GEORG NEUMAYER'S MAGNETIC SURVEY OF THE COLONY OF VICTORIA 1858–1864

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From 1858 to 1864 Georg Neumayer supervised and personally observed measurements of magnetic declination, inclination and intensity at the Flagstaff Hill and the new Melbourne observatories. During this time he also travelled extensively to make regional observations at over 230 locations throughout the colony. The setting up and the layout of his instruments in the observatories, the measurements made and a brief summary of the published results is included here as are accounts of each of Neumayer's trips, some of which were to remote regions and at times made in hazardous conditions. Neumayer's travelling companions are identified and specific incidents are highlighted. His innovative study of the Cranbourne meteorite is discussed along with his mentions of the magnetic responses of geological structures he had seen in his travels. Neumayer's regional magnetic results and his published magnetic maps are then summarised and placed into context with work by others.

Keywords: Flagstaff Observatory, Magnetic Survey of Victoria, Cranbourne Meteorite

> By a Magnetic Map of a country we can draw a conclusion as to its probable value for agricultural and mining purposes. It is more than probable that there exists a relation of terrestrial Magnetism and the great tracts of auriferous land in Australia, and such a map would enable us to point out new spots of the above mentioned interest without making trials on an expensive scale. (Neumayer 1857)

Georg Neumayer was just 31 years of age when he penned these bold and somewhat prophetic words. They were part of his submission to W.C. Haines, the then Chief Secretary of the Colony. Georg was after funding and he needed to make his points strongly.

His emphasis on the relationship between magnetism and geology, which he repeated a number of times in the correspondence, never waned throughout his stay in Victoria; even in his final published survey results in 1869 he reiterated this theme. His writings clearly indicate that his personal interest in magnetics at that time was of an applied nature. Without downplaying his observatory work or for that matter any academic thoughts he may have held, he was keen to establish a practical use for his magnetic data.

Despite his embellished submission to Haines, Neumayer envisaged a number of uses for his magnetic survey that nowadays are not at all outrageous —for magnetism, in addition to its prime use in mineral exploration and geological mapping, is one of a number of tools useful in soil, groundwater and salinity studies.

He certainly did, however, leave himself open to negative responses with his unannounced appearance in Melbourne, his active self-promotion, and his somewhat exaggerated claims for the use of a magnetic survey of the colony.

I am not going to dwell on this, but on reading Robert Brough Smyth's anonymous article in the October 1857 edition of *The Illustrated Journal of Australasia*, one can identify with his argument against Neumayer's magnetic survey and that public money could be better spent. Brough Smyth pointed out there would be insufficient data obtained in the regional survey to be of any use to the general public; it was just a pity that he stooped to personal attacks on Neumayer, as his technical objections were not all that unreasonable.

Although we know Neumayer received moral support from the start, for him to ask the colonial government for financial assistance for the running of a magnetic observatory and a magnetic survey of the colony was somewhat risky to say the least, but his plea did work. The clincher to the authorities and the business community was not his magnetic work, however, but his planned weather and oceanographic reporting.

In October 1858 Neumayer (1858: 102) wrote this:

> The magnetic part of the Observatory will, in its working, furnish the facts on which to base a magnetic survey of the colony, which will be carried out with the staff and the instruments of the Observatory, a large addition to which is expected early, namely, those used by Professor Lamont in making the magnetic survey of Spain.

Johann Lamont, Neumayer's Scottish born professor and mentor in Munich, undoubtedly had a major influence on his plans, which, in a nutshell, was (a) a five year program of continuous magnetic and meteorological observations at a fixed observatory location and (b) a regional survey of evenly distributed magnetic and associated observations throughout the colony; optimistically planned, I might add, at a station separation of 10 miles.

Although Lamont was Neumayer's mentor, and one would feel was his major influence, Neumayer specifically wrote in the preface of his final 1869 magnetic survey report that it was in fact Sir Edward Sabine, the then President of the Royal Society London, who encouraged him to commence the survey.

Neumayer's Victorian program certainly duplicated the way others had been collating and presenting terrestrial magnetic data in the UK and Europe, and minimally in North America from the late 1830s. Technically, the magnetic survey of Victoria was not unique, but it was large and it was the first in the southern hemisphere.

Neumayer (along with Lamont, and Sabine particularly) required the Victorian survey to be tied to those in Europe, so in addition to having his instruments, including all the needles and magnets, calibrated at the Munich Observatory before he departed, it seems he also tied his magnetic instruments to the Hamburg Observatory immediately before his departure in the ship *La Rochelle*; and then on his arrival in Melbourne he was to spend the first six weeks observing with his instruments both onboard the ship and ashore.

In addition to observations he may have made in this six week period, it is assumed he went to some lengths to position the anchorage site of the ship and other points ashore. Knowing his thoroughness, he was also very likely (with crew assistance) to have swung the compass of the ship. He certainly went through an exhaustive procedure to magnetically tie Melbourne to Munich and Hamburg. None of these early calibrations and observations, made many months before the establishment at the Flagstaff Hill observatory, were published. His 1869 map of Melbourne, indicating his observatory locations and the general geology, also shows a fixed buoy location for ship compass swings (Fig. 1).

It needs to be said that at the time of his arrival, and for the whole time he spent in the colony, Georg Neumayer was convinced there was a relationship between changes in the earth's magnetic field with the changes in air pressure, wind and the weather generally, and this in many ways explains his dedication to precise observation—he was looking for correlations and patterns.

