



Sveriges Geologiska Undersökning

Processing Report

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Kiruna-Fjallasen / Kiskamavaara Airborne Geophysical Survey

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1. Project Overview

1.1 Introduction

This report provides information regarding the processing methodology of Air-FTG and airborne gravity, as conducted by Bell Geospace.

1.2 Project Location

The projects are Kiskamavaara and Kiruna-Fjällasen, surveyed in 2024 and 2025 respectively, both located in Sweden - the location of the survey areas are shown in **Figure 1.1**.

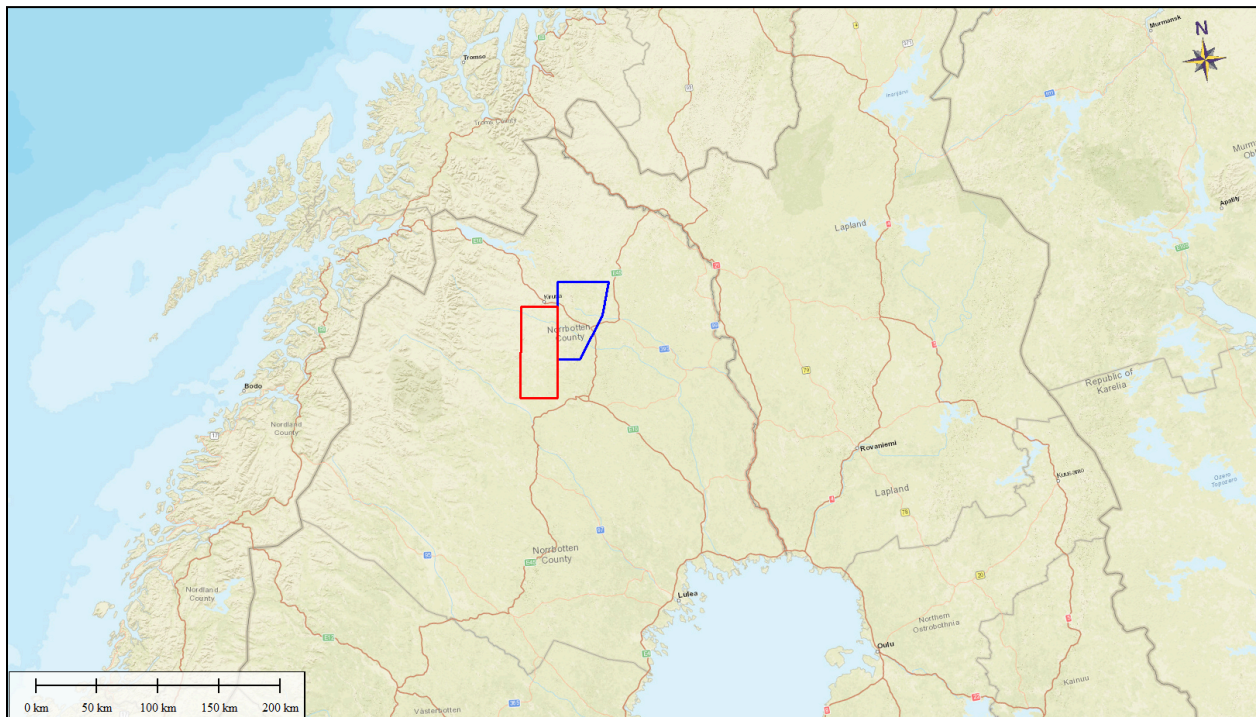


Figure 1.1: Geographic extents of the projects Kiruna-Fjällasen (red) and Kiskamavaara (blue).

1.3 Scope of Work

The objective of the survey was:

- › To acquire and process approximately 18 860 line kilometres (9 867 and 8 993 line kilometres across Kiruna-Fjällasen and Kiskamavaara respectively) of Air-FTG and

airborne gravity, which will be utilised to focus exploration efforts within the area of interest.

Data processing was initially applied separately to each survey block shortly after acquisition was complete. The updated processing scheme improved data consistency across both survey blocks by reapplying selected later processing steps to both survey blocks collectively; thus there were minor discrepancies comparing the updated and previous results.

1.4 Outline of Report

The report outlines the data processing sequence and highlights any issues which arose and the solutions implemented. The report is divided into the following sections plus appendices:

- › **Section 1**, current section, presents an overview of the project.
- › **Section 2** details the processing sequence for the collected datasets.
- › **Section 3** includes the key products of the final processed data and details on the deliverables sent to the client.
- › **Appendices 1-8** contain supplementary material regarding data processing methodologies and deliverables.

1.5 Coordinate Reference System

All coordinates stated throughout the report, as well as all final deliverables, are referenced to the Coordinate Reference System (CRS) shown in **Table 1.1**.

Table 1.1: Coordinate Reference System (CRS)

Projection Method	SWEREF99 TM
Horizontal Datum	SWEREF99
Vertical Datum	Earth Gravitational Model 1996 (EGM96)
Length Units	Metre

1.6 Data Availability and Sources

The following data and information was available prior to the survey commencement:

- › Country borders, cities and smaller settlements, no-fly zones.
- › Lidar data provided by the client.
- › Ground gravity station data provided by the client.

2. Data Processing

2.1 Air-FTG Processing

Using only the best quality Air-FTG data acquired, a series of processing steps were performed to obtain the final measured gravity gradient data used for interpretation. Although re-flown survey lines are present in the database, only the best quality lines are selected for processing. Specific processing methods may have varied slightly depending upon survey layout, weather conditions, and other factors affecting the data. The standardised Air-FTG data processing scheme is provided in **Figure 2.1**.

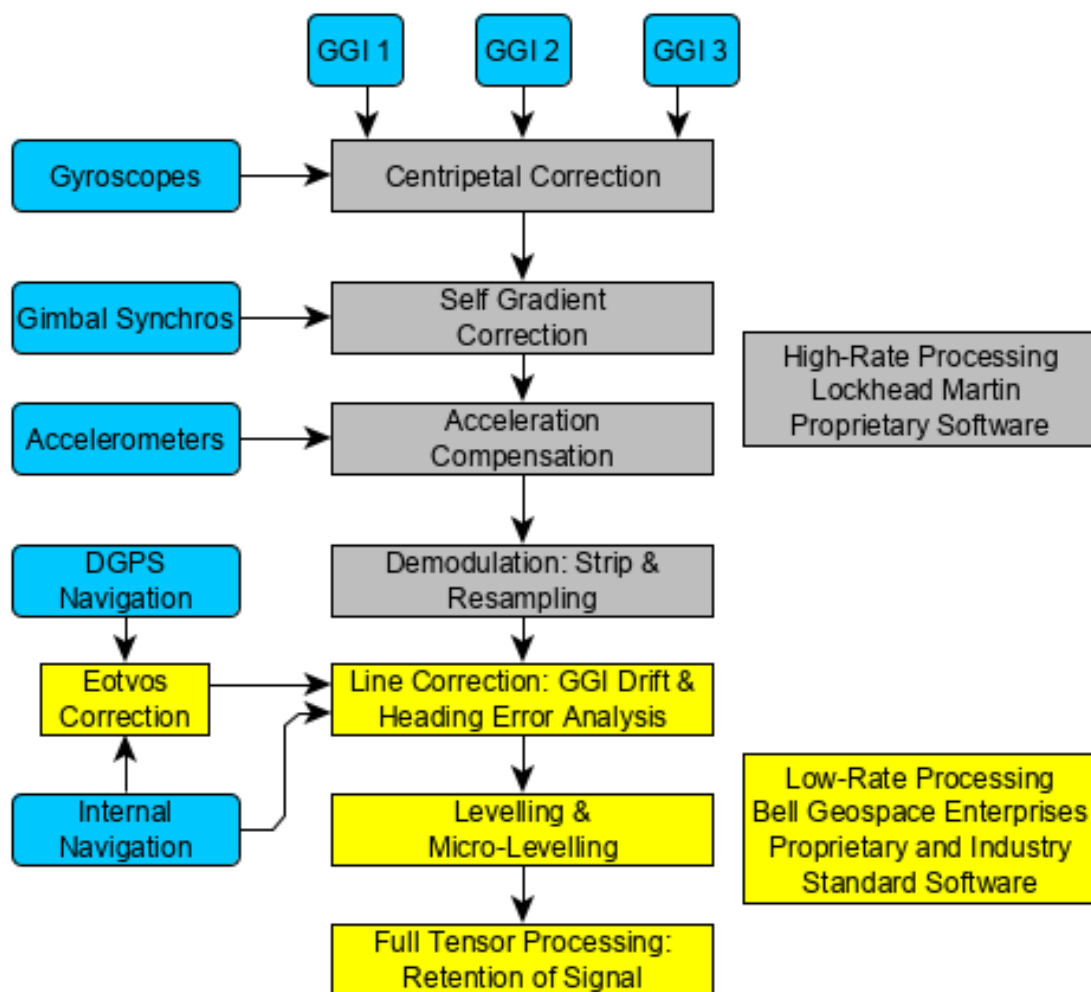


Figure 2.1: Air-FTG Processing Summary

Air-FTG datasets have been processed with the Full Spectrum Tensor processing scheme, where the Air-FTG datasets have been partially levelled to processed iCORUS/GT-Z airborne gravity data. Further in-depth discussion is provided in **Appendix 2**.

On completion of the Full Spectrum Tensor processing scheme, including Full Tensor Noise Reduction (FTNR), the following datasets were produced (**Table 2.1**).

Table 2.1: Air-FTG standard datasets

Product	Brief Description
FA FTNR	Processed Free Air response of the Air-FTG system
TC100 FTNR	Terrain response calculated above the geoid from a digital terrain model and later processed using FTNR. Terrain density set to 1.00 g/cm^3
TCD FTNR	Final processed terrain-corrected response calculated with the formula: $TCD \text{ FTNR} = FA \text{ FTNR} - (TC100 \text{ FTNR} * 2.67 \text{ g/cm}^3)$ 2.67 g/cm^3 is the bulk rock density above the geoid

Each Air-FTG dataset consists of six gradient tensor components (T_{xx} , T_{xy} , T_{xz} , T_{yy} , T_{yz} and T_{zz}) - background information on Air-FTG tensor components is described in **Appendix 1**. In addition, the gravitational potential field (T_z) was calculated for each dataset using FTNR.

As well as the standard processed datasets, additional interpretative Air-FTG datasets were generated using Contact Lineament Processing (CLP). CLP is a multi-directional filter algorithm which computes a series of interpretative maps using the Air-FTG FTNR results. Details on the CLP processing scheme are described in **Appendix 4**.

Air-FTG data processing was initially applied separately to each survey block shortly after acquisition was complete; to improve data consistency across both survey blocks, TC100, FTNR and CLP stages were reapplied to both survey blocks collectively.

2.2 Airborne Gravity Data Processing

Using only the best quality airborne gravity (iCORUS/GT-Z) data acquired, a series of processing steps was performed to produce the following products listed in **Table 2.2**. Further in-depth discussion on the airborne gravity processing scheme is described in **Appendix 3**.

Table 2.2: iCORUS/GT-Z processed datasets

Product	Brief Description
FAA G_z	Processed Free Air iCORUS/GT-Z airborne gravity response
TC100 G_z	Terrain response above the geoid calculated from an extended digital terrain model. Terrain density set to 1.00 g/cm^3
TCD G_z	Final processed terrain-corrected iCORUS/GT-Z airborne gravity response calculated with the following formula: $\text{TCD } G_z = \text{FAA } G_z - (\text{TC100 } G_z * 2.67 \text{ g/cm}^3)$ 2.67 g/cm^3 is the bulk rock density above the geoid

Airborne gravity data processing was initially applied separately to each survey block shortly after acquisition was complete; to improve data consistency across both survey blocks, 2D FFT spatial filters were reapplied to both survey blocks collectively.

A supplementary processing scheme was implemented to compute the low-frequency response of the processed airborne gravity data, which was then added to Air-FTG gravity

data. The resulting Full Spectrum Gravity potential field (T_{ze}) products are listed in **Table 2.3** and further in-depth discussion is provided in **Appendix 2**.

