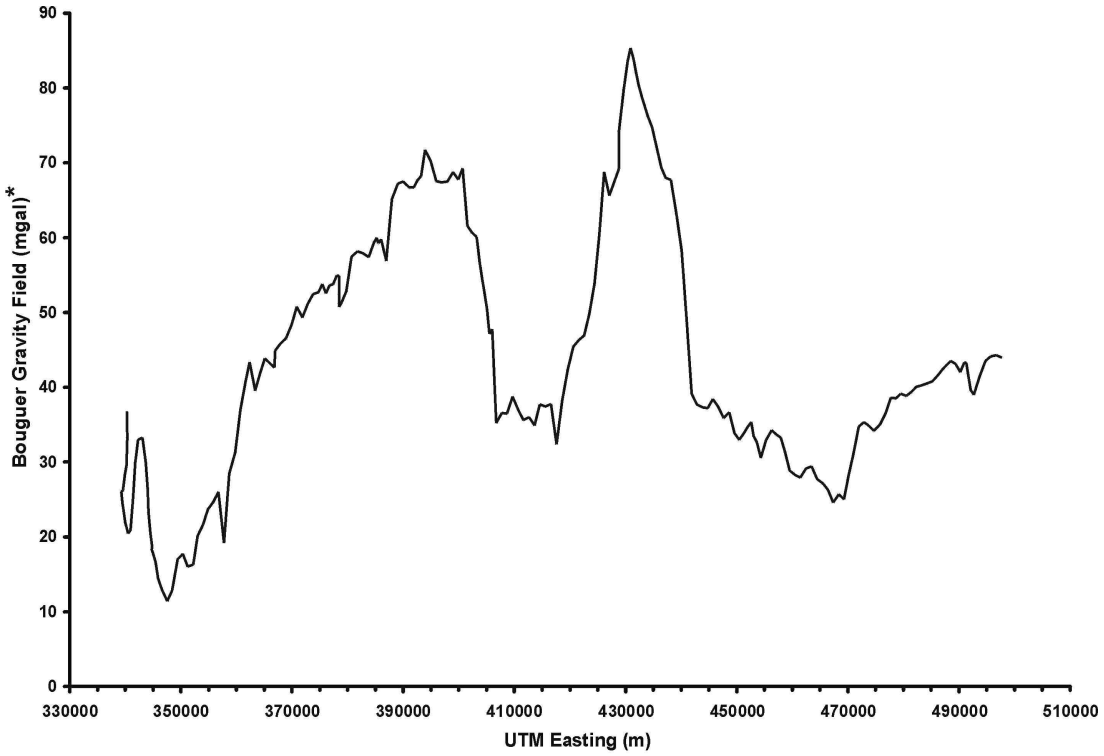
Station	Northing (m)	Easting (m)	Gravity (mgal)	Total Magnetic Field (nT)
1	5857460	497738	743.9722531	59166.00
2	5857475	496715	744.2860888	59265.90
3	5857392	495685	744.1313447	59245.95
4	5857322	494722	743.4937507	59355.90
5	5857176	493709	741.3558240	59235.27
6	5857234	492656	739.0088650	59215.40
7	5857978	492091	739.6096866	59202.10
8	5859301	491593	741.9407692	59546.90
9	5859953	491338	743.2716683	59484.60
10	5860830	490967	743.3221563	59537.70
11	5861496	490206	742.0189398	59470.80
12	5862035	489344	743.1606265	59492.50
13	5862513	488508	743.4934354	59448.80
14	5862679	487749	742.9932876	59706.90
15	5861874	487068	742.3997261	59598.18
16	5861496	486161	741.5788324	59477.80
17	5861382	485161	740.7498255	59483.92
18	5861382	484152	740.4921680	59493.01
19	5861664	483190	740.2230045	59481.64
20	5862023	482292	740.0620327	59439.55
21	5862535	481389	739.3329319	59241.70
22	5863077	480487	738.8426297	59217.16
23	5863100	479528	739.1086199	59623.78
24	5863626	478620	738.5347946	59351.72
25	5864045	477706	738.6015566	59279.00
26	5864076	476756	736.5155847	59282.96
27	5864108	475750	734.9990135	59323.42
28	5864281	474724	734.1808311	59258.20
29	5864173	473717	734.8860859	59326.98
30	5863699	472857	735.3186972	59412.60
31	5863198	471947	734.7419093	59509.96
32	5862697	471050	731.1967151	59457.29
33	5862220	470186	728.3287944	59457.83
34	5861737	469297	725.0024528	59435.69
35	5861284	468387	725.6697235	59449.56
36	5861146	467384	724.5757523	59483.31
37	5861256	466386	726.2760048	59400.05
38	5861693	465490	727.1629032	59392.42
39	5861720	464496	727.6946178	59481.54
40	5861645	463460	729.4216002	59472.91
41	5861577	462474	729.1575168	59597.28
42	5861340	461472	727.9231734	59543.02
43	5860937	460556	728.2533234	59614.89
44	5860717	459544	728.8495620	59586.26
45	5860960	458655	731.4334554	59459.50
46	5861766	457955	733.2350541	59619.62
47	5862443	457211	733.6151633	59647.50
48	5862889	456276	734.2222623	59636.30
49	5862836	455271	732.9252051	59714.90
50	5863132	454312	730.5885528	59675.80
51	5863914	453649	732.6766898	59603.40
52	5864672	453012	733.4944905	59568.90
53	5865555	452606	735.3543983	59624.60
54	5866326	451949	734.6725809	59630.90
55	5867064	451211	733.8296251	59686.62
56	5867726	450479	732.9635208	59513.34
57	5868214	449621	733.8480091	59540.04
58	5868479	448633	736.6394109	59492.73
59	5868748	447626	735.8752308	59464.42
60	5869015	446633	737.4053964	59398.61
61	5868690	445706	738.4103762	59330.06
62	5868325	444769	737.1820129	59314.50
63	5867975	443809	737.3085898	59306.72
64	5867849	442850	737.7005983	59254.88
65	5868174	441892	739.1116316	59187.55
66	5868765	441041	748.5230237	59268.71
67	5869227	440120	758.2093043	59211.56
68	5869229	439147	763.0929512	59143.72