NEUMAYER'S MAGNETIC OBSERVATORIES

The first of Neumayer's Flagstaff Hill rooms for his magnetic observations was his purpose built 16 sided and 12 foot diameter Horary House (Fig. 2); this room with its double walled timber frame, fixed with copper and brass nails and sunk into the ground included a skylight. His three instruments for the hourly reading of magnetic declination, inclination and horizontal intensity were set on sandstone pillars, as were his viewing telescopes and an outside mount for mirrors that was used in the accurate positioning of the telescopes. All of his instruments and telescopes were trigonometrically located to each other and to the outside world. Neumayer wrote that the principle reason for setting the Horary House underground was to avoid large changes in temperature. He also wrote that the instrumentation pillars were positioned

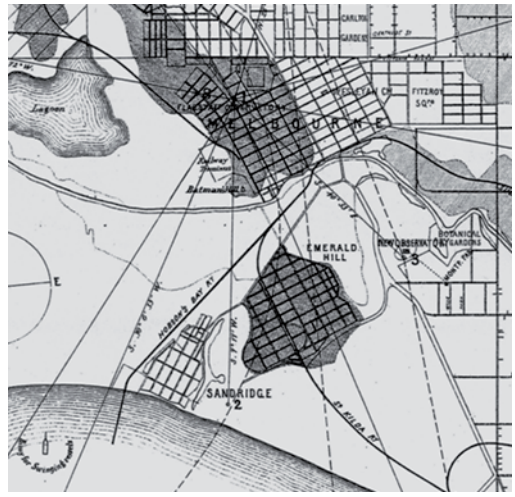

Fig. 1. Detail of Neumayer's map of Melbourne showing observatory sites and geology.

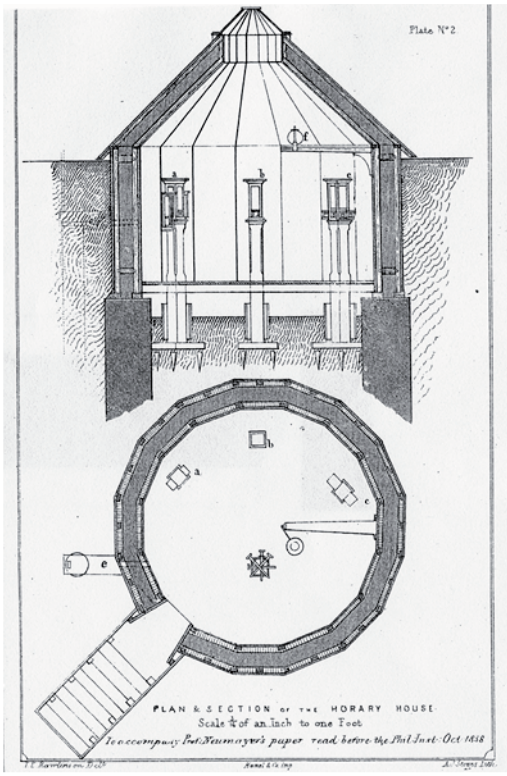

Fig. 2. The 'Horary House' Flagstaff Hill Observatory.

to where a breeze or vibration was not a problem; however, we know the latter eventually made the site unusable. Rock blasting in the nearby King Street cutting eventually cracked the pillars, and at times put the instruments into continuous oscillation.

The second magnetic room on Flagstaff Hill, also of timber, and fixed with brass and copper nails, was that known as the Absolute House (Fig. 3 see C on Neumayer's plan, D being the Horary House). This building contained two stone pillars oriented along the magnetic meridian—one being for a magnetic theodolite with its declinometer, and the other for a dip circle; both these instruments, in addition to their primary use, were suitable for measuring absolute magnetic intensity by either the magnet deflection method, or by the alternative and much older method of oscillation. This room also had a skylight. According to Neumayer the use of small magnetic needles in these absolute instruments helped in his temperature correction computations, as the needles quickly stabilised to the ambient temperature.

Knowing true north-south, or the astronomical azimuth, was essential for the orientation for the magnetic theodolite's declinometer, and holes were made in the walls of the Absolute House to obtain bearings to distant objects to obtain this azimuth—one of these holes gave sight along the meridian to a stone pillar in the centre of a small brick circular room—this pillar had a mount for a universal instrument used to determine the true meridian and this in turn was transferred by sight to the magnetic theodolite. The revolving roof of this circular construction could be made open to the sky of course. Neumayer's chronometers (which rarely get mentioned) were also kept in this room. These were the three main magnetic rooms of the observatory. Computations were done in the offices (at A on plan Fig. 3).

On the 1 May 1858, Neumayer's magnetic instruments were fully operational. The magnetic observations in the Horary House were made on the hour, with all other instruments being read at varying times around this, both before and after the hour. All readings, including the meteorological observations, were done in a set sequence and in a period of six and half minutes. Neumayer's observation procedure only changed at the time of major magnetic disturbances when the magnetic instruments were then read every five minutes and on a few occasions every minute.

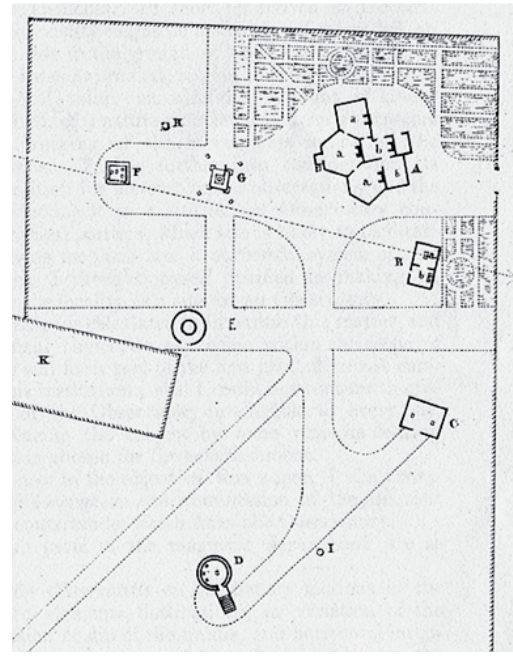

Fig. 3. Plan of Flagstaff Hill Observatory.

Every five days Neumayer, or more than likely one of his observers, updated the mean for every hour's data.

The Absolute House observations were periodic in nature, and were initially made at the beginning of every month if conditions were favourable (that is, if the sun was quiet), with the observations made continuously for a period of 36 hours. However, as time went by Neumayer reduced these absolute observations to the beginning of every second month.

In May and June of 1860 Neumayer and R.L.J. Ellery determined the St.Kilda Road site was by far the most suitable for the new observatory and, when magnetic observations were commenced there some two years later, the relative positions of his instruments within the new houses were made identical to that at Flagstaff Hill. Neumayer did, however, add a large declinometer needle with a four foot long supporting thread in his new Absolute House.

The azimuths and locations for all of the instruments were precisely surveyed in so the changed magnetic values at the new site could not be attributed to any changes in the relative position of the instruments on their new piers—he didn't miss a trick, although he did later need to fine tune his calculations.