Table 2.3: Air-FTG Full Spectrum Gravity datasets

Product	Brief Description
FA FTNR T_{ze}	Full Spectrum Gravity result of Air-FTG FA FTNR T_z merged with iCORUS/GT-Z airborne gravity FAA G_z
TCD FTNR T_{ze}	Full Spectrum Gravity result of Air-FTG TCD FTNR T_z merged with iCORUS/GT-Z airborne gravity TCD G_z

3. Data Results & Deliverables

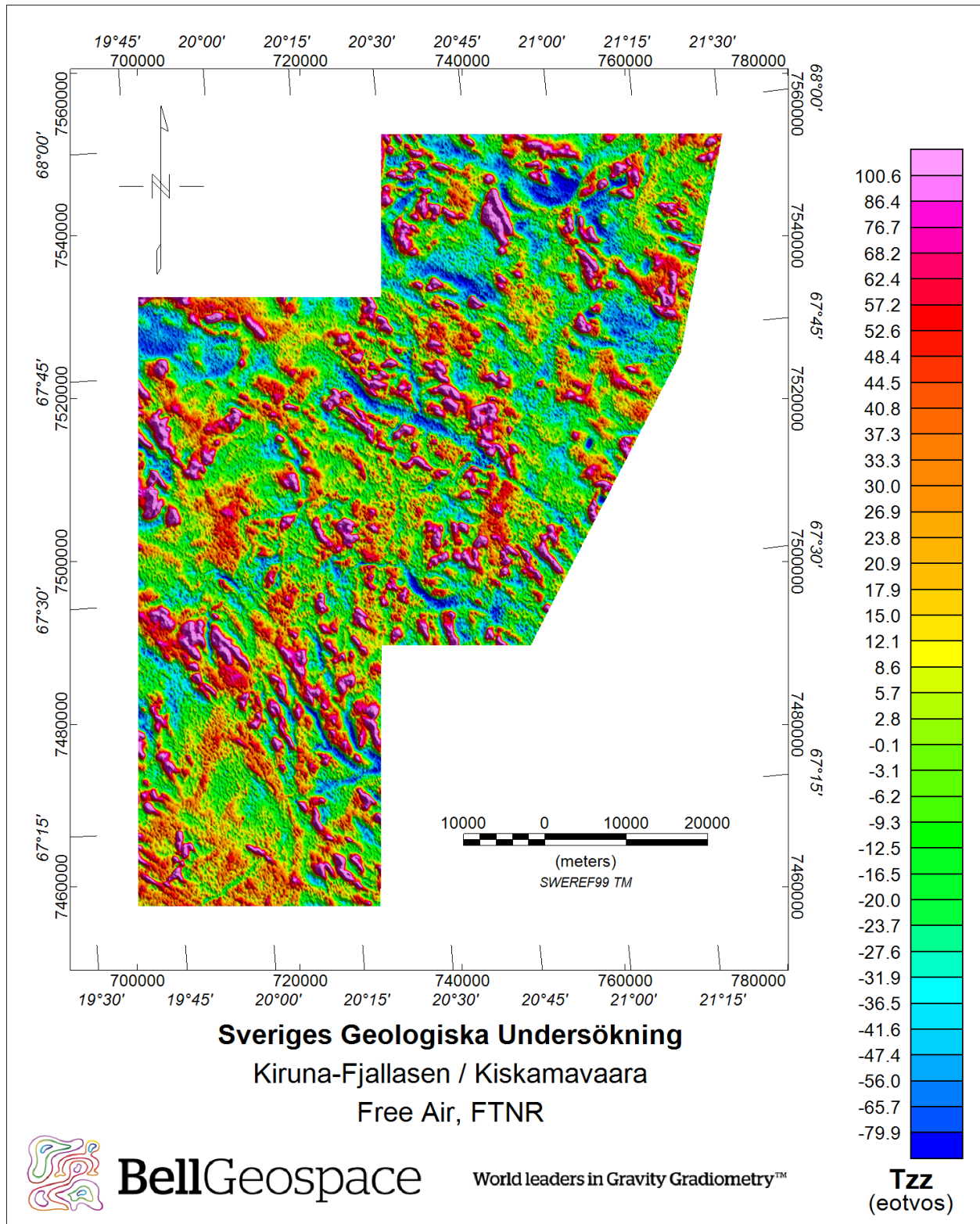
3.1 Key Products

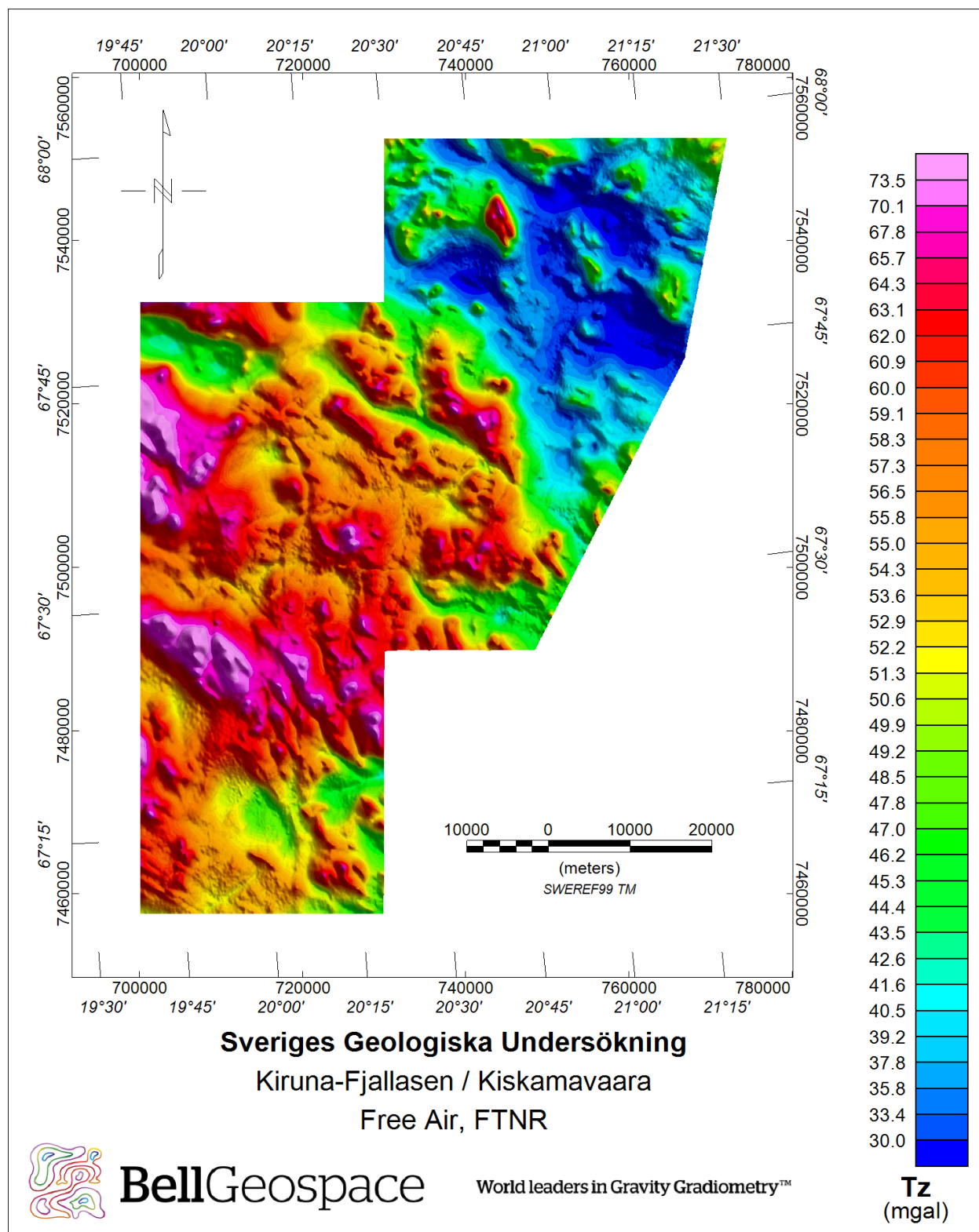
Gridded images were generated from the processed databases with a grid cell size set to a quarter of the nominal spacing across in-lines. Several maps were generated and are featured in this section (**Table 3.1**).

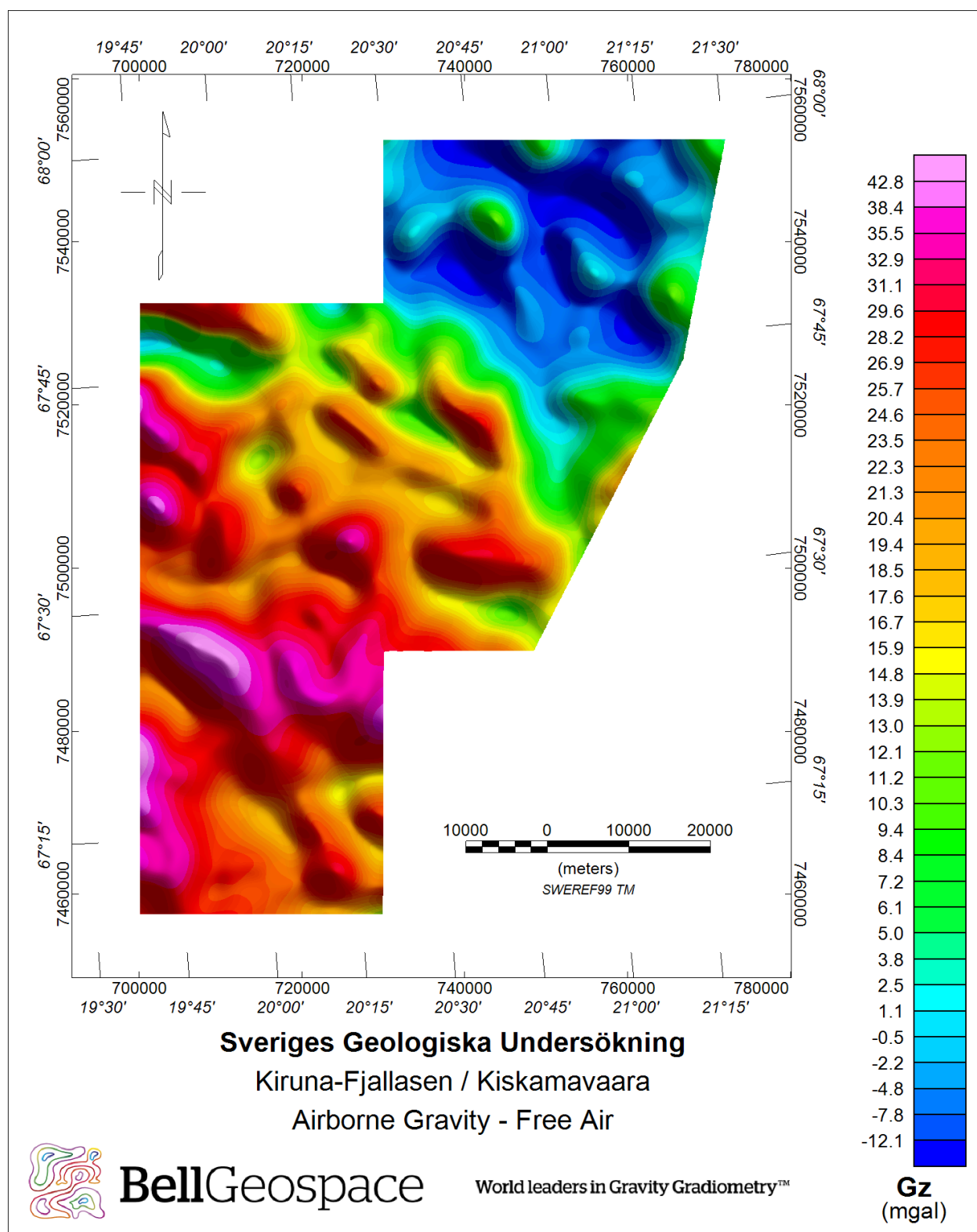
Table 3.1: Product descriptions

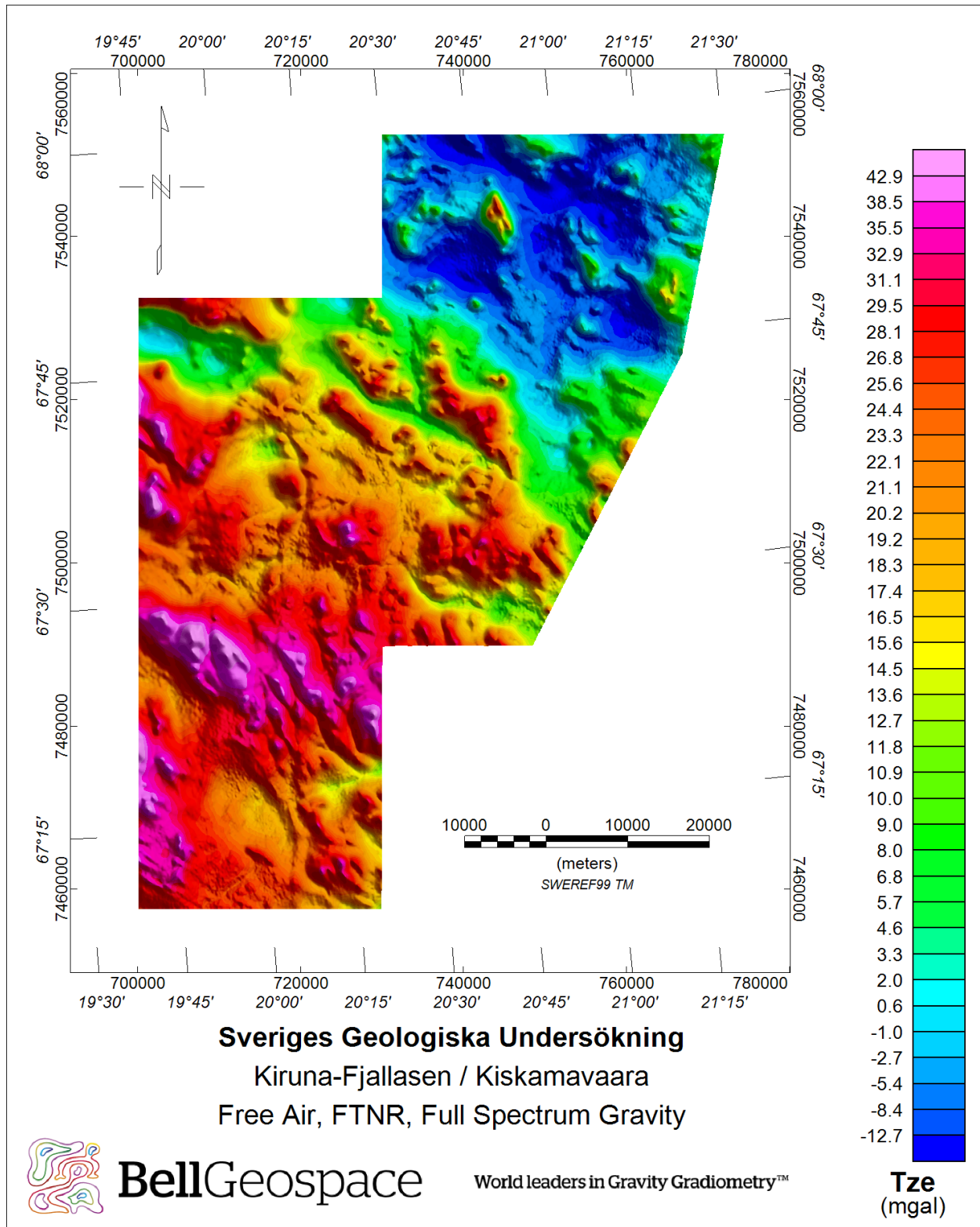
Map	Product	Processing Details
Figure 3.1	FA FTNR T_{zz}	Free Air response, processed with Full Tensor Noise Reduction
Figure 3.2	FA FTNR T_z	Free Air response, processed with Full Tensor Noise Reduction
Figure 3.3	FAA G_z	Free Air iCORUS/GT-Z airborne gravity response
Figure 3.4	FA FTNR T_{ze}	Full Spectrum Gravity - Free Air
Figure 3.5	TCD FTNR T_{zz}	Terrain-corrected response, processed with Full Tensor Noise Reduction
Figure 3.6	TCD FTNR T_z	Terrain-corrected response, processed with Full Tensor Noise Reduction
Figure 3.7	TCD G_z	Terrain-corrected iCORUS/GT-Z airborne gravity response
Figure 3.8	TCD FTNR T_{ze}	Full Spectrum Gravity - Terrain-corrected
Figure 3.9	CLP T_{zz}	Contact Lineament Processed based on TCD FTNR T_{zz}