69	5869331	438139	767.7330879	59169.97
70	5869710	437212	767.9701777	59167.82
71	5870284	436414	769.3696920	59265.48
72	5870910	435552	772.1402273	59102.34
73	5871500	434749	774.7351580	59081.19
74	5872074	433958	776.3022025	59235.85
75	5872278	432960	778.6744332	59088.51
76	5872989	432342	780.4651730	59059.87
77	5873826	431897	782.0178223	59016.64
78	5874737	431391	784.0072984	59040.72
79	5875634	430917	785.3528216	59050.30
80	5876544	430415	783.6337647	59069.72
81	5877180	429692	779.7810773	59061.34
82	5877699	428786	774.2220911	59075.27
83	5878178	428786	769.1983987	59078.19
84	5878683	427051	765.6588199	59079.77
85	5879178	426178	768.7475098	59125.70
86	5879676	425304	760.3961358	59136.66
87	5880187	424411	753.9110155	59187.24
88	5880578	423496	749.8280363	59226.32
89	5880961	422546	746.9027434	59215.90
90	5881333	421606	746.2914727	59232.32
91	5881442	420593	745.4162685	59239.54
92	5881511	419599	742.3583427	59215.49
93	5881602	418577	738.1790844	59223.27
94	5881698	417589	732.3618337	59219.16
95	5881798	416555	737.7796155	59215.06
96	5882048	415571	737.4134989	59288.89
97	5882311	414596	737.7122512	59253.78
98	5882554	413626	734.8879958	59253.18
99	5882524	412622	735.9857197	59274.57
100	5883075	411651	735.6250263	59229.40
101	5883330	410675	736.9673896	59215.85
102	5883584	409678	738.7493801	59199.24
103	5883837	408706	736.4793746	59211.58
104	5884103	407716	736.5330316	59191.93
105	5884341	406719	735.2246819	59237.33
106	5885025	405980	747.7614939	59209.64
107	5885941	405531	747.1432290	59198.44
108	5886849	405094	750.4192911	59186.75
109	5887767	404650	752.5342564	59195.10
110	5888691	404204	754.4560572	59160.37
111	5889599	403755	756.4977221	59171.76
112	5890400	403182	760.1159684	59163.62
113	5891006	402378	760.6776792	59166.42
114	5891600	401576	761.5865390	59149.82
115	5892235	400721	769.2519369	59172.13
116	5892737	399873	767.7540419	59191.89
117	5892935	398931	768.7791588	59361.61
118	5893142	397931	767.5023364	59455.42
119	5893361	396900	767.3922911	59405.51
120	5893562	395935	767.5606731	59364.65
121	5893764	394957	770.2467272	59306.56
122	5894020	393952	771.7283506	59195.60
123	5894667	393192	768.2315568	59179.71
124	5895431	392545	767.6893795	59217.75
125	5896209	391882	766.7341583	59203.16
126	5896771	391019	766.7548480	59128.77
127	5896880	389985	767.5101022	n.a.
128	5896968	389021	767.2398117	59103.65
129	5897036	387986	765.1131855	59097.56
130	5897059	386964	756.8956568	59217.50
131	5897396	386026	759.7580775	59131.95
132	5898220	385491	759.2532084	59123.74
133	5899256	385260	760.0071610	59100.86
134	5899980	384754	759.3083813	59128.30
135	5899927	383757	757.3757418	59094.76
136	5899803	382765	757.8697757	59104.63
137	5899648	381769	758.1946631	59137.06
138	5899659	380732	757.4708172	59159.01