NEUMAYER'S OBSERVATORY MAGNETIC OBSERVATIONS PUBLISHED

In 1867, on his return to Germany, Neumayer published, in full, the mean hourly declinations and horizontal intensities from the horary houses covering his five year epoch; he also tabled solar and lunar variables and amplitude data for the period. He published no unfiltered data. Figure 4 shows the meaned diurnal profiles of horizontal magnetic intensity for his full epoch – only large disturbances were deleted to produce this picture. He compiled similar diagrams for declination and inclination. According to Neumayer there were 34 903 raw readings of horizontal intensity made during the epoch, so this one image is the graphical representation of all that magnetic intensity data. It shows what would be typically expected of the horizontal magnetic intensity, with typical decreases during the day, and typical offsets and compressions over the annual cycle.

Despite the tremendous amount of data he obtained, Neumayer was not prepared to make any conclusion on the secular change in declination from 1858 to 1863. However, he did conclude there was a slight reduction in horizontal intensity and a distinct increase in inclination over the period. His published table summarising the inclinations made from the Absolute Houses, along with a few from The University of Melbourne, certainly indicates the increase (see Fig. 5). It needs to be mentioned that Neumayer in 1867 wrote that he was extremely disappointed in the number of errors that slipped through in his final publications—this figure likely includes one of them. The location for the observation of 11 April 1861 probably should refer to 'Melbourne University'.

Neumayer wrote in his 1867 publication that he abandoned the thought of including any of his additional measurements made during magnetic disturbances, although he went on to say there was enough material for a special publication. It never happened. His few published tables were the final portrayals of many years of dedicated work—not much to show for it all.

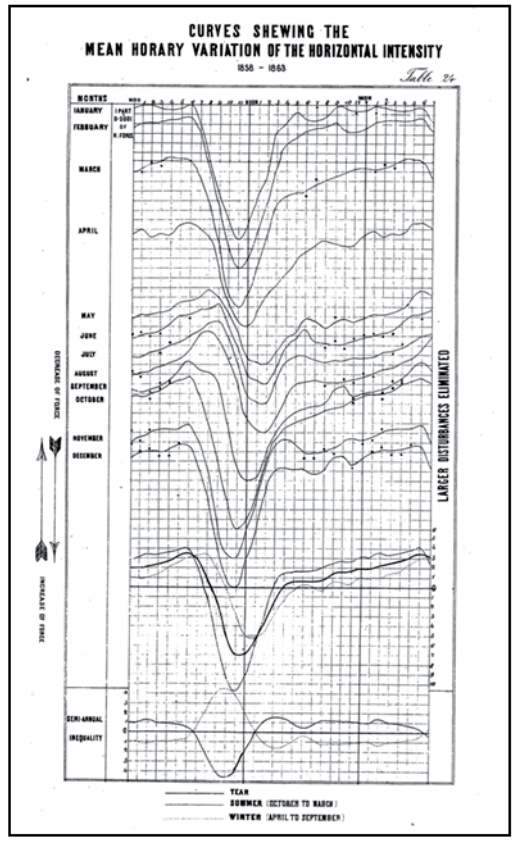

Fig. 4. Neumayer's mean horizontal magnetic intensity for Melbourne 1858–63.

RESULTS OF THE OBSERVATIONS ON THE ABSOLUTE MAGNETIC INCLINATION. (1857—1864)

YEAR.	DATE.	LOCALITY.	INCLINATION.
1857	April 1st and 4th	Enclosure of the University	67° 3·22 South*
1858	September 2d and 3d ..	Flagstaff Observatory ...	67°18·09 ,,
1859	January 9th and 12th ...	,, ,,	67°20·70 ,,
,,	April 1st	Enclosure of the University	67° 7·55 ,, *
,,	September 21st	Flagstaff Observatory ...	67°17·99 ,,
1860	June 10th	,, ,,	67°19·09 ,,
,,	August 27th	,, ,,	67°20·06 ,,
1861	April 11th	Melbourne Observatory ..	67° 8·17 ,, *
,,	August 21st	Flagstaff Observatory ...	67°20·92 ,,
1862	September 8th....	Melbourne Observatory ..	67° 5·47 ,,
1863	January 21st	,, ,,	67° 5·71 ,,
,,	June 3d and 6th	,, ,,	67° 7·42 ,,
,,	August 11th	,, ,,	67° 7·00 ,,
,,	October 2d	,, ,,	67° 7·30 ,,
1864	March 17th to 22d	,, ,,	67° 9·15 ,,
,,	June 17th	,, ,,	67° 9·82 ,,

Fig. 5. Neumayer's magnetic inclinations for Melbourne 1857-64.

Neumayer rarely mentioned his employed observers by name in any of his publications; however, I have been able to positively identify eight people who observed for Neumayer. Some are well known to us—this is very likely an incomplete list. They were Jacob Bauer, John Osborne, William Wills, Charles Pickering, Charles Moerlin, B. Loewy and two casuals Edwin Welch and John Rose.

NEUMAYER COMMENCES HIS FIELD WORK

With the observatory running smoothly, Neumayer was able to travel extensively around the colony. Fifteen of his journeys were specifically to observe terrestrial magnetism, and 10 of these were expeditions in the true sense, some turned out to be hazardous.

His field work started very slowly with a short trip to Kilmore in December 1858, when accompanied by R.L.J. Ellery and others to experiment with his two newly arrived Lamont magnetic theodolites (Fig. 6). He found the magnetism of the local rocks 'severely affected their magnets'.

Then in early May 1859, accompanied by the interested politician George Verdon, he observed in suburban Footscray and in the centre of the Williamstown cricket ground. These two stations were to be the first in his colony-wide network. He followed up in late June 1859: when travelling alone in his spring cart, he observed near Castlemaine, Maldon and Maryborough only to be halted by poor weather.