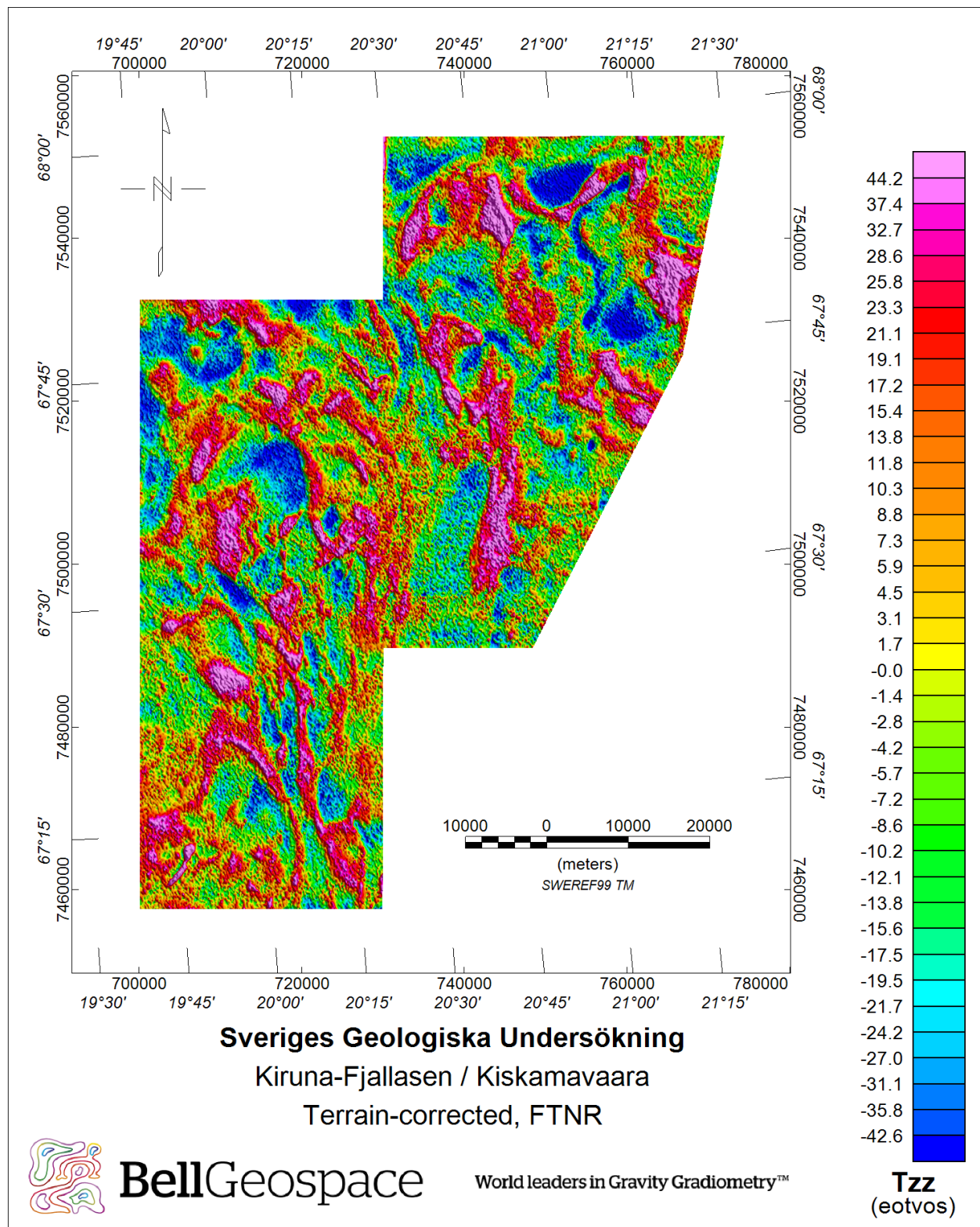
Additionally, images of all terrain-corrected Air-FTG tensor components are displayed in **Appendix 8**.