Note: n.a. – not available

Table GS-26-1: Final reduced data collected along The Pas Moraine. (continued)

Station	Northing (m)	Easting (m)	Gravity (mgal)	Total Magnetic Field (nT)
139	5900052	379772	752.8388751	59162.47
140	5900567	378921	751.3308050	59181.93
141	5901453	378444	750.7670867	59174.88
142	5902431	378475	751.1539582	59195.34
143	5903456	378473	752.4656099	59197.28
144	5904488	378501	754.9285824	59197.15
145	5905386	378051	754.9059180	59227.49
146	5906147	377381	753.7807690	59222.32
147	5906910	376730	753.6321773	59237.49
148	5907675	376082	752.5488548	59320.82
149	5908429	375444	753.7855193	59162.32
150	5909245	374763	752.6658824	59212.82
151	5909598	373824	752.4613443	59178.32
152	5909823	372843	751.1948798	59242.32
153	5910042	371852	749.3544261	59243.82
154	5910260	370863	750.7393139	59338.32
155	5910479	369881	748.3624167	59357.82
156	5910694	368881	746.5509168	59343.82
157	5910903	367927	745.8498502	59378.82
158	5911333	366974	744.9044811	59425.99
159	5911837	366837	742.6546755	59418.91
160	5912330	365127	743.8360134	59406.70
161	5912808	364239	741.7998561	59423.50
162	5913259	363401	739.5699152	n.a.
163	5913055	362392	743.3699025	59419.82
164	5913546	361632	740.7737708	59461.20
165	5913890	360738	737.0049555	59450.00
166	5914164	359740	731.2939461	59431.72
167	5914196	358727	728.4532679	59437.51
168	5914374	357733	719.2326881	59480.44
169	5914642	356731	726.0349467	59434.99
170	5914896	355784	724.6576232	59416.28
171	5915336	354876	723.6880104	59422.71
172	5915776	353980	721.5415817	59423.76
173	5916014	353010	720.1496355	59428.69
174	5916663	352237	716.2876046	59355.74
175	5917086	351241	715.9991811	59344.92
176	5917427	350323	717.7264784	59344.85
177	5917777	349389	717.0336991	59326.86
178	5918172	348418	712.7592863	59264.36
179	5918666	347565	711.4071499	59289.79
180	5918970	346620	712.8753619	59230.80
181	5919717	345921	714.4153984	59249.31
182	5920575	345438	716.5724935	59246.40
183	5921470	344902	718.0726629	59289.41
184	5922430	344719	718.2000676	59356.41
185	5923468	344785	718.6938585	59384.42
186	5924406	344523	720.3940734	59276.85
187	5925405	344185	723.2860610	59200.27
188	5926346	343996	726.4345840	59157.20
189	5927343	343690	729.9990379	59339.71
190	5928149	343081	733.2728764	59403.22
191	5928828	342275	732.9728171	59767.12
192	5929689	341782	729.9683254	59818.09
193	5930637	341373	724.8825867	59445.11
194	5931550	340965	720.8761342	59252.95
195	5932510	340522	720.4696566	59449.86
196	5933335	340016	721.9054533	59718.21
197	5934223	339475	724.4513863	59656.05
198	5935139	339249	725.9881211	59865.40
199	5936141	339587	726.1680679	59645.75
200	5937090	339904	728.3252691	59641.54
201	5938036	340222	729.5421650	59344.33
202	5939018	340349	733.2706124	59253.62
203	5940062	340250	736.7634993	59236.96