In November 1859, he departed Melbourne on his first extended journey (see the route shown in green in Fig. 7); observing firstly at Geelong and Queenscliff before then backtracking to Ballarat, where on the 3 December, with the mineralogist and mine owner Henrique Rosales, he observed at a number of locations, firstly in the gardens of the Prince Albert Hotel, then the top of Black Hill (where his azimuth was relayed to him by heliotrope from the hotel) and

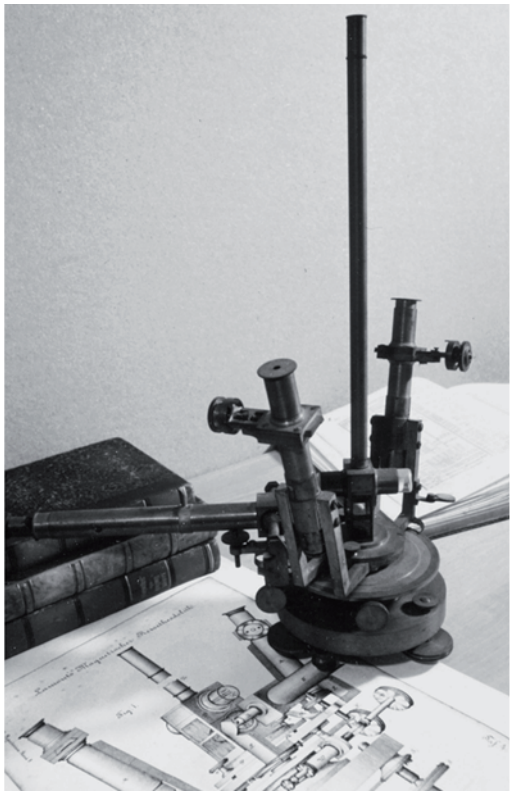

Fig. 6. A Lamont 'Reisetheodolit' Heinrich Soffel.

then into the mine tunnel directly beneath. The difference between his two measurements at Black Hill, in modern terms, was about 100 nanoTeslas and this suggests his instrument was working fine but geologically the measurement had no real significance. It was however a pioneering attempt at underground mining geophysics. Figure 8 shows his original field notebook pages made at Black Hill on that day; his notebooks are currently archived in the Library of the Bundesamt fuer Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency) in Hamburg. They show, as well as his astronomical bearings, the observed angle deflections of his declination and inclination needles caused by the magnets set at various distances and orientations. These deflections were later mathematically converted to magnetic intensity. Neumayer published no comments on these observations.

His Ballarat observations were interrupted when he, according to his published narrative (Neumayer 1869: 8), rushed to Melbourne to allay concerns on his appointment of William Wills. When he arrived back a few days later he wrote of his shock to find a fire had destroyed much of the town. Typically though, he just continued on with his work observing along a route to Warrnambool, Port Fairy and Portland before returning to Melbourne by steamer. This trip of about 1100 km had him observe magnetic components at 21 stations, the density of his stations being much less than he had originally envisaged.

It took him three and a half hours (on good days) to fix his position and make measurements at each station and it was this lengthy observation time, along with the practicalities of travel and cost constraints, which greatly limited the number of stations he was able to observe throughout the survey.

On the 12 September 1860, Neumayer was running late when he crossed the Murray River at Swan Hill (see the route shown in red in Fig. 7). He was riding alone on a borrowed horse and leading another, and he was carrying his scientific instruments, including one of his two Lamont magnetic theodolites, for use by William Wills on the Victorian Exploring Expedition. He stopped and observed with the instruments shortly before crossing the Murrumbidgee and again before catching up with the expedition. Neumayer and Wills then observed together near a number of camps before reaching the Darling River at Pooncarie.

The main expedition party was trailing some days behind, and after saying his goodbyes to Wills he travelled back to the main party with Burke, Neumayer was later to write:

> On parting Mr. Burke asked me to make him a promise that, should he get lost, no one but myself should undertake the search after him. (Neumayer 1869: 13)

Within days Burke discarded most of the scientific equipment, with the Lamont magnetometer and other instruments being returned to Neumayer in Melbourne. Neumayer of course had hoped that Wills would observe all the way to the Gulf of Carpentaria.

Following his return to Melbourne (carrying VEE correspondence with him), Neumayer was soon back in Swan Hill continuing his survey along the Murray. He then headed south into the scrub and onto Horsham, arriving back in Melbourne for Christmas. In just over three months he had travelled 2000 km, mostly on horseback, and had made observations at 44 stations.

I need to digress and include here details on Neumayer's involvement with the Cranbourne meteorites.

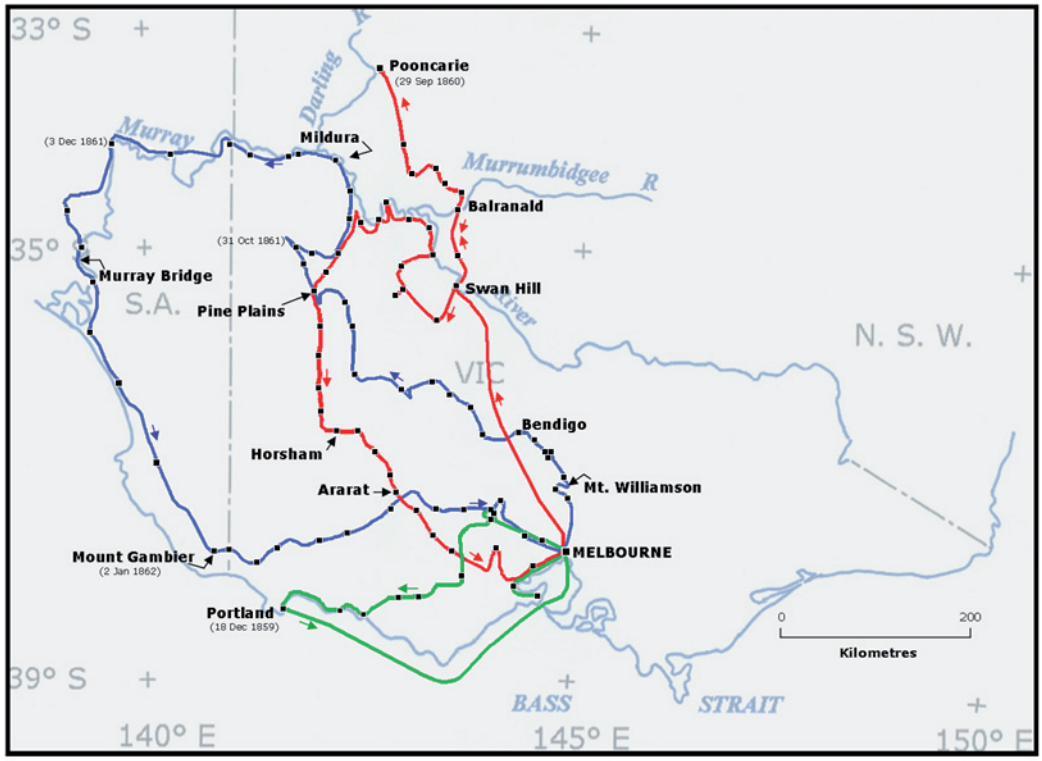

Fig. 7. Neumayer's field trips November 1859 – January 1862.