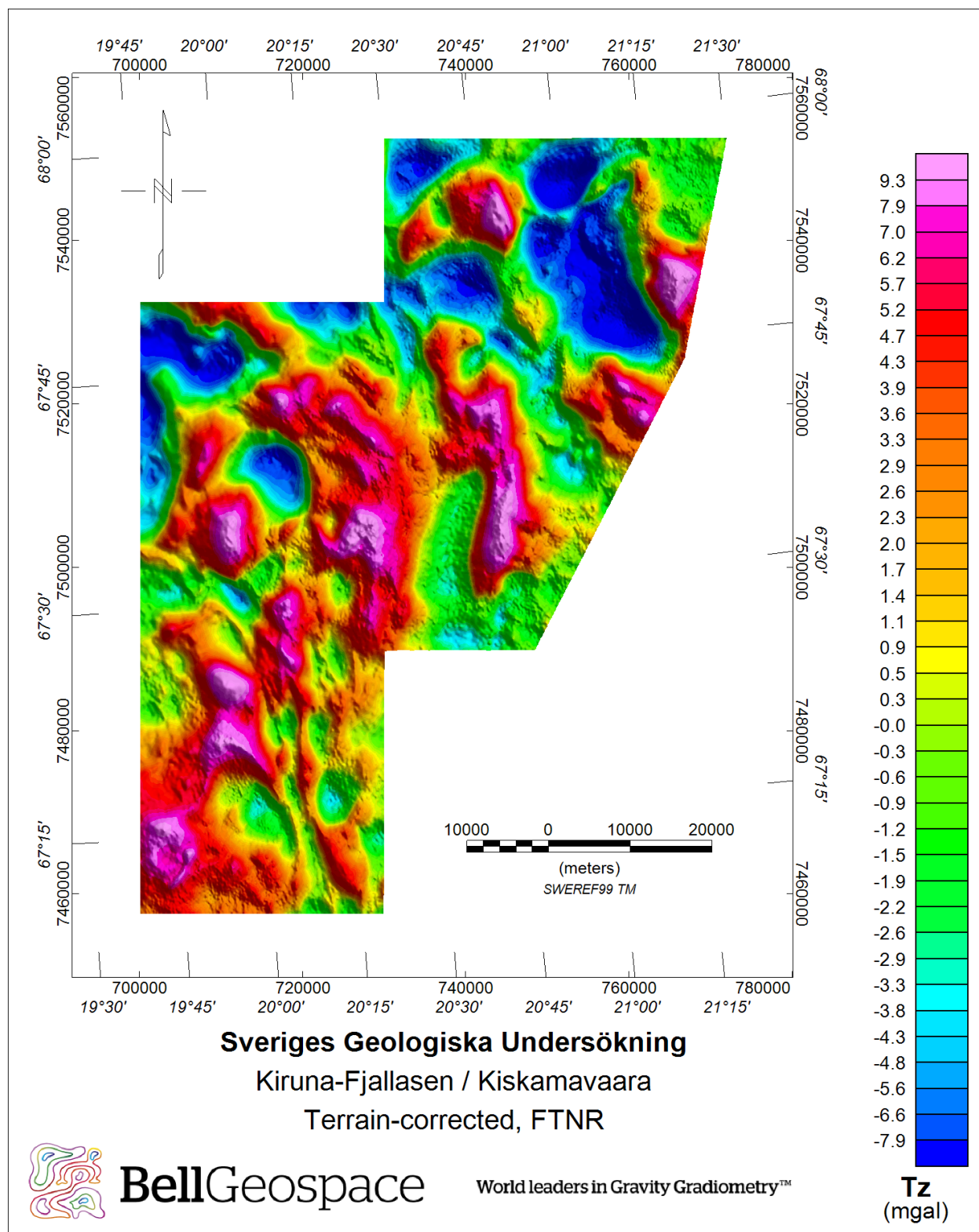
Figure 3.1: FA FTNR T_{zz}

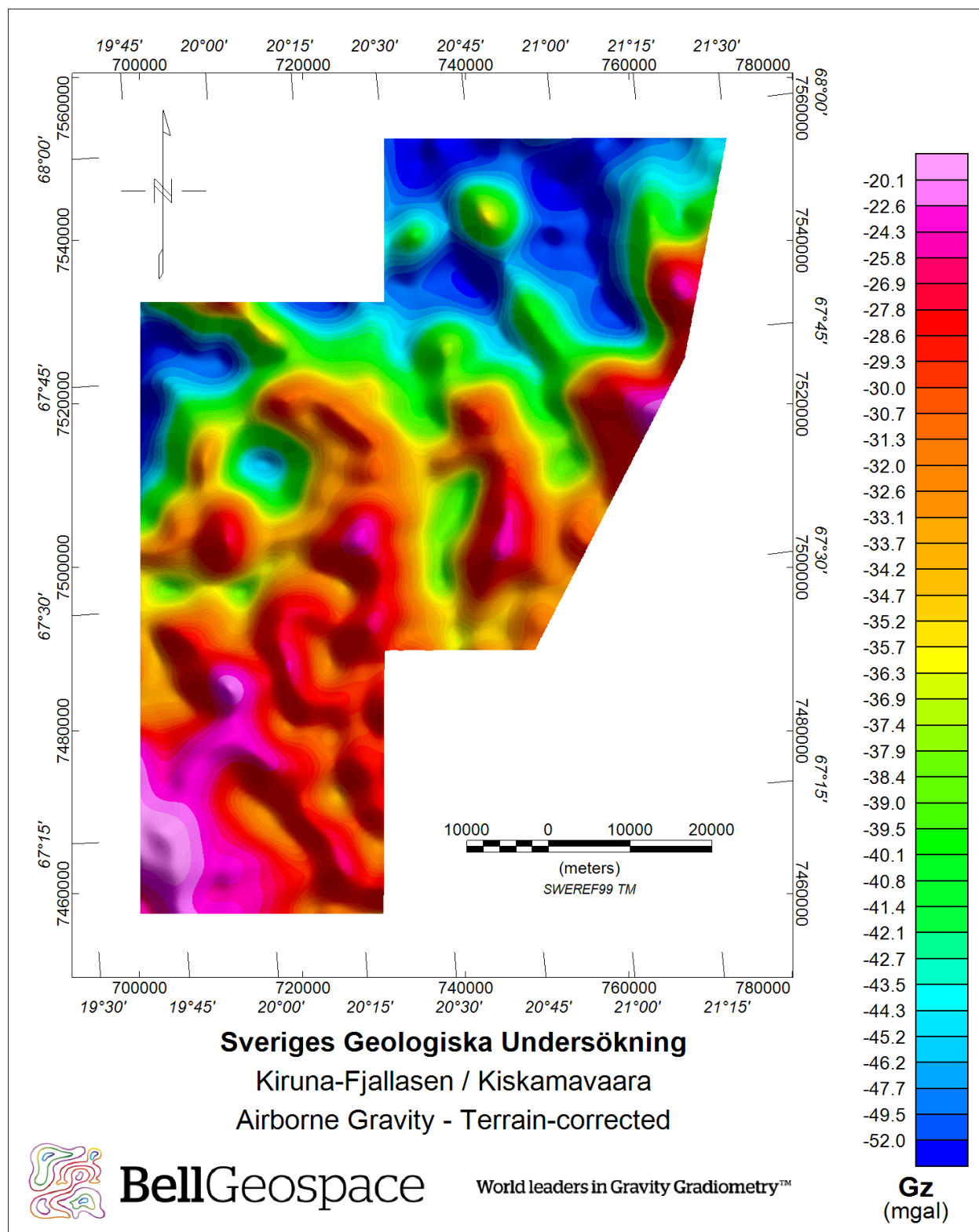
Figure 3.2: FA FTNR T_z

Figure 3.3: FAA G_z

Figure 3.4: FA FTNR T_{ze}

Figure 3.5: TCD FTNR T_{zz}

Figure 3.6: TCD FTNR T_z

Figure 3.7: TCD G_z

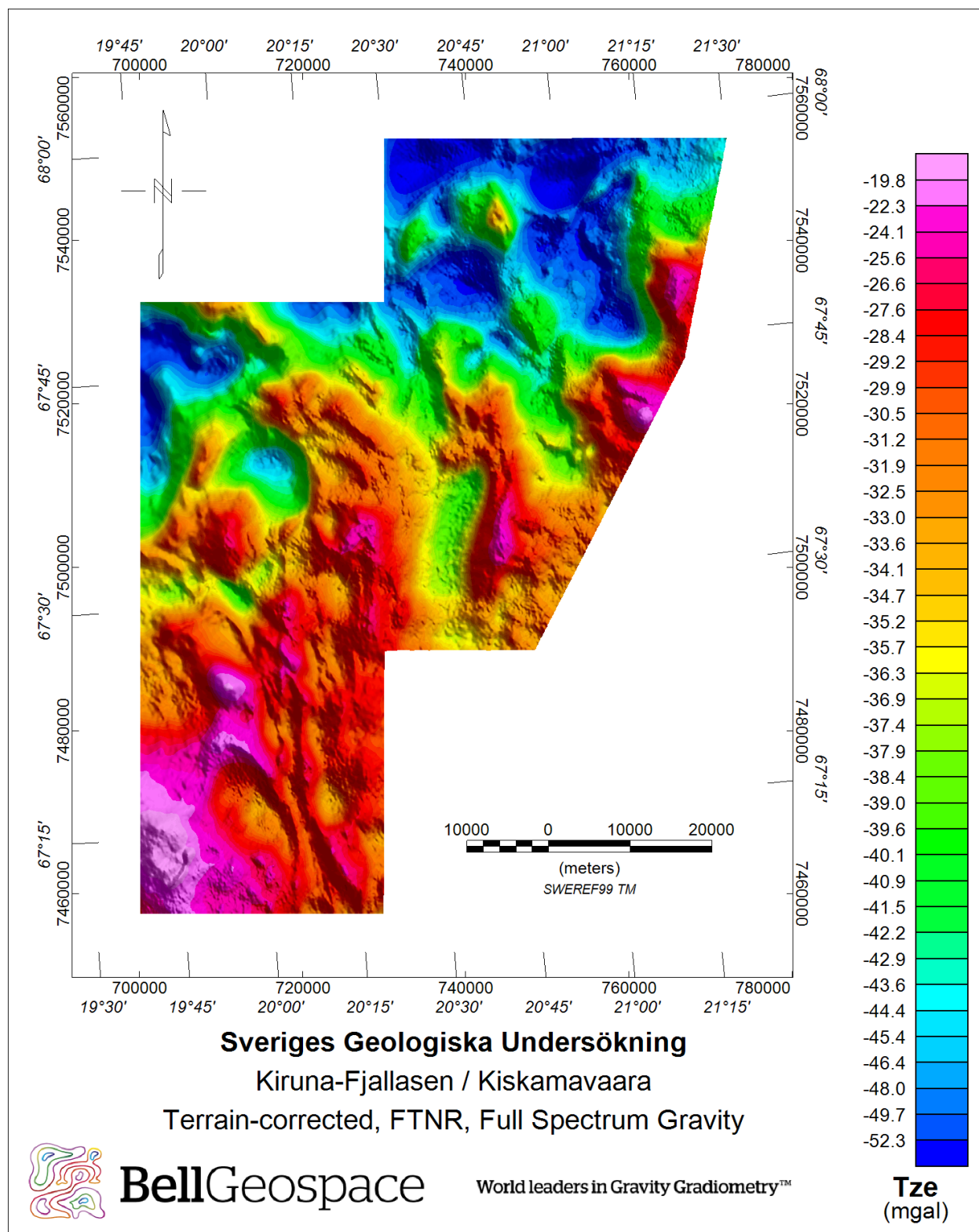
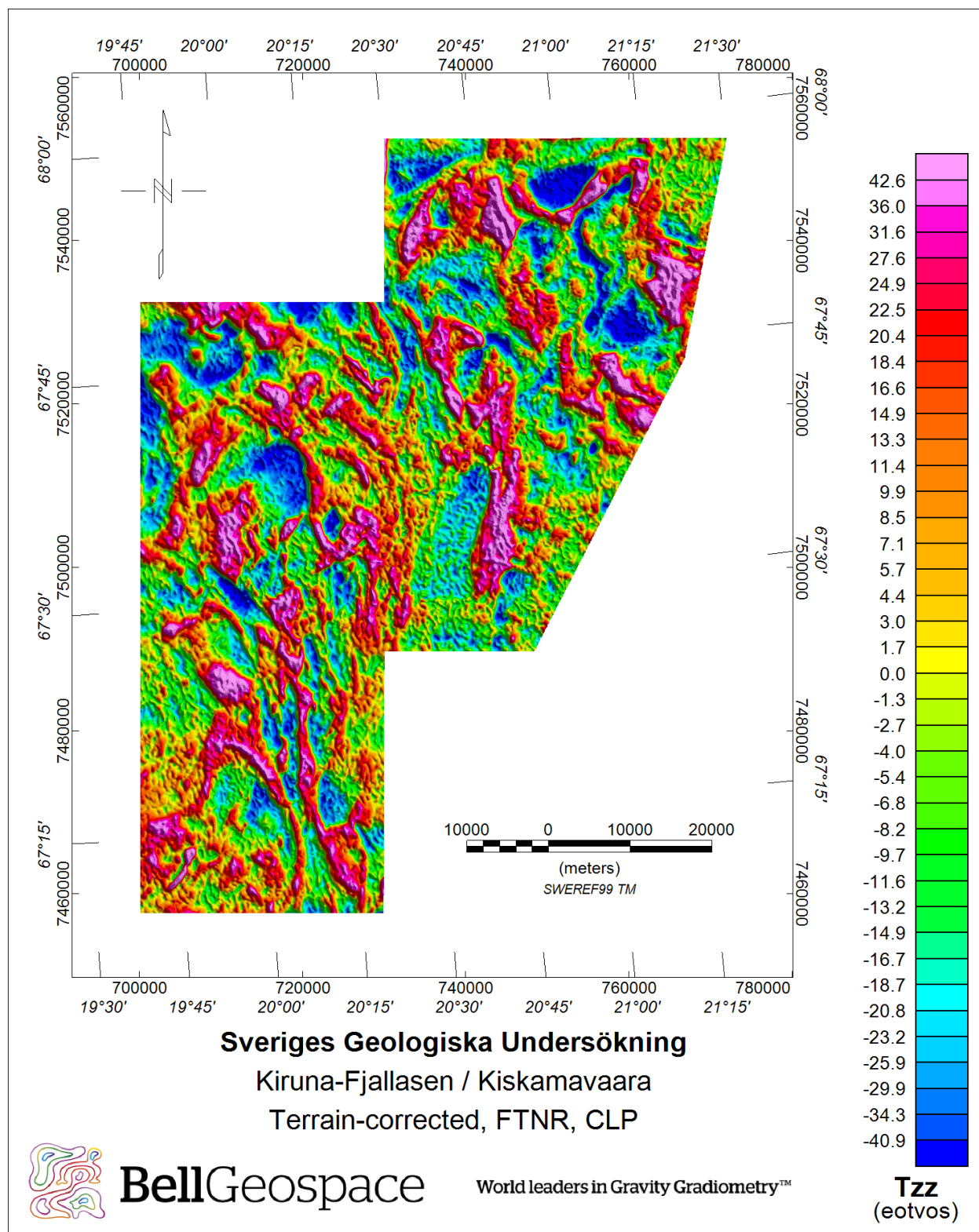


Figure 3.8: TCD FTNR T_{ze}

Figure 3.9: CLP T_{zz}

3.2 Deliverables

All final deliverables were created in Geosoft Oasis montaj software. Once the master databases were compiled, several digital products were generated in the following formats:

- › Air-FTG databases in Geosoft and ASCII formats. Channel descriptions are given in **Appendix 5**.
- › Airborne gravity databases in Geosoft and ASCII formats. Channel descriptions are given in **Appendix 6**.
- › Grids in Geosoft and ASCII formats. Geosoft grid files are delivered with accompanying .gi files, which contain supporting data from Geosoft Oasis montaj. Grid names and descriptions are given in **Appendix 7**.

Appendices



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World leaders in Gravity Gradiometry™

Appendix 1 Tensor Components: Background Information

Gradiometer data differs in many aspects from conventional high-resolution gravity data. One important difference is in bandwidth, which begins at 500 metres or less for gravity gradient data versus approximately 3,000 metres for conventional gravity. The greatly increased bandwidth allows for the retention of short wavelength signals generated by shallow to intermediate geologic features which are otherwise not retained in conventional gravity datasets. The increased sensitivity allows for much greater resolution and is the reason gradiometer data can be successfully incorporated into the subsequent interpretation at prospect level.

The gradient of a scalar field, such as gravitational potential, is mathematically represented as a 3×1 matrix of numbers commonly called a vector. The gradient of a vector field is mathematically represented as a 3×3 matrix of numbers commonly called a tensor. Each element of the tensor represents the rate of change of one of the components of the vector with respect to one of the principal coordinate axes. Thus, when T is a scalar field:

$$\text{grad}(T) = \nabla T = \left[\frac{\partial T}{\partial x} \quad \frac{\partial T}{\partial y} \quad \frac{\partial T}{\partial z} \right] = [T_x \quad T_y \quad T_z]$$

$$\text{grad}(\text{grad}(T)) = \begin{bmatrix} T_{xx} & T_{xy} & T_{xz} \\ T_{yx} & T_{yy} & T_{yz} \\ T_{zx} & T_{zy} & T_{zz} \end{bmatrix}$$

In the expressions above, T_x , T_y and T_z represent the acceleration of gravity with respect to the three coordinate axes. On the other hand, T_{xx} , T_{xy} , T_{xz} etc. represent the rate of change of each component of gravity as one's position changes in the three principal coordinate axes. By the definition of a potential field, as stated in Laplace's Equation, the sum of the diagonal components of the tensor is zero, i.e.:

$$\nabla^2 T = T_{xx} + T_{yy} + T_{zz} = 0$$

One may also show that the tensor is symmetrical about its diagonal, *i.e.*:

$$\begin{aligned}T_{ij} &= T_{ji} \\T_{xy} &= T_{yx} \\T_{yz} &= T_{zy} \\T_{xz} &= T_{zx}\end{aligned}$$

As a consequence of these two relationships, only five components of the gradient tensor are independent. For example, if one knows, T_{xx} , T_{xy} , T_{xz} , T_{yy} and T_{yz} , the remaining four components can be uniquely determined by the relationships given above.

Each of the gravity gradient tensor components responds uniquely to the size, shape and thickness of density anomalies providing extensive constraint during the interpretation process. All five independent tensor components are utilised in the interpretation process to determine the centre of mass (T_{xz} and T_{yz}), edges (T_{xx} and T_{yy}) and corner (T_{xy}) of the anomaly. The expression of T_{zz} , the vertical component, more closely resembles conventional gravity in that the anomaly is shown in the correct spatial position over the centre of geologic mass and is thus more easily related to subsurface geology.

For more information, please refer to *Potential Theory in Gravity & Magnetic Applications* by Richard J. Blakely (Cambridge University Press, 1996).

3D FTG Field: **Vectors** and **Tensors**

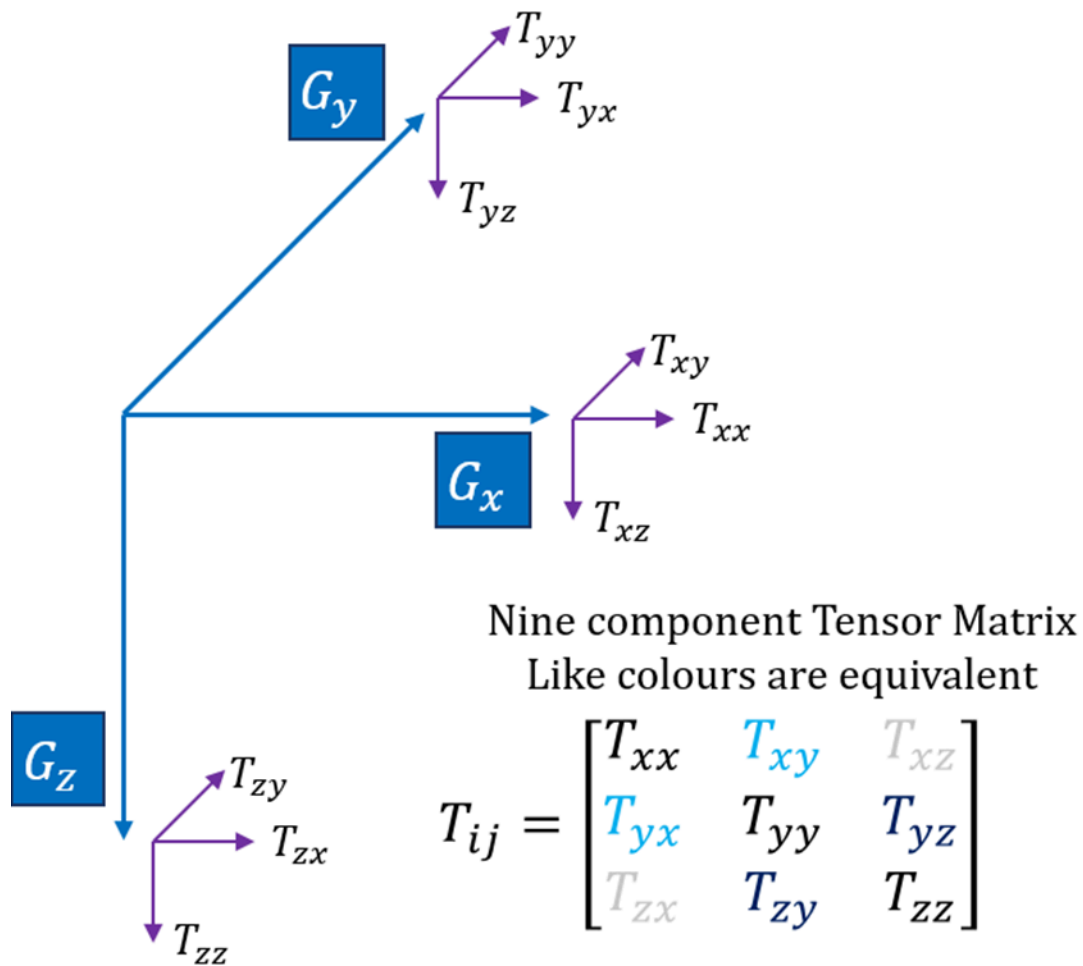


Figure A1.1: Relationship of the gravity vector ($[G_x G_y G_z]$) to the FTG tensor

Appendix 2 Air-FTG Data Processing Details

Detrimental noise in Air-FTG originates from a variety of sources (e.g. aircraft motion, instrument effects, weather conditions), all of which have variable effects on data quality. The data is put through a series of processing steps in order to compensate and mitigate these effects.