Note: n.a. – not available



*700 mgal is subtracted from the reduced gravity readings.

Figure GS-26-2: Profile of the Bouguer gravity anomaly showing two gravity peaks of approximately 60 mgal.

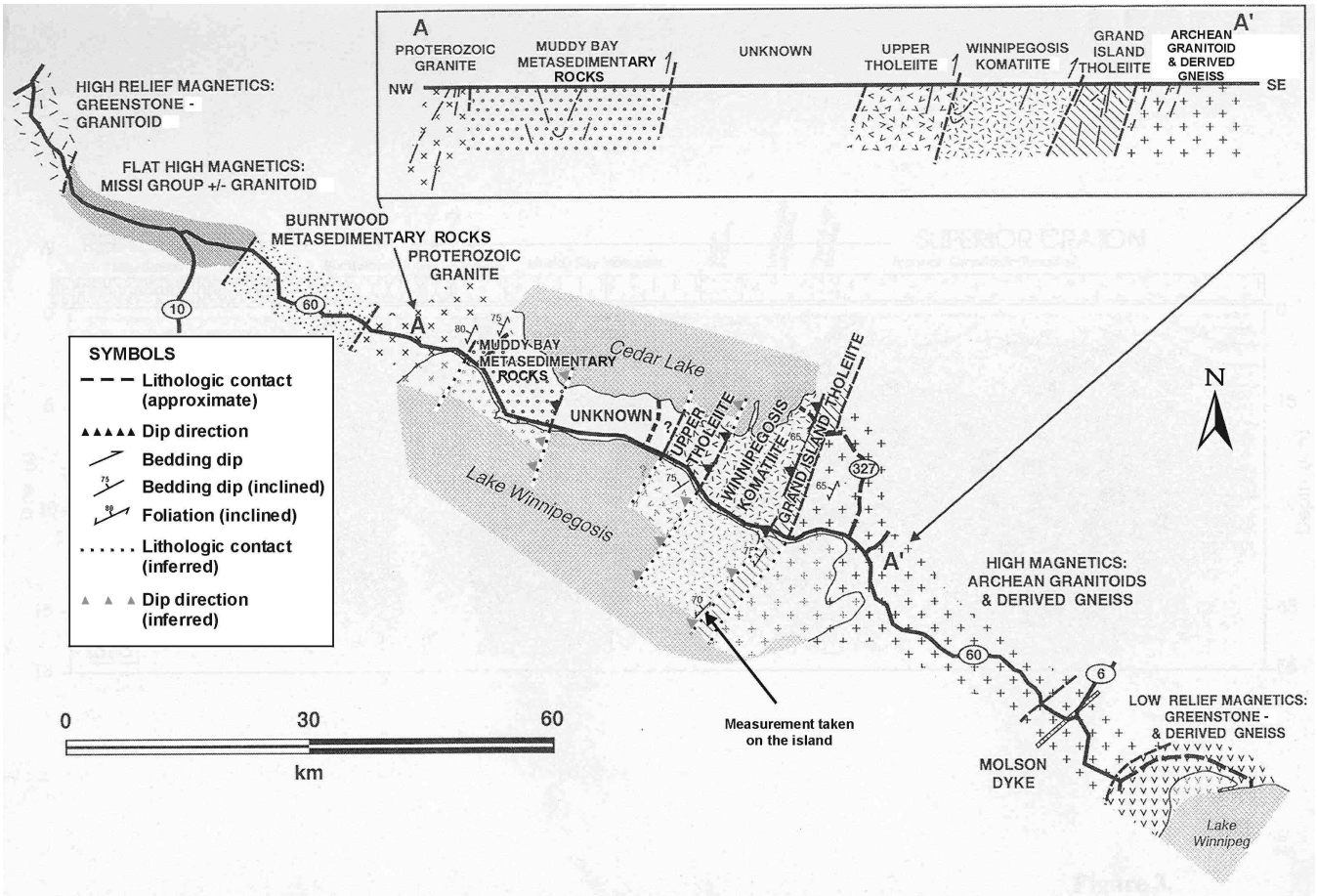