On the 11 February 1861, Neumayer in the accompaniment of others, travelled to Cranbourne to look at the two large iron meteorites that had been recently uncovered. He was so impressed with the larger of the two that he set about measuring it in detail, and in his 1869 narrative he included this important description (Neumayer 1869: 25):

> ...The earth around the meteorite had been removed to the depth of two feet; the lower part, however, was not visible, the hole being partly filled up with water. A magnetic needle suspended by a silk thread and approached towards it, showed at once that the upper accessible part was of northern magnetic polarity, the South end of the needle being attracted. Moving the needle about 1 foot 10 in. below the upper surface of the mass its magnetism changed from North to South, from which I concluded that its total height would be about 4 ft. But the distance from the top at which this change in polarity took place, was by no means constant for all parts of the sides of the mass varying from 2 ft. 4 in. to 1 ft. 4 in., from which I concluded that the shape of its lower part was that of a wedge; basing thereupon, I calculated the total weight of the mass to be 4.3 tons ...

Now, this description and innovative interpretation of the mass and dimensions of the meteorite gains significance, for in the following year (21 February 1862), Neumayer, Alfred Selwyn and Richard Daintree visited the site to witness its removal. Neumayer, aided by Daintree, remeasured its magnetic properties and then Daintree photographed it in situ being held precariously in position by a screw jack (see Fig. 9). This photograph, one of two taken by Daintree, clearly shows Neumayer's chalk orientations marks, and what appears to be a line tracing the meteorite's 'magnetic equator'. The meteorite weighed in at 4.1 tons with its unusual shape and dimensions being almost exactly as Neumayer had calculated in the previous year. Neumayer's interpretation of the dimensions and mass of the still buried meteorite is by far the earliest quantitative interpretation based off rock magnetism that I have sighted. It is a benchmark measurement in

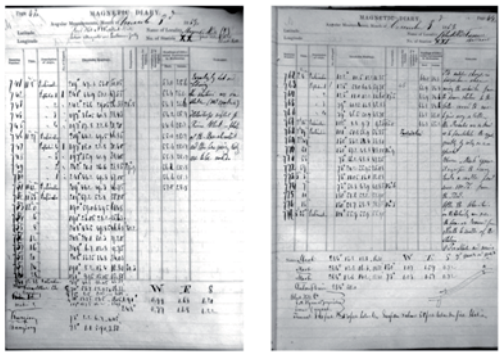

Fig. 8. Neumayer's field notebook 3 December 1859 Bundesamt fuer Seeschifffahrt und Hydrographie.

applied geophysics and it was obtained simply by just a needle on a thread!

For his next travels Neumayer bought an American covered wagon to replace his old spring cart. This new wagon, to be drawn by two horses, was central to his plans to camp out and to avoid impositions on remote settlers. It also gave him, for the first time, the opportunity to make night-time observations. In late September 1861 Neumayer, his unnamed assistant, along with the well known Dr Hermann Beckler (who had in the previous year resigned from the Victorian Exploring Expedition) and a young man named Irvine headed to the Murray River, travelling via Bendigo to the parched country on the eastern edge of the Big Desert (see the route shown in blue in Fig. 7). It was in this country, which had been recently burnt, where Neumayer and Irvine, on a horseback excursion into the desert, ran out of both food and water: they were very lucky, after a few days, to get back to Beckler at a rendezvous near Ouyen. Beckler had already given them up for lost.

On the 8 November 1861 on reaching the Murray south of Mildura, Neumayer learnt of the loss of Burke and Wills – he wrote that he was distraught.

A week or so later, Neumayer and his companions temporarily left the wagon and crossed the Murray to Wentworth; this break, to be of 10 days, was partly to give respite to the horses, which were suffering, but also to wait for the mail. Neumayer took the opportunity to set up a temporary solar observatory where he later described having viewed a number of sunspot groupings. He became quite ill from sunstroke but his observations ceased only when he could no longer view through his telescope because of multiple mosquito bites to his face and eyes.

Fig. 9. The Cranbourne meteorite. A Richard Daintree photograph dated 21 February 1862 State Library of Victoria.

Travelling back to the south of the river the horses continued to struggle, in at times gale force winds, enveloping dust and soft sand.

On reaching Murray Bridge around the 16 December, Beckler received correspondence that he had been subpoenaed to appear before the Royal Commission on the Burke and Wills tragedy, and immediately left for Melbourne (via Adelaide). Neumayer and his two remaining companions continued on, observing along the Coorong to Mount Gambier and Ararat, before arriving back in Melbourne on or about the 22 January 1862. This long and at times difficult trip of almost 1800 km took four months and added 46 stations to the survey.

In early April 1862 Neumayer, his assistant Mr Sahner, and his artist friend Nicholas Chevalier headed for the Cape Otway lighthouse (see the route shown in red in Fig. 10).

On reaching Apollo Bay they joined Samuel McGowan, the Superintendent General of Telegraphs and others, including another artist and friend of Neumayer, Eugene von Guérard. They then travelled on as a group along the beaches and rocky shoreline to the lighthouse. Von Guérard sketched as they went and importantly for us he produced, in addition to others, two scenes (see Fig. 11). In the scene identified as 'The Glory Hole' Neumayer is easily recognisable by his peak cap, three quarter length coat and glass barometer strapped to his back. With the risk of damage to his barometer on the rocks becoming too great, Neumayer actually backtracked and climbed around this place.

Following observations at the Cape Otway lighthouse and on their return to Apollo Bay, Neumayer and Chevalier left the others and turned inland to join

Fig. 10. Neumayer's field trips April 1862–January 1863.