High-Rate Post Mission Compensation (HRPMC): Air-FTG raw datasets recorded in the field consist of two signals, Inline and Cross, for each of the three gravity gradient instruments (GGIs), providing six independent signals. The GGI output channels undergo initial data processing in the field through a proprietary software package referred to as High-Rate Post Mission Compensation (HRPMC). This step operates on the most highly sampled data, utilising gyroscope outputs at 1024 *Hz* and GGI outputs at 128 *Hz*. HRPMC compensates the data for most physical conditions encountered during signal acquisition. This includes corrections for the gradients of the aircraft and instrument itself. Files monitoring GGI platform status are logged in real-time and used to create tables of coefficients that are subsequently used in processing. A series of complex algorithms within the program use these files to generate coefficients for each 2-hour segment of data acquisition. These coefficients are necessary to calculate corrections for aircraft motion and position relative to the instrument during the survey. Another set of corrections are made to remove gradients due to the centripetal accelerations that result from the rotation of each of the three GGIs.

Strip, Average and Reformat (SAR): Upon completion of HRPMC, the data is subjected to another processing step referred to as SAR, which strips out unnecessary data elements, averages the remaining data to a reduced sampling rate and reformats it into a 24-column binary file. The averaging process in SAR allows the processor to choose the data sampling rate for all subsequent processing and final data; in this case 1 second. The SAR files are composed of daily blocks of data and are combined to create one file containing all the data for the entire survey. Since Air-FTG data is recorded continuously, this file also contains data recorded during traverses, turns, and on lines that are later re-acquired for various reasons.

The data recorded in these instances are deleted before final processing. During the SAR procedure, navigation and aircraft attitude data is combined with the gravity gradient data using a time-based merge.

Preparing Master Database: SAR files are imported into a single Geosoft database utilised for subsequent data processing. Other datasets (e.g., terrain and drape values) are also imported into the database. Projected coordinates (X and Y) are computed from corresponding geographic coordinates (*Latitude* and *Longitude*) and data outside the survey boundaries is deleted from the database, before applying further corrections.

GGI to Tensor Components Conversion: GGI datasets, which are measured in an internal coordinate reference frame, are transformed to gradient tensor components of an East-North-Down coordinate reference frame based on the following:

$$\begin{bmatrix} T_{zz} \\ (T_{yy} - T_{xx})/2 \\ T_{xy} \\ T_{yz} \\ T_{xz} \end{bmatrix} = M \begin{bmatrix} \text{Inline2} - \text{Inline1} \\ \text{Inline3} - \text{Inline2} \\ \text{Cross1} \\ \text{Cross2} \\ \text{Cross3} \end{bmatrix}$$

where M represents a matrix of known coefficients, derived utilising Lockheed Martin's software. All Air-FTG datasets provided in the final deliverables are referenced to East-North-Down gradient tensor components; no GGI datasets are provided. Background information on gradient tensor components is provided in **Appendix 1**.

Terrain Corrections: In order to isolate local geological anomalies, Free Air Air-FTG data is corrected for topographical features. The digital terrain model (DTM) utilised for calculating the terrain correction dataset was derived from the following products:

- › Onshore topography was derived from processed lidar data merged with Aster data. The merged dataset was used for elevation points above the geoid (0m).

Terrain corrections are based on a right rectangular prism model described in *Plouff (1996)*. For each tensor component, TC100 is generated from a series of closed form expressions – *Li & Chouteau (1998)*.

The terrain corrections (TC100) are calculated for each GGI/gradient tensor component with a bulk density of 1.00 g/cm^3 . The Free Air datasets were then compensated for terrain effects using TC100 and a bulk rock density of 2.67 g/cm^3 ; this density may be altered later in the processing, prior to FTNR application.

Levelling to airborne gravity: Compared to conventional gravity data, Air-FTG data may have a relatively unstable low-frequency bandwidth. This limitation was corrected by partially levelling the Air-FTG data to the acquired and fully processed iCORUS/GT-Z airborne gravity dataset. The levelling corrections were calculated for each Air-FTG tensor component with the following procedure:

- › The airborne gravity (iCORUS/GT-Z) dataset is first processed. Details are discussed in **Appendix 3**.
- › Equivalent tensor components are calculated from the processed terrain-corrected airborne gravity data.
- › The difference of the filtered airborne gravity and unlevelled Air-FTG terrain-corrected tensor component data is calculated.
- › A low-order trend of the difference is calculated across each flown line. This levelling correction is then applied to the unlevelled Air-FTG data.

Micro-Levelling: In some cases, the tie-line levelling sequence is not adequate for suppressing short-term noise effects, and in such cases a micro-levelling filter is applied to each FTG channel. The basic sequence is as follows:

- › First, a decorrugation noise filter is applied to the in-line data gridded at 0.25 times the across in-line spacing, producing a grid consisting of both residual noise and high-frequency bandwidth of the geological response.

Table A2.1: Decorrugation noise filter parameters

High-Pass Butterworth Filter	<i>Filter Order</i> - 6 <i>Cut-Off Wavelength</i> - Minimum four times the across in-line spacing
Directional Cosine Filter	<i>Number of Degrees</i> - 2 <i>Direction</i> - Aligned to in-line survey heading <i>Mode</i> - Pass

- › Generally, flight noise exhibits smaller amplitudes than that of geological responses, as well as longer wavelengths parallel only to the in-line direction; the application of an amplitude limit and low-pass Naudy filter isolates the geological response from the decorrugation noise grid.

Table A2.2: Naudy filter and amplitude limit parameters

Naudy Filter Length	Across in-line spacing (or longer to help retain more geological signal)
Naudy Filter Tolerance	0.0001
Amplitude Limit Mode	Clip/Zero
Amplitude Limit Value	Standard deviation of the decorrugation grid (or higher to suppress more noise)

- › Finally, the noise data is subtracted from the original dataset to create a micro-levelled result. For surveys with higher noise levels, it may be necessary to apply micro-levelling at least twice with different constraints.

Full Tensor Noise Reduction (FTNR): Residual noise including white noise is reduced further with Bell Geospace's proprietary Full Tensor Noise Reduction (FTNR) software, by using all levelled Air-FTG gradient tensor components collectively.

It is based on the principle that each independent tensor component measures the same potential field, *i.e.*, the gravitational potential is governed by Laplace's Equation:

$$\nabla^2 T = T_{xx} + T_{yy} + T_{zz} = 0$$

While the geological signal is consistent, noise is random for each gradient tensor component. Hence, each Air-FTG tensor has a predictable response that can be used to identify and remove noise from all the tensor components. This idea has been previously demonstrated by *Sanchez et al. (2005)*.

FTNR uses a Fourier-domain method to process levelled Air-FTG data. The basic methodology utilised is as follows:

- › Each independent tensor component, as well as the aircraft altitude, is gridded using standard techniques with a grid cell size set to a fraction (0.25-0.50) of the nominal across in-line spacing.
- › The noise reduction, based on Fourier-domain formulas from *Blakely (1996)*, is computed on a flat plane at an altitude below the level of the input observations. The relations between the tensor components in the Fourier-domain allow each one to be calculated five different ways; these are then stacked together as a noise-reduced dataset.

- › The processed data is then transferred to the actual observation locations using upward-continuation.
- › The processed, upward-continued and noise-reduced data is then differenced against the starting levelled data and the exercise is repeated to reduce noise content in the higher frequency residual data. The FTNR cycle ends when no discernible signal is evident in the residual data.
- › At the end of each cycle, the processed data is summed with that from the previous iteration, forming the FTNR dataset. The input data for each cycle is calculated from the difference of the original levelled dataset and latest FTNR dataset.
- › The final processed FTNR dataset is exported for all independent gradient tensor components.

Brewster (2016) describes the algorithm employed with FTNR for Air-FTG data and includes a description of key controls for successful deployment. One of the primary control parameters is the wavelength cut-off, the smallest wavelength that FTNR will attempt to correlate between the gradient tensor components. This constraint is essential for Fourier-domain calculations and is typically set to match the nominal across in-line spacing. Another control parameter determines when the data has been processed to an acceptable level, thus ending the cycle. Default settings normally produce valid results in a practically time frame but may require adjustment for datasets that consist of scant signal.

FTNR was applied directly to the terrain-corrected levelled gradient tensor components, as well as the TC100 gradient tensor components. A final Free Air Air-FTG dataset was calculated from the FTNR products utilising the following equation:

$$FA\ FTNR = TCD\ FTNR + (\rho_r \cdot TC100\ FTNR)$$

- › $\rho_r (g/cm^3)$ is the bulk rock density above the geoid

Gravitational Potential Field (T_z): A natural by-product of the FTNR process is the generation of a high signal-to-noise ratio Gravitational Potential from the tensor components. This is

transformed to produce both noise-reduced tensor components and a conventional gravity field (T_z).

Full Spectrum Gravity (T_{ze}): Air-FTG T_z is normally devoid of low-order regional trends. This is a mathematical limitation of the FTNR algorithm which calculates T_z from tensor component data. This limitation was solved by calculating the missing regional trends by comparing the Air-FTG with airborne gravity data:

- › The radial average power spectra (RAPS) of both Air-FTG and airborne gravity data were plotted and compared (**Figure A2.1**). The cross-over point between the generated RAPS profiles for Air-FTG and secondary gravity dataset was identified at 15 km wavelength.
- › A difference map of airborne gravity and Air-FTG gravity data was gridded, and then a 2D low pass filter of 15km cut-off was applied. This filtered trend was then subsequently added to the Air-FTG T_z to calculate T_{ze} .

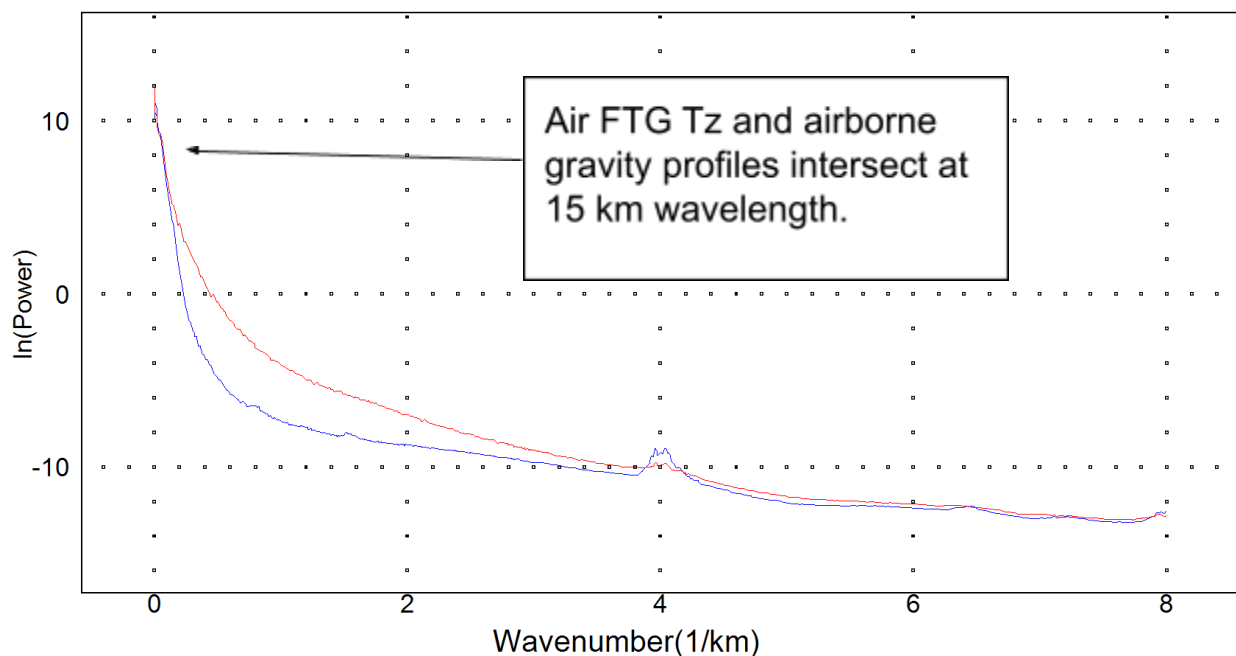


Figure A2.1: RAPS profiles of Air-FTG gravity (red) and airborne gravity (blue) data.