Figure GS-26-3: Map view of lithological units in survey area (from Lucas et al., 1996).

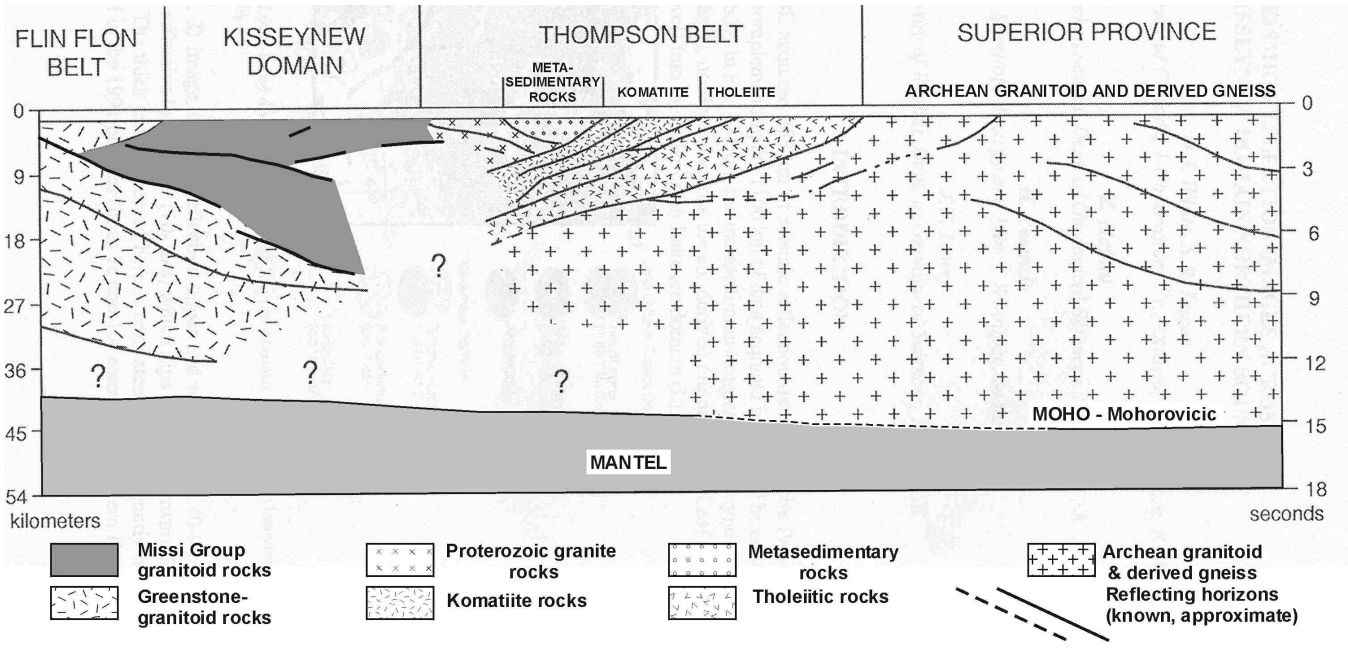


Figure GS-26-4: Seismic model along Line S3B (from Lucas et al., 1996).