Mr. Sahner who had travelled ahead to Colac. They then travelled to the Grampians where Neumayer and Chevalier climbed Mount William to observe and sketch. Just north of the ranges, on the 15 May, they reached Mrs Carter's station, Rosebrook, where Neumayer, in addition to his magnetic observations, made a series of sunshots to determine his longitude. These longitude observations were some of the very few that he observed during his time in the colony—most of his published longitudes having been later calculated from bearings and site descriptions.

While Neumayer was observing at Rosebrook, Chevalier was nearby painting the scene (Fig. 12).

They then travelled to Mount Arapiles (which they also climbed) before turning east to Horsham and then the Murray River at Echuca, arriving back in Melbourne in late June after about 1400 km and another 33 observations. A number of Chevalier's (and Australia's) most iconic paintings were based on his sketches and preliminary oils made during this trip.

On the 16 October 1862, with a new assistant Edward Brinkmann and Eugene von Guérard as a guest, Neumayer set off towards the Australian Alps (see the route shown in blue in Fig. 10).

Two days out from Melbourne, Neumayer climbed Mount Disappointment to observe on the summit. He found the government geodesist R.G. Petty camped there and together they made both magnetic and astronomical observations with Neumayer borrowing Petty's chronometer, as he had done once before, to time some absolute intensity oscillations. That evening von Guérard sketched and he has left us with an image of Neumayer's camp and wagon (Fig. 13).

On reaching Benalla a few days later, Neumayer, in his somewhat typical stilted manner, described his observation site:

> ... The instrument put up and adjusted. Engaged in magnetical and astronomical observations. Dense forest all round. The geological formation is Silurian. The magnetic theodolite was put up close to three large trees, one of which was marked in my usual manner ... (Neumayer 1869: 68).

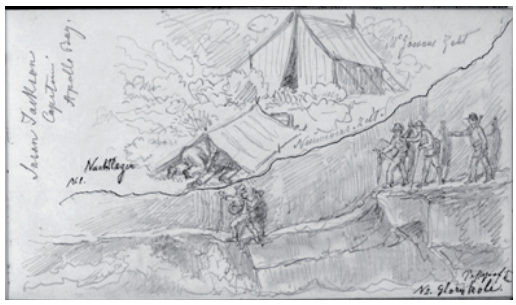

Fig. 11. Eugene von Guérard's 'The Glory Hole' 16 April 1862 Dixson Galleries, State Library of New South Wales. (See also page 129).

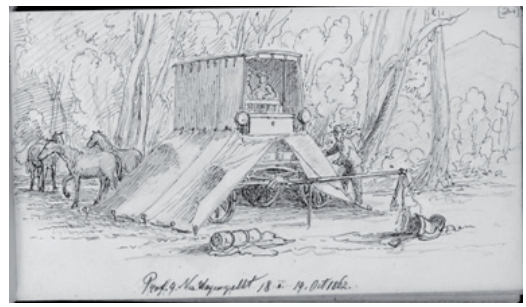

Fig. 13. Von Guérard's sketch of Neumayer's wagon 18th October 1862 Dixson Galleries, State Library of New South Wales. (See also page 130).

What Neumayer failed to mention was that von Guérard was nearby, leaving us with an almost animated record of Neumayer observing with his Lamont magnetic theodolite (Fig. 14). A great record.

On reaching Albury and engaging a local resident John Twynham as a guide, they then travelled into the high country via the Mitta Mitta River.

Neumayer and von Guérard were then to climb the remote Mt Gibbo before travelling to Benambra and heading for Mount Kosciusko. They became lost but fortuitously they met Mr Weston, the manager of Tom Groggin's station, travelling in the opposite direction, who volunteered to guide them to the top.

On the 18 November 1862, after leaving their horses at Groggin's and packing Neumayer's horse Tommy with all the instruments, blankets and rations, they climbed for the summit. However, it soon became too difficult for the horse and he was unloaded and left tied securely to a tree. Carrying all the gear in backpacks the five men reached the peak the next day.

Fig. 12. Chevalier, Nicholas, 1828-1902. View from Rosebrook, Mrs Carter's station, 15 May 1862 [picture] Painting : oil on academy board ; 29.3 x 40.5 cm. Rex Nan Kivell Collection NK817. National Library of Australia (nla.pic-an2252983).

The wind was blowing a gale and as von Guérard sketched the panorama, Neumayer and Brinkmann, sheltered by rocks, boiled water for their barometric altitude observation. They determined their height to be 7176 ft.

Then, with a warning from von Guérard that a violent storm was fast approaching, they all immediately vacated the summit.

On the rush down, Brinkmann realised he had left the maps behind and returned (with Neumayer's dog Hector) to collect them, but within moments the storm hit with great ferocity, accompanied by freezing conditions and then fog. Hector returned when called by Neumayer, but Brinkmann didn't. Neumayer and von Guérard, supporting an exhausted and collapsed Twynham, stumbled (in the fog) upon a terrified and tangled Tommy, and upon reaching their campsite they found it totally destroyed. They were in serious trouble, in near blizzard conditions, with both Brinkmann and Weston missing and it was to take Neumayer some effort to get a fire going. It wasn't until about 11 pm that Weston stumbled into camp after having sighted the fire.

Fig. 14. Neumayer observing at Benalla 24 October 1862 Dixson Galleries, State Library of New South Wales. (See also page130).

The next morning (20 November 1862) Neumayer and von Guérard went looking for Brinkmann. They unsuccessfully searched for him throughout the day and Neumayer feared the worst. They did, however, find the maps. The following day Neumayer diligently observed the horizontal magnetic intensity near the summit.

Leaving some provisions and directions behind at the campsite they reluctantly headed back. On reaching Benambra and then Omeo, Neumayer offered a £20 reward for anyone who would return with him to search for Brinkmann—but he received no responses. They then commenced the travel back to Albury with Neumayer observing as normal.

There were a number of instances during this journey where Neumayer made detailed inspections of local geological outcropping, where he measured the magnetic properties and recorded locations. For instance at Flour Bag Plains area near Mt Hotham, he wrote in his narrative that he both measured and recorded the magnetism of some quartz reefs. Figure 15 shows his original observation data from that place—but his quartz reef measurements are not included: he must have recorded them separately. Disappointingly, none of this potentially historic exploration geophysical data was ever published.