References:

Brewster, J. 2016. Reducing Noise by Transforming and Combining Gravity Gradient Components. In R.J. Lane (editor), Airborne Gravity 2016 – Abstracts from the ASEG-PESA Airborne Gravity Workshop, Geoscience Australia, in press.

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Plouff, D.: "Digital terrain corrections based on geographic coordinates, Geophysics 31, 1208." (1966).

Li & Chouteau: "Three-Dimensional Gravity Modelling in All Space", Surveys in Geophysics, 19, 339-368 (1998).

Sanchez, Vinicio, David Sinex, Yaoguo Li, Misac Nabighian, David Wright, and David von G Smith: "Processing and inversion of magnetic gradient tensor data for UXO applications. In 18th EEGS Symposium on the Application of Geophysics to Engineering and Environmental Problems." (2005).

Blakely, Richard J.: "Potential theory in gravity and magnetic applications." (1996).

Pedersen L. B. and Rasmussen T. M.: "The gradient tensor of potential field anomalies; some implications on data collection and data processing of maps, Geophysics, 55, 1558-1566." (1990).

Appendix 3 Airborne Gravity (iCORUS/GT-Z) Processing Details

Airborne gravity processing was primarily carried out by Transparent Earth Geophysics (TEG), with the exception of the terrain corrections, which were completed by Bell Geospace.

GTQC20 Processing: GTQC20 is a TEG proprietary acceleration QC software program developed by Moscow State University (MSU). The software unpacked and converted the raw gravimeter acceleration and gravimeter platform binary files to ASCII format. Additionally, GTQC20 applied an 18-second GPS leap second offset to the gravimeter data for synchronisation purposes and performed standardized error-checking procedures.

The following GTQC20 processing parameters were examined using these nominal specifications:

- › Coarse-channel saturations (+1.0 g) Flagged
No Saturation = 0, Saturation = 1
- › Lost, missing, extra or corrupted records Flagged
- › Gravimeter hardware status problems Flagged

Flight conditions associated with turbulence are generally the major cause of gravimeter saturations. In these instances, the GTQC20 software flags a +1.0 g full dynamic range saturation.

GTNAV Processing: GTNAV is a TEG proprietary software program developed by MSU. The software processed the acquired GPS data to produce a differentially post-processed solution. GTNAV also estimated the iCORUS/GT-Z platform misalignment errors and was used for QC of the raw GPS and INS navigation data from the gravimeter.

GTNAV output data was used for both flight path recovery and the integration of GPS and INS data for later computation of the Free Air gravity anomaly. For QC of the flight path and GPS quality, the results were imported into an Oasis montaj database and inspected.

GTGRAV Processing: GTGRAV is a TEG proprietary software program developed by MSU. The primary purpose of GTGRAV was to model the Free Air gravity anomaly and perform QC of the resulting data on a flight-by-flight basis. These results were then imported into an Oasis montaj database for further QC and processing operations.

GTGRAV models the relative Free Air gravity anomaly and includes the following corrections:

- a) **Static Correction:** Correction based on pre-flight and post-flight reference measurements.
- b) **Eötvös Correction:** The Eötvös correction compensates for the vertical component of centripetal acceleration induced by motion over a rotating, ellipsoidal Earth. The formula used for the correction, referenced from *Harlan (1968)* relative to the GRS 1980 (GRS80) reference ellipsoid, is as follows:

$$g_E = 2v_e\Omega \cos(\phi) + \frac{v_n^2}{a} \left[1 + \frac{h}{a} + f(2 - 3\sin^2(\phi)) \right] + \frac{v_e^2}{a} \left[1 + \frac{h}{a} + f(2 - f\sin^2(\phi)) \right]$$

where g_E is the Eötvös correction in m/s^2 at latitude ϕ , v_e is the easterly component of velocity in m/s , v_n is the northerly component of velocity in m/s , a is the semi-major axis of the Earth in *metres*, h is the altitude of the observation point in *metres*, f is the flattening of the Earth and Ω is Earth's rotation rate.

- c) **Latitude Correction (Theoretical Gravity):** The latitude correction compensates for changes in apparent vertical gravity due to the rotation and ellipsoidal shape of the Earth. The formula for the theoretical gravity g_T , in *mGals*, on the GRS80 reference ellipsoid at latitude ϕ is as follows:

$$g_T = g_e \left[\frac{1 + k \sin^2(\phi)}{\sqrt{1 - e^2 \sin^2(\phi)}} \right]$$

where g_e is the normal gravity value at Earth's Equator (978032.67715 *mGal*), k is a derived constant and e is the first numerical eccentricity.

- d) **Atmospheric Correction:** The atmospheric correction compensates for the average change in the mass of the atmosphere between the reference ellipsoid and the observation point. The formula used for the correction is referenced from *Wenzel (1985)* and is as follows:

$$g_{atm} = 0.874 - 9.90 \times 10^{-5}h + 3.56 \times 10^{-9}h^2$$

where g_{atm} is the atmospheric correction in *mGals* and h is the elevation of the observation point in *metres*.

- e) **Altitude (Free Air) Correction:** The altitude correction compensates for altitude changes using the vertical gravity gradient. The formula used for the correction is referenced from *Hinze et al. (2013)* and is as follows:

$$g_a = (0.3087691 - 4.398 \times 10^{-4} \sin^2(\phi))h + 7.2125 \times 10^{-8}h^2$$

where g_a is the altitude correction in *mGal* at latitude ϕ and h is the elevation of the observation point in *metres*.

After application of the above gravity corrections, a Kalman filter with 137 seconds cut-off is applied. The results were imported into an Oasis Montaj database for further analysis and presentation.

Final Processing: The following processes were applied in Oasis montaj to produce the final relative Free Air gravity anomaly:

- a) Aircraft GPS heights relative to the GRS80 ellipsoid were converted to orthometric height. Necessary *NValues* for the conversion were determined from the Earth Gravitational Model 1996 (EGM96) at 15' resolution. *NValues* represent geoid undulations relative to the GRS80 ellipsoid (spheroid). For this calculation, EGM96 geoid model *NValues* were subtracted from aircraft GPS heights relative to the GRS80 ellipsoid.

$$h_{\text{EGM96 Geoid}} = h_{\text{GRS80 Ellipsoid}} - N\text{Value}$$

- b) Relative Free Air anomaly observations with respect to the GRS80 ellipsoid were converted to relative Free Air anomaly observations with respect to the EGM96 geoid.

$$gFA_{\text{EGM96 Geoid}} = gFA_{\text{GRS80 Ellipsoid}} - (0.3086 * N\text{Value})$$

- c) Zero-order tie-line levelling corrections based on mis-tie values were applied utilizing the *Statistical Levelling GX* module within Oasis montaj.
- d) Additional micro-levelling corrections were applied utilizing the *PGW Microlevelling* module within Oasis montaj.
- e) Remaining residual noise was removed utilizing a 2D FFT spatial filter with a cut-off wavelength of 6 kilometres. This filter was initially applied separately to each survey

block shortly after acquisition was complete; to improve data consistency across both survey blocks, the 2D FFT spatial filter was reapplied to both survey blocks collectively.

Terrain Corrections: The DTM utilised for calculating the terrain correction dataset was derived from the same datasets used for Air-FTG terrain corrections with the following alterations:

- › The DTM was extended to 100 kilometres beyond the survey block to account for significant topographic variations the iCORUS/GT-Z instrument could detect.
- › A 2D low-pass Butterworth filter with 6 kilometre cut-off wavelength was then applied directly to the TC100 dataset to suppress slight topographic variations undetectable by the iCORUS/GT-Z instrument. This filter was initially applied separately to each survey block shortly after acquisition was complete; to improve data consistency across both survey blocks, the 2D FFT spatial filter was reapplied to both survey blocks collectively.

Absolute Values: The relative gravity data was adjusted to absolute values by utilising ground gravity station data provided by the client.

- › The free air response of ground gravity and airborne gravity datasets were both mapped and compared.
- › The average difference between the datasets was added as a bias correction to the airborne datasets.

References:

Harlan RB (1968). Eötvös correction for airborne gravimetry, J. Geophys. Res. 3, 4675-4679.

Wenzel, H., 1985. Hochauflösende Kugelfunktionsmodelle für das Gravitationspotential der Erde [1]: Wissenschaftliche arbeitender Fachrichtung Vermessungswesen der Universität Hannover, 137.

Appendix 4 Air-FTG Contact Lineament Processing Details

For interpretation, methods are required to help identify and visualise geological structures at various depths. An example is applying a series of low-pass filters. However, this risks over-smoothing and potentially removing shallow depth anomalies. Many exploration targets, for example dikes and faults, are by nature directional and elongated. Thus, a directional filter is often more suitable than a general low-pass filter, if orientated correctly to align with the structure (*Brewster et al., 2014*).

Contact Lineament Processing (CLP) is a patented image processing tool developed by Bell Geospace, which applies a directional filter that varies with location and is assigned automatically using the full tensor component dataset. The direction of the filter at any location is based on the strike direction (θ_s) calculated from the following equation from *Pederson (1990)*:

$$\tan(2\theta_s) = 2 \frac{T_{xy}(T_{xx} + T_{yy}) + T_{xz}T_{yz}}{T_{xx}^2 - T_{yy}^2 + T_{zz}^2 - T_{yz}^2}$$

The basic methodology is as follows:

- › Calculate the strike angles (θ_s) based on the aforementioned equation.
- › Apply a directional filter to each gradient tensor component, with the local direction of the filter aligned with the strike angle.
- › Due to each gradient tensor component being filtered separately, they no longer measure the same potential field. The solution is to run the FTNR process on the directionally-filtered tensor components.
- › Recalculate the strike angles with the directionally-filtered, FTNR dataset.
- › Procedure is repeated for a few cycles until the strike angles are refined.

CLP was applied to the terrain-corrected FTNR gradient tensor components to produce the CLP results. This process was applied in multiple 'Runs', with each run screening for different

magnitudes of strike lengths to identify the array of structural features present in the dataset. This was achieved by repeating the CLP with the '*residual*' dataset – the difference between the original FTNR dataset and the previous CLP run datasets combined.

CLP run outputs were also combined to give a multi-directional, filtered version of the FTNR dataset, which can then be used both as a standalone interpretative product and a base for generating further interpretative products.

References:

Brewster, J., Mataragio, J. and Murphy, C. 2014. A self-steering directional filter for focussed imaging of full tensor gradiometer data. SEG 2014. Expanded abstracts.

Pedersen L. B. and Rasmussen T. M.: "The gradient tensor of potential field anomalies; some implications on data collection and data processing of maps, Geophysics, 55, 1558-1566." (1990).

Appendix 5 Air-FTG Database Channel Index

Channel Name	Description	Units
YYMMDD	Date in year-month-date	
HHMMSS	Time in hours-minutes-seconds	
Time	Interval FTG time in seconds after January 6, 1980	
X_UTM34N	X-coordinates in WGS 84, UTM 34N	metres
Y_UTM34N	Y-coordinates in WGS 84, UTM 34N	metres
X_SWEREF99	X coordinates in SWEREF99	metres
Y_SWEREF99	Y coordinates in SWEREF99	metres
Lat	Latitude (WGS84)	decimal degrees
Lon	Longitude (WGS84)	decimal degrees
Altitude	Altitude of the aircraft for the GPS (referenced to EGM96)	metres
Drape	Ideal planned drape surface	metres
EastVelocity	Horizontal velocity of the aircraft, in the East-West direction. Positive: East, Negative: West	metres/second
NorthVelocity	Horizontal velocity of the aircraft, in the North-South direction. Positive North, Negative: South	metres/second
VertVelocity	Vertical velocity of the aircraft in the Z-Direction Positive: Down, Negative: Up	metres/second
Heading	Platform heading angle. Positive: clockwise from North. Negative: Anticlockwise from North	radians

Pitch	Pitch of the aircraft from horizontal	radians
Roll	Roll of the aircraft from horizontal	radians
Terrain	Digital terrain model	metres
FA_*	Unlevelled Free Air Air-FTG data	eötvös
FA_lev_*	Levelled Free Air Air-FTG data	eötvös
FA_lev_FTNR_*	Levelled Free Air Air-FTG data. Full Tensor Noise Reduced	eötvös or mGal
FA_lev_FTNR_ T_z _Res	High-pass Butterworth filter applied to FA lev FTNR T_z	mGal
FA_lev_FTNR_ T_{ze}	Full Spectrum Gravity of Air-FTG and iCORUS/GT-Z airborne gravity data	mGal
TC100_*	Forward modelled FTG response of terrain above the geoid, with a density of 1.00 g/cm^3	eötvös
TC100_FTNR_*	Forward modelled FTG response of terrain above the geoid, with a density of 1.00 g/cm^3 . Full Tensor Noise Reduced	eötvös or mGal
TCD_FTNR_*	Terrain-corrected, Full Tensor Noise Reduced Air-FTG data	eötvös or mGal
TCD_FTNR_ T_z _Res	High-pass Butterworth filter applied to TCD FTNR T_z	mGal
TCD_FTNR_ T_{ze}	Full Spectrum Gravity of terrain-corrected Air-FTG and iCORUS/GT-Z airborne gravity data	mGal
CLP_*	Contact Lineament Processed Air-FTG data	eötvös

Appendix 6 Airborne Gravity (iCORUS/GT-Z / GTZ) Database Channel Index

Channel Name	Description	Units
Line	Line number	integer
LineType	Traverse or Tie (L or T)	string
Flt	Flight number	integer
Fid	Fiducial	integer
Date	Flight Date	YYYYMMDD
GPSTime	GPS - Time since start of GPS day	HHMMSS
Longitude	Longitude WGS84 in decimal degrees	degrees
Latitude	Latitude WGS84 in decimal degrees	degrees
X_UTM34N	Easting - WGS84 UTM 34N	metres
Y_UTM34N	Northing - WGS84 UTM 34N	metres
X_SWREF99	X coordinates in SWREF99	metres
Y_SWREF99	Y coordinates in SWREF99	metres
FDRSat	Full dynamic range saturations (+/- 1.0g) Flag 1 = saturation	integer
GPSSecs	GPS seconds since start of GPS day	seconds
GPShtE	Aircraft GPS height relative to GRS80 ellipsoid	metres
GPShtG	Aircraft GPS height relative to EGM96	metres
SVs	Number of common visible satellites (Post processed)	integer
PDOP	GPS - Position dilution of precision (post processed)	float

FAA_E	Relative free-air anomaly. Unlevelled. Relative to GRS80 ellipsoid. 100 sec filter.	mGal
FAA_G	Relative free-air anomaly. Unlevelled. Relative to EGM96. 100 sec filter.	mGal
FAA_TL	Relative free-air anomaly. Tie levelled. Relative to EGM96.	mGal
FAA_ML	Relative free-air anomaly. Microlevelled. Relative to EGM96.	mGal
FAA_2DLP_6KM_Absolute	Absolute free-air anomaly. Levelled. Relative to EGM96. 100 sec filtered & low pass spatial filtered (6km)	mGal
TC100	Forward modelled gravity response of terrain above the geoid, with a density of 1.00 g/cm^3 .	mGal
TCD_2DLP_6KM_Absolute	Absolute terrain-corrected (2.67 g/cm^3) anomaly = FA100_2DLP_6KM_Absolute - $2.67 \times \text{TC100}$	mGal

Note: The above information is for reference purposes only. Generally, Geosoft exports or imports in alphabetical order only.