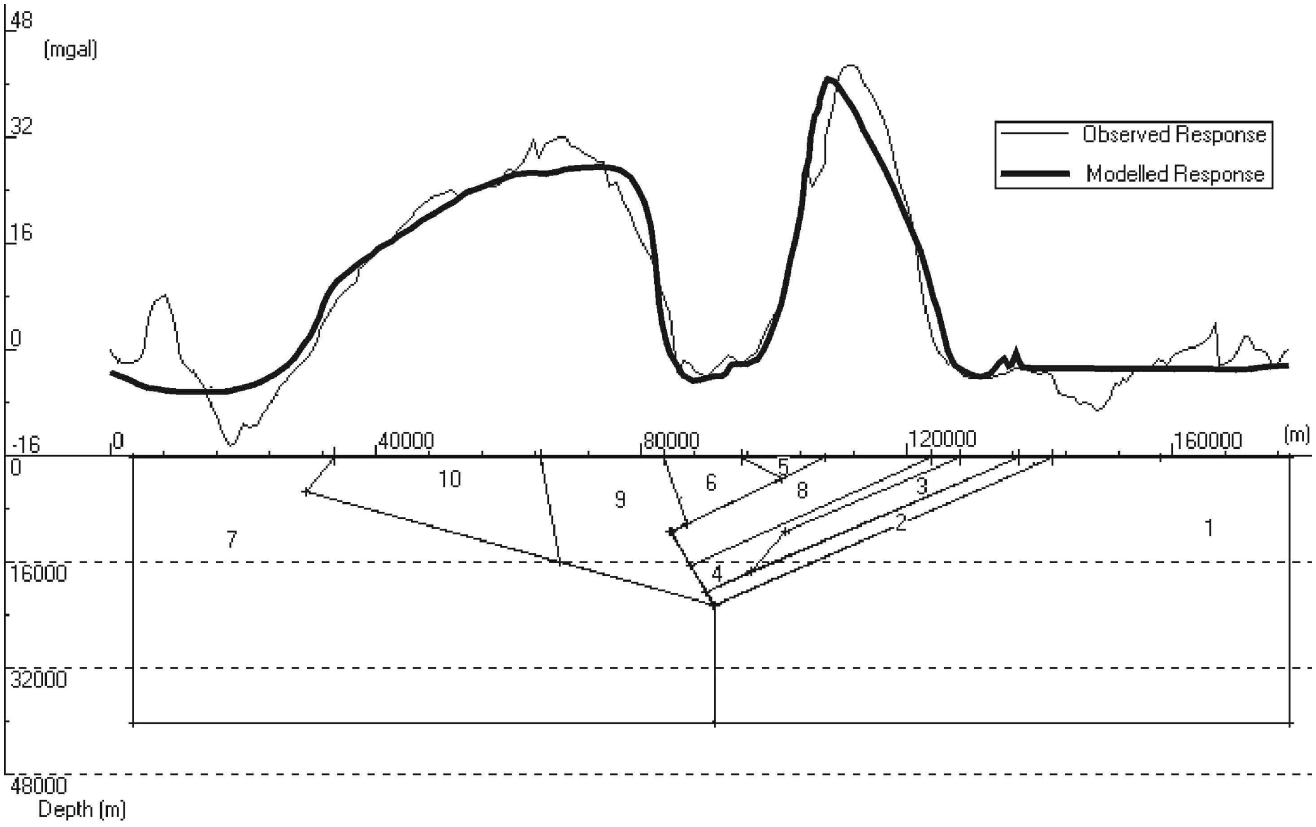


Figure GS-26-5: Preliminary model fitted to the gravity data. The model consists of 10 crustal bodies.

Table GS-26-2: Typical and average analyses of selected elements and element ratios.