On the 6 December 1862 near Yackandandah, Brinkmann suddenly appeared, according to Neumayer in 'a most deplorable condition'. Amazingly, he had walked hundreds of kilometres via Thredbo and Kiandra – and he had carried two glass barometers on his back undamaged. Neumayer was ecstatic. Collecting their wagon at Wodonga and farewelling John Twynham, they continued on with their survey via Yarrawonga and Shepparton and then westward towards Wedderburn before travelling back to Melbourne. This eventful trip covered about 1400 km and added another 30 stations to Neumayer's total.

Following a short trip circling the Mornington Peninsula in March 1863 (see the route shown in green in Fig. 10) Neumayer, accompanied by Edward Brinkmann on their favourite horses, Tommy and Jimmy, and with the faithful Hector at heel, travelled and observed in a loop to Mansfield and in rugged country to the remote Wood's Point (see the route shown in red in Fig. 16). The weather and the condition of the horses, however, became so poor that Neumayer was compelled to abort this trip; he had planned to head east. He did, however, add another 15 stations before calling it off.

In mid November 1863, whilst Brinkmann prepared the horses and wagon for a foray into East Gippsland, Neumayer made a quick trip by rail and coach to Ballarat, Maryborough and some gold diggings to check on some earlier inconsistencies in his observations (see the route shown in green in Fig. 16). This excursion, his last to the goldfields, added another eight stations. At Castlemaine he took time to visit the newly erected monument to Burke and Wills.

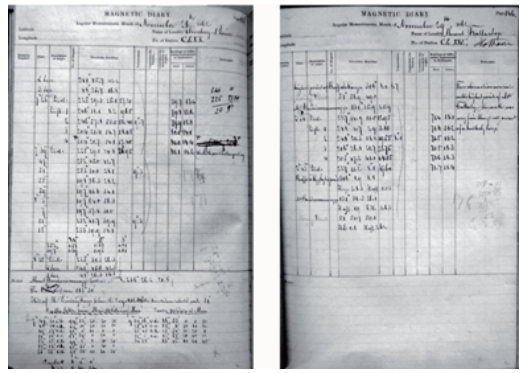

Fig. 15. Neumayer's field notebook 28th – 29th November 1862 Bundesamt fuer Seeschifffahrt und Hydrogaphie.

To complete his regional survey within his planned timeframe was now of some concern, so within days of returning from Castlemaine, on the 28 November 1863, accompanied by his friend Nicholas Chevalier, Neumayer headed east to join Brinkmann (see the route shown in blue in Fig. 16). Things didn't start too well when he found his transit instrument was damaged, necessitating a return to Melbourne for repair and then, because of the boggy conditions, he had to leave the wagon behind. The whole Gippsland trip was then by horseback.

The track east according to Neumayer was lined with horse skeletons and a number of times their horses became bogged. The weather was so poor, it was not until they were east of Traralgon that a full set of observations could be made. Their travel then became decidedly dangerous when in windy and wet conditions they turned inland into the tall timber. They lit great bonfires to keep both men and horses warm.

It took them almost two weeks to travel to the summit of Mt Useful, only to then reach it in dense fog, although it did clear for a period and Chevalier sketched the scene. Neumayer found the magnetism on the summit was very anomalous, so much so he was later to delete the station results from his network. On heading down they got lost a number of times.

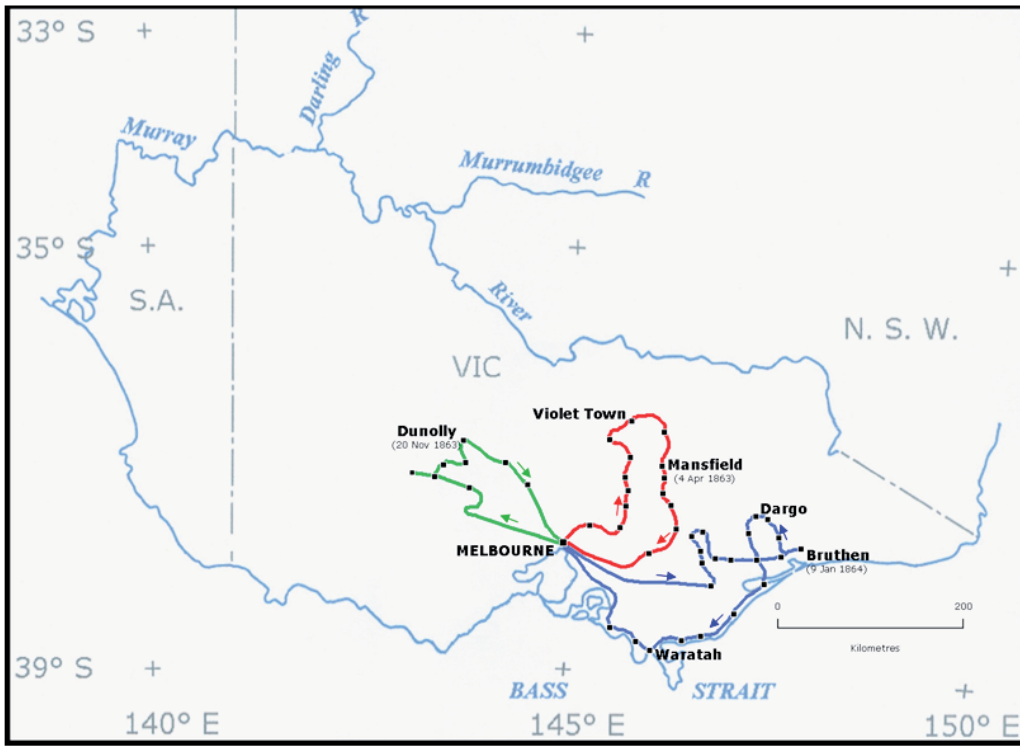

Fig. 16. Neumayer's field trips March 1863 – February 1864.

They travelled as far east as Bruthen before again heading north into the tall timber and to where Neumayer described the old diggings as 'very wrteched looking' (Neumayer 1869: 113). On reaching the isolated Dargo Station on the 14 January 1864 Neumayer met with the old explorer and cattleman Angus McMillan and according to Neumayer they sat and talked for two days.

Heading back south to the coast they turned west, firstly to Port Albert and then onwards towards Waratah.