Appendix 7 Grid Name Index

This section outlines the naming conventions and descriptions for all grid files delivered; details on the grid directory structure are included in the Project Deliverable File Directory report. Data products are generated within the Oasis montaj software package. * denotes variable tensor components (T_{xx} , T_{xy} , T_{xz} , T_{yy} , T_{yz} and T_{zz}) or gravitational potential data (T_z and T_{ze}).

Air-FTG Processed Grids

Grid Name	Description	Units
FA_FTNR_*	Free Air Air-FTG data processed with FTNR	eötvös
TC100_FTNR_*	Terrain response calculated above the geoid from a digital terrain model and later processed using FTNR. Terrain density set to 1.00 g/cm^3	eötvös
TCD_FTNR_*	Terrain-corrected Air-FTG data processed with FTNR	eötvös

Air-FTG Interpretative Grids

Grid Name	Description	Units
CLP_*	Contact Lineament Processed Air-FTG data	eötvös

Gravity Processed Grids

Grid Name	Description	Units
FA_FTNR_ T_z	Processed Free Air Air-FTG gravity data	mGal
FA_FTNR_ T_z _Res	Processed Free Air Air-FTG gravity with 2D high-pass Butterworth filter applied	mGal

TC100_FTNR_ T_z	Forward modelled Air-FTG gravity response of terrain above the geoid, with a density of 1.00 g/cm^3 . Full Tensor Noise Reduced	mGal
TCD_FTNR_ T_z	Processed terrain-corrected Air-FTG gravity data	mGal
TCD_FTNR_ T_z _Res	Processed terrain-corrected Air-FTG gravity with 2D high-pass Butterworth filter applied	mGal
FAA_ G_z	Free Air iCORUS/GT-Z airborne gravity data	mGal
TC100_ G_z	Forward modelled iCORUS/GT-Z gravity response of terrain above the geoid, with a density of 1.00 g/cm^3	mGal
TCD_ G_z	Terrain-corrected iCORUS/GT-Z airborne gravity data	mGal
FA_FTNR_ T_{ze}	Full Spectrum Gravity of Air-FTG and iCORUS/GT-Z airborne gravity Free Air data	mGal
TCD_FTNR_ T_{ze}	Full Spectrum Gravity of terrain-corrected Air-FTG and iCORUS/GT-Z airborne gravity data	mGal