No.	Rock name	Body type	Depth (m)	Strike (deg)	Dip (deg)	Plunge (deg)	Density (g/cm^3)
1	Archean granitoid	polygonal prism	250	40	90	0	0.00
2	Grand Island tholeiite	polygonal prism	250	40	90	0	-0.01
3	Winnipegosis komatiite	polygonal prism	250	40	90	0	-0.05
4	Upper tholeiite	polygonal prism	250	40	90	0	0.23
5	Muddy Bay metasedimentary rocks	polygonal prism	250	40	90	0	-0.35
6	Proterozoic granite	polygonal prism	250	40	90	0	-0.19
7	Greenstone/granitoid	polygonal prism	250	40	90	0	-0.01
8	Unknown	polygonal prism	250	40	90	0	0.16
9	Burntwood metasedimentary rocks	polygonal prism	250	40	90	0	0.05
10	Missi Group	polygonal prism	250	40	90	0	0.06

Magnetic Survey

The magnetic survey was completed using the Scintrex MP-3 Proton Magnetometer, with a sensitivity of 1 nT. Total magnetic field readings were taken at the same stations as the gravity measurements. Two total magnetic field readings were taken at each station and then averaged. A magnetic base station was used and was revisited approximately every two hours.

Data reductions

The magnetic field drift was removed from the data by using a base station with total magnetic field repeat readings. The final reduced data are shown in Table GS-26-1.

Results

The total magnetic field profile is shown in Figure GS-26-6. There are numerous high-frequency, high-amplitude spikes in the response but there are also general magnetic trends that can be seen (including the rise from 350000 to 370000 east). Initial comparison of the Bouguer gravity anomaly and total magnetic field suggests an inverse correlation.

Modelling

Some preliminary two-dimensional modelling of the magnetic data was done using the same computer program as the gravity data (Potent). A linear regional trend was removed from the data, such that the east and west ends of the survey had

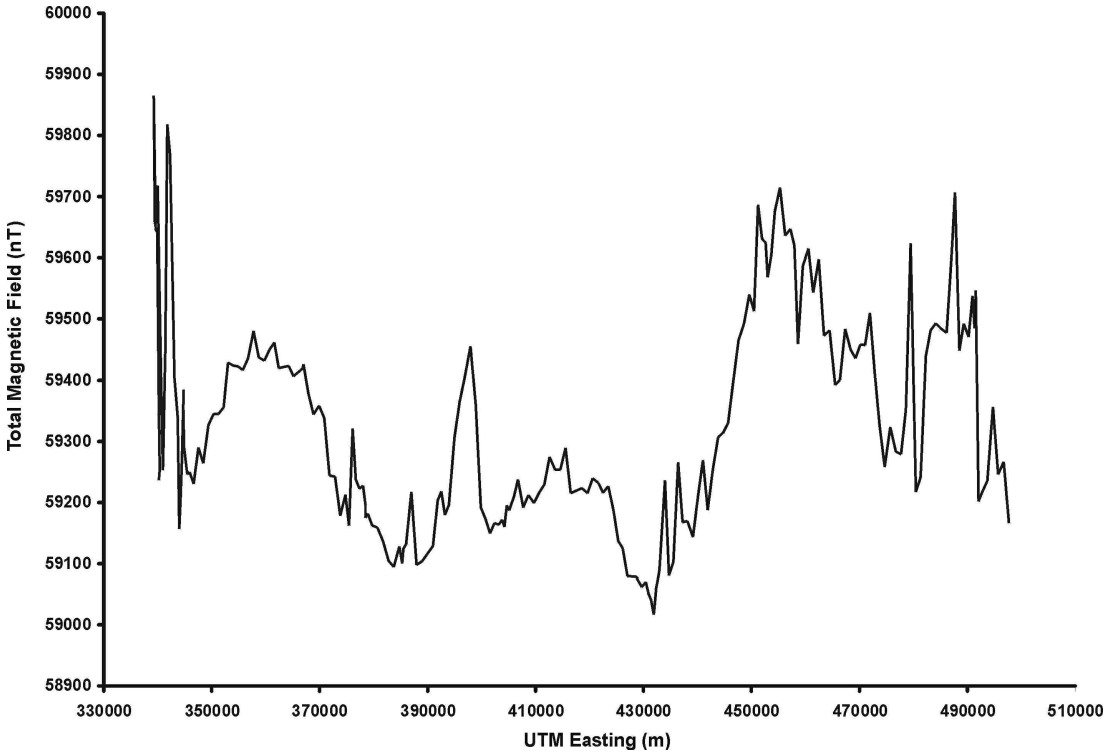
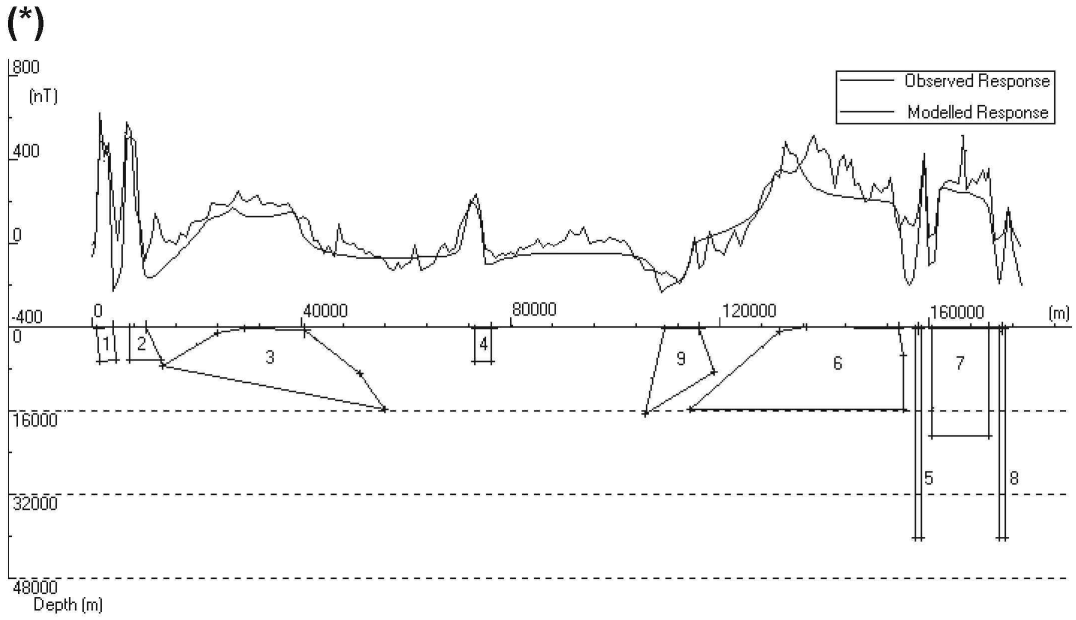