On the 28 January, after crossing the Franklin River, Neumayer turned to see his faithful canine companion Hector collapse into convulsions and within six minutes die from a bait. Poor old Hector, except for some rail and coach trips he had travelled almost every inch of Neumayer's travels around Victoria.

Chevalier in the meantime had made an excursion to Wilson's Promontory and in his attempt to catch up became thoroughly confused when he missed Hector's pad prints, getting lost for two days, this was despite Neumayer having clearly blazed a trail. On reaching the Powlett River, Chevalier was also to miss Neumayer's marked safe crossing, and in his attempt to cross he almost drowned when he was swept downstream with his horse. Neumayer wrote that Chevalier lost everything he carried – including, sadly, all of his sketches.

With the completion of this difficult 800 km and the addition of 23 observations Neumayer ended his Victorian field work.

He then made a short trip to Tasmania and between the 13 and 19 April 1864 he tied his instruments to the site of the defunct Rossbank Magnetic Observatory in Hobart.

I hope by mentioning all of Neumayer's magnetic survey trips I have adequately emphasised the great distances he travelled during his time in the colony. He had travelled about 10 000 km, mostly on horseback, on his magnetic survey and he had observed at 235 stations. Edited details of every one of these stations were published in 1869 along with his accompanying narrative and magnetic maps.

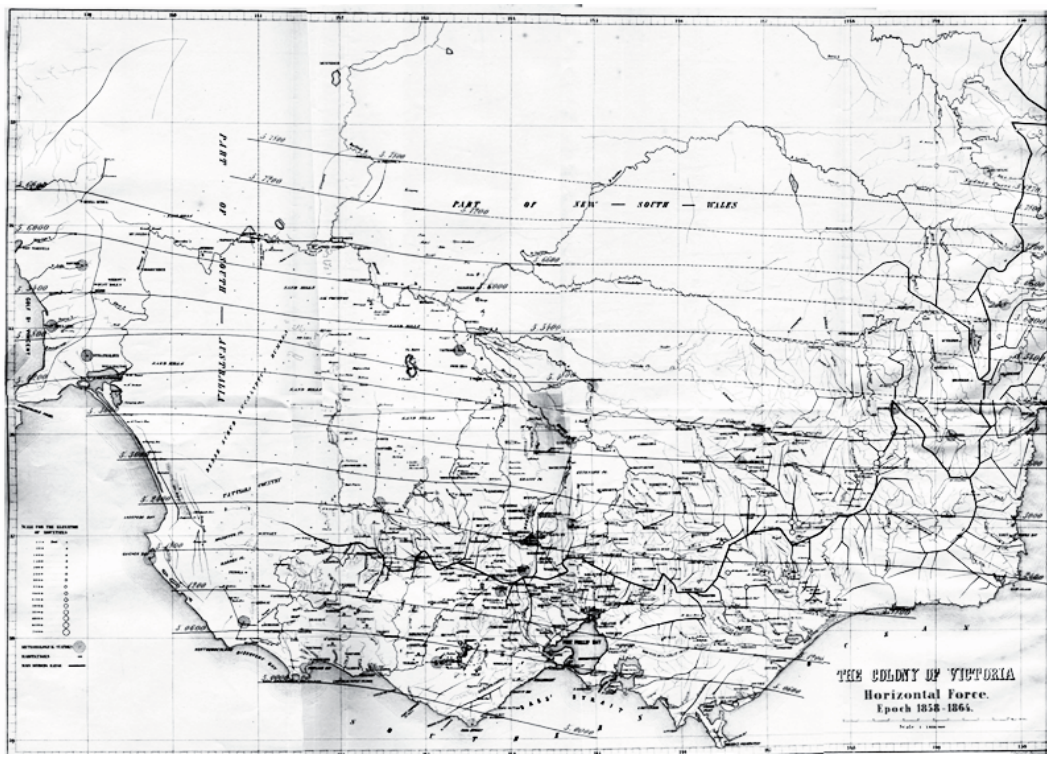

Fig. 17. Neumayer's Horizontal Magnetic Intensity map of Victoria.

NEUMAYER'S MAGNETIC MAPS

His final three magnetic survey maps were presentations of contours of magnetic declination, inclination and horizontal intensity. Figure 17 shows the horizontal intensity map. His portrayed contours were quite smooth, with all 'near surface' magnetic anomalies being removed, and were similar in both style and content with the regional magnetic maps by others of the era. They certainly were technically compatible with those produced by Lamont and Sabine. It is likely Neumayer followed Sabine's advice (or maybe even instructions) on his presentation. The magnetic intensity contour interval shown (0.06 British Units) is equivalent to 276.65 nanoTeslas.

The question is left though as to whether these smoothed contours were the product that Neumayer personally wanted to publish, as the data he had obtained in Victoria, like his Pfalz survey previously, was of a disturbed nature. Neumayer may have been stuck between a rock and a hard place because if one contours up his 235 stations, using his exact published values (which I have done) the horizontal intensity map would look as shown in Figure 18. Producing such an alternative map was not a desired regional product either, with the local disturbances and the broad station density making it of little or no use geologically; it does show however, the amount of smoothing Neumayer made to his final map product.

SUMMARY

Historically, it is disappointing that the detailed observatory data that Neumayer and his assistants obtained in Melbourne on short term magnetic or solar events, and the near continuous observations made during magnetic storms, were not published.

It is also a pity that Neumayer's observations over geological targets, similar to his Cranbourne observations, were not published as they were truly pioneering. They were observations that followed in the tradition of just a handful of individuals, including Humboldt in the 1790s, the Norwegians Keilhau, Boeck and Abel in the 1820s and Douglass Houghton and William Burt in Michigan in the 1840s. Neumayer was following in their footsteps. It was not until 1879, when Robert Thalén published (in German)

Fig. 18. Neumayer's magnetic station locations and horizontal intensity contours that have been modified to honour his observed values. Drawn and compiled by Doug Morrison.

the first technical publication on the use of magnetics in geological mapping. The first English text on the subject by the Canadian Eugene Haanel did not appear until 1904.

Overall though, Georg Neumayer's Victorian magnetic work is an important scientific record—pioneering in some instances—and of considerable significance to those who study the ongoing changes in the earth's magnetism.

ACKNOWLEDGEMENTS

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