Terrain Grids

Grid Name	Description	Units
DTM	Digital terrain model	metres

Appendix 8 Air-FTG Tensor Products

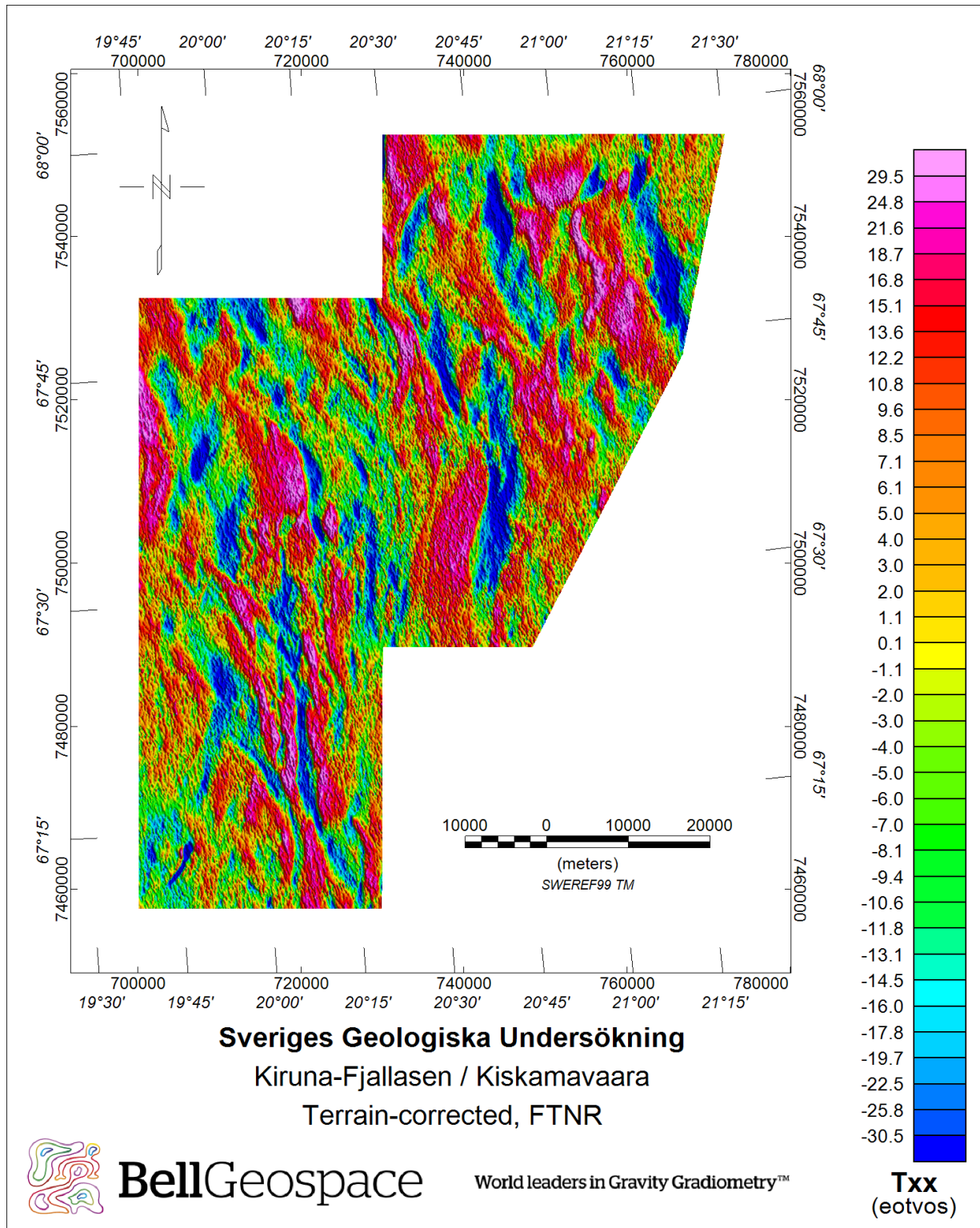


Figure A8.1: TCD FTNR T_{xx}

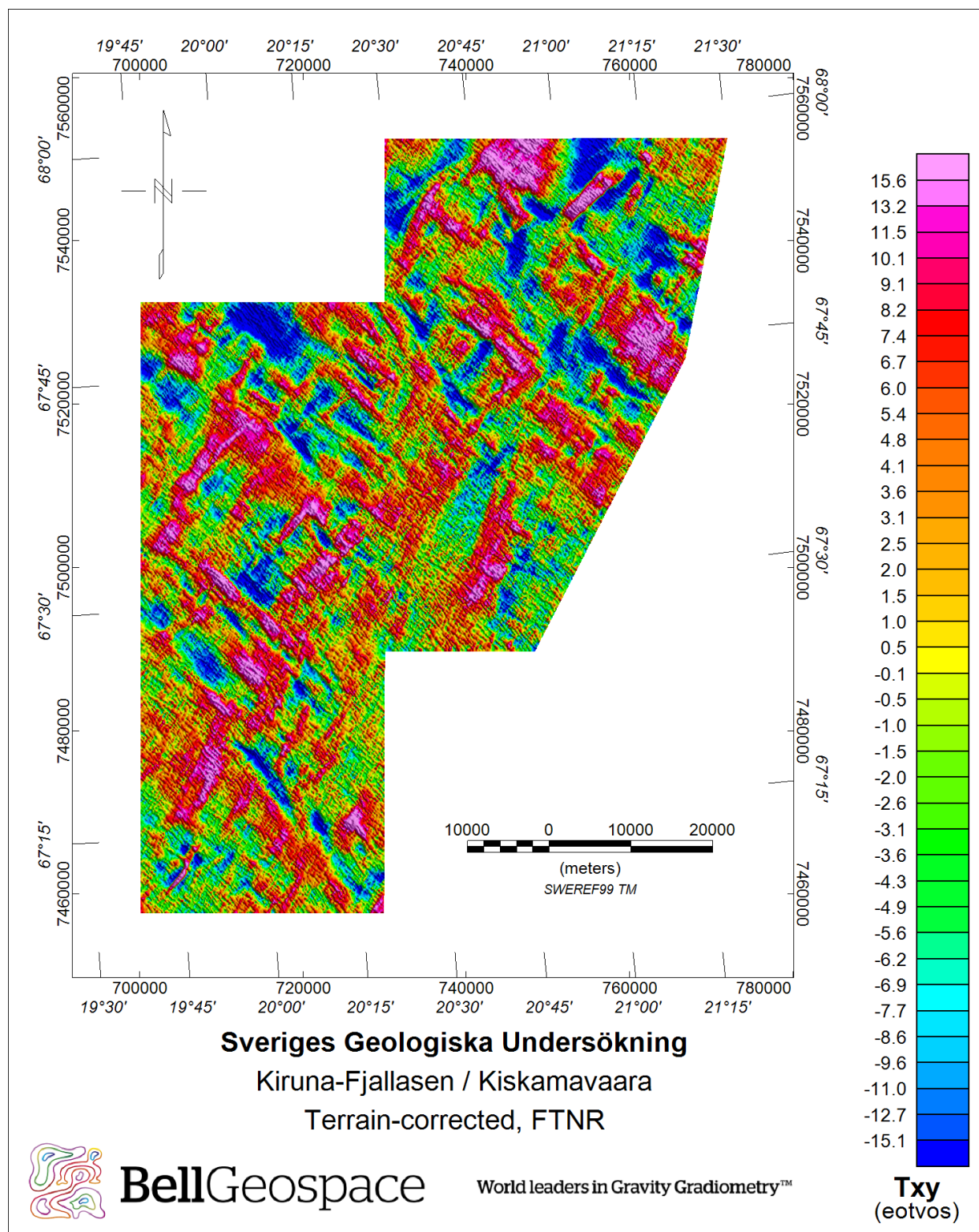
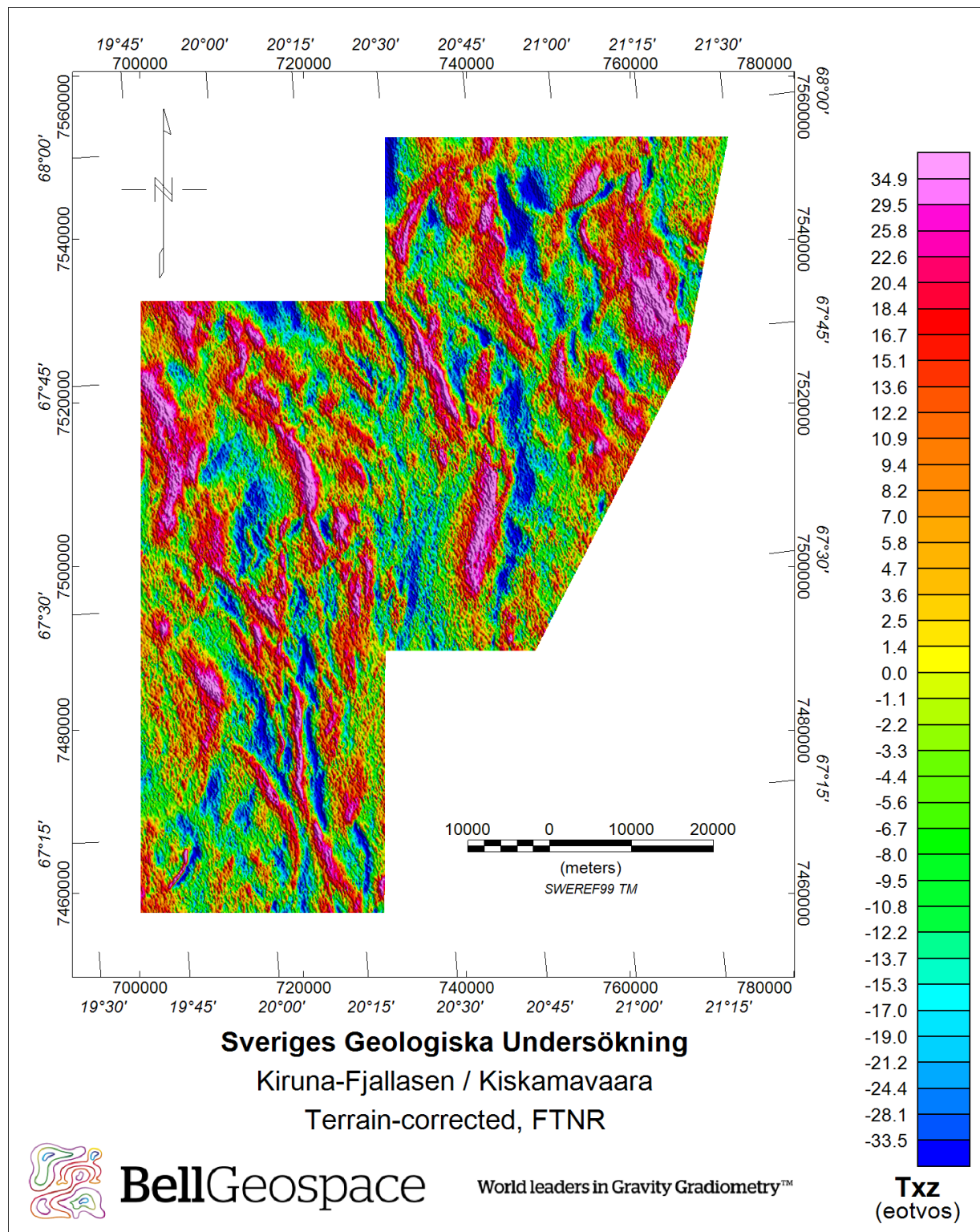
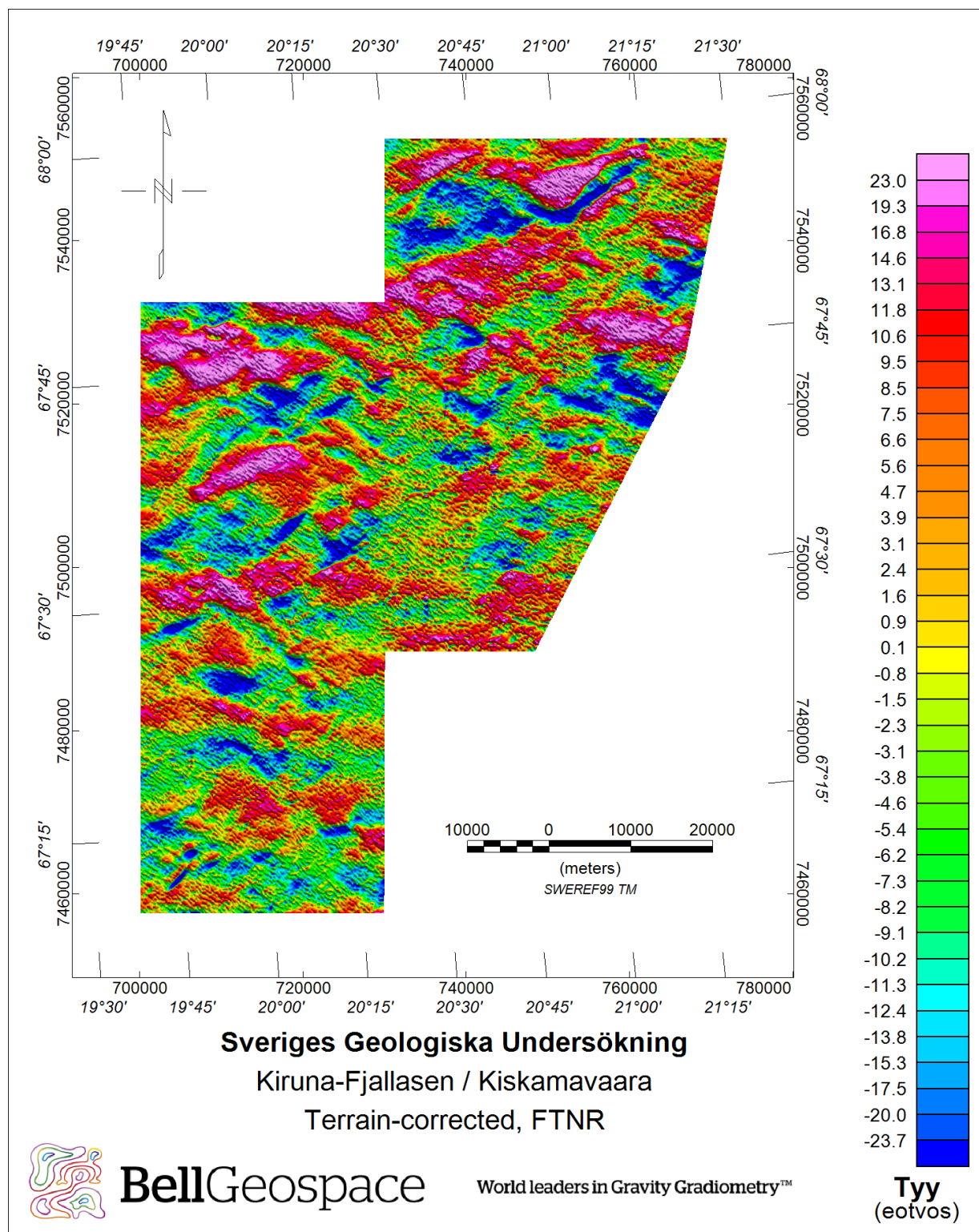
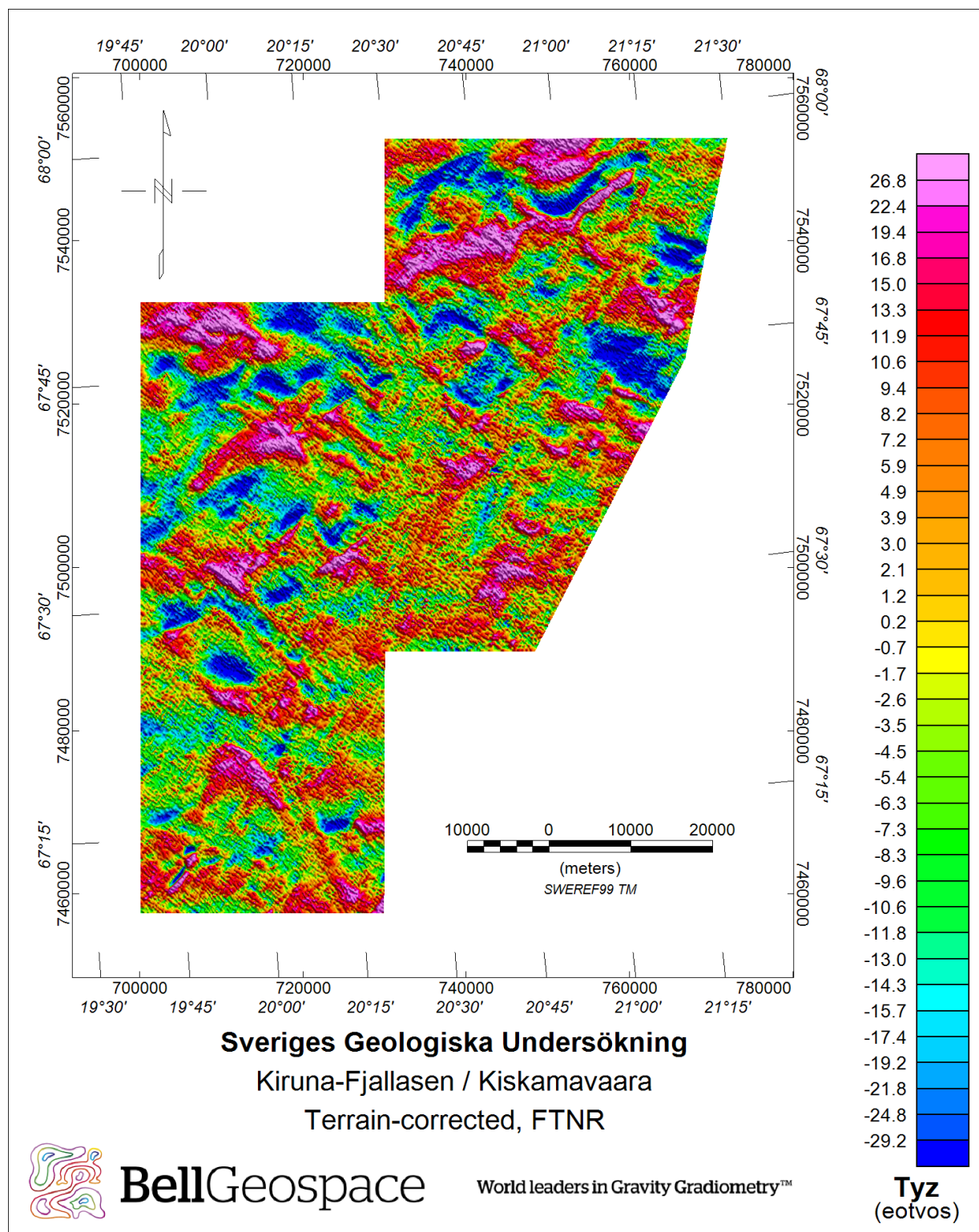
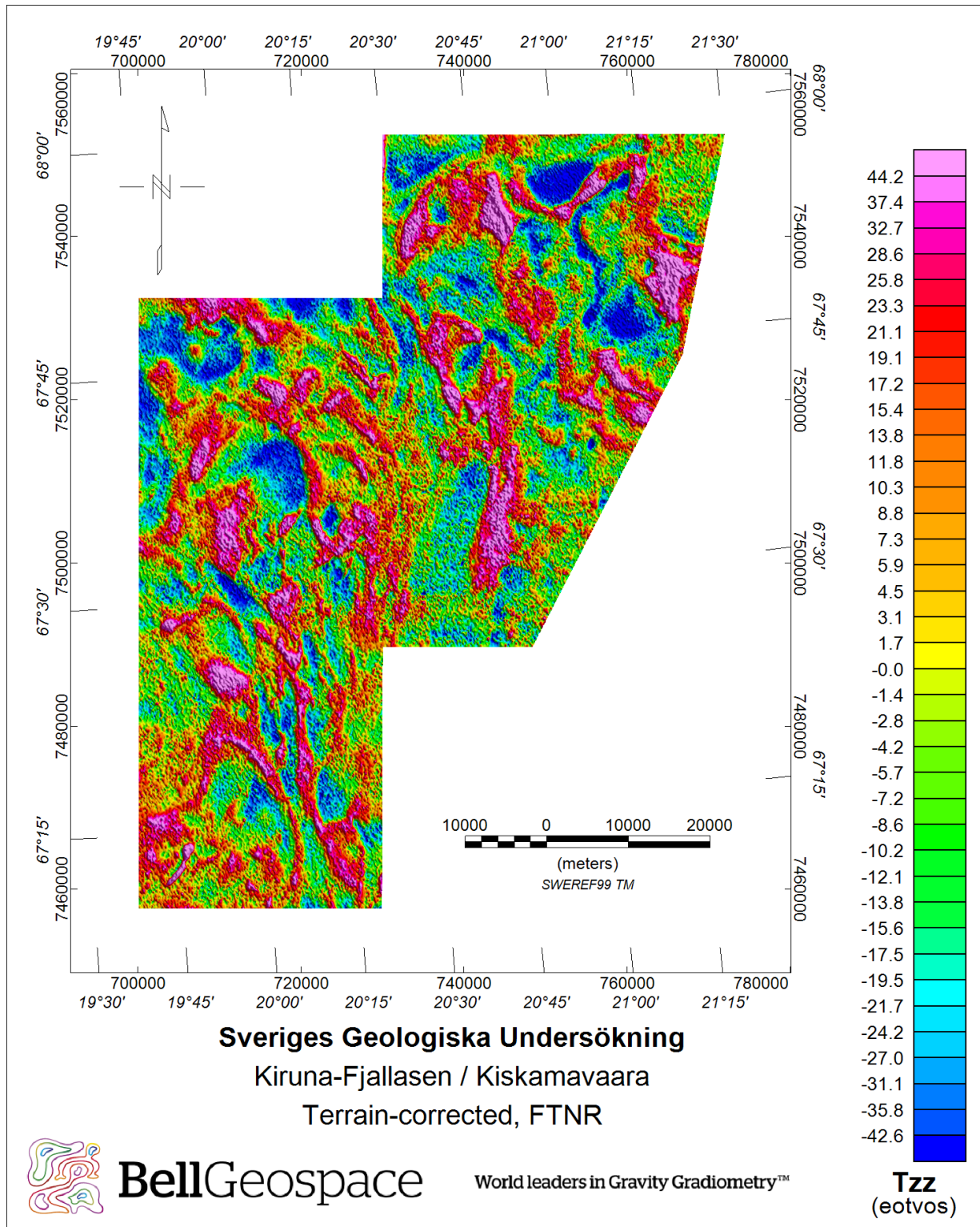


Figure A8.2: TCD FTNR T_{xy}

Figure A8.3: TCD FTNR T_{xz}

Figure A8.4: TCD FTNR T_{yy}

Figure A8.5: TCD FTNR T_{yz}

Figure A8.6: TCD FTNR T_{zz}