Figure GS-26-6: Profile of total magnetic field response. An inverse relation with the Bouguer gravity anomaly is evident.

the same value. The aim of the modelling was to provide a very simple model that fit some of the general magnetic trends in the data. Since the magnetic response is less sensitive to depth, the model was confined to the upper crust. These data were modelled based on susceptibility; however, it is possible that some of the response is due to remanence. The model consists of seven polygonal prisms, located in the upper crust, and two dykes. The data were fitted by iteratively adjusting the magnetic susceptibility, and the apexes of the bodies. In this model, the inducing field was given a magnitude of 59 000 nT, an Azimuth of 014 degrees and an inclination of –69 degrees. As with the gravity data, the bodies were given a strike direction of 040 degrees. The final model is illustrated in Figure GS-26-7. The bodies in this model are poorly resolved at depth. Some drastic changes in the depth of the apexes of the bodies do not greatly affect the magnetic response. The model shows agreement with the gravity model in that the larger bodies (9, 6 and 3) show the same dip directions as the gravity bodies in this area. The characteristics of the bodies of the magnetic model are given in Table GS-26-3.



(*) 59,200 nT is subtracted from the reduced Total Magnetic Field readings.

Figure GS-26-7: Preliminary model fitted to the magnetic data. This model consists of nine upper crustal bodies, including two dykes.

Table GS-26-3: Characteristics of the bodies in the magnetic model.

No.	Body type	Depth (m)	Strike (deg)	Dip (deg)	Plunge (deg)	Susceptibility (SI)
1	polygonal prism	80	40	85	0	0.0280
2	polygonal prism	80	40	89	0	0.0273
3	polygonal prism	571	40	90	0	0.0126
4	polygonal prism	250	40	90	0	0.0122
5	dyke	250	40	90	0	0.0332
6	polygonal prism	286	40	90	0	0.0196
7	polygonal prism	250	40	90	0	0.0183
8	dyke	250	40	90	0	0.0198
9	polygonal prism	250	40	90	0	-0.0070

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