

TECHNICAL REPORT

for

Playfair Mining Ltd. Vancouver, Canada

RKV 2020 PROJECT IN NORWAY



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TECHNICAL REPORT

DRONE BORNE GEOMAGNETIC SURVEY RKV PROJECT 2020 IN NORWAY for PLAYFAIR MINING LTD VANCOUVER, CANADA

JOHANNES B. STOLL DECEMBER 2020

MOBILE GEOPHYSICAL TECHNOLOGIES GMBH

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1. INTRODUCTION

Mobile Geophysical Technologies (MGT) conducted an aero-magnetic survey for Playfair Mining Ltd. On six areas in the PKV 2020-Project area in Norway. The sites are located about 100 km south of Trondheim in the vicinity of Tynset.

The survey was conducted between Nov. 3rd and Nov. 10th, 2020. Six areas were surveyed in this time and 320 line kilometers were produced. A 10 kg octocopter from Aerialis GbR (Bremerhaven, Germany) was used in this survey (Fig. 1). The regular lines were flown at 50 m spacing, which were predominately oriented northwest-southeast. The control lines were flown at 500 m spacing and perpendicularly oriented to the regular lines. The flight altitude was approx. 50 m above ground. The average speed was about 5 m/s. On Nov 10th the multicopter crashed on area Borsjoho on the fourth flight. It was the last area to be operated on this project. Only 15% of the area of Borsjoho could be produced.



Figure 1: Photo taken on the Storboren area, Nov 8th, 2020

2. SURVEY AREAS

The six survey areas are situated in the Tynset area, a municipality in Innlandet county (Fig. 2). Tynset is situated about 300km north of Oslo and 100km south of Trondheim. The survey blocks are rectangular shaped. The size of the areas varies from 1.4 to 3.5sqkm. The terrain is mountainous and the elevation ranges from 900 m to 1200 m above sea level. The locations of the survey areas are shown in Fig. 2. The coordinates of the survey blocks were provided by Playfair Mining Ltd. and are shown in Tab. 1:

Area Name	Corner	Easting (UTM)	Northing (UTM)	Latitude [°]	Longitude [°]	SIZE [sqkm]	
Kvikne	А	572680	6937230	62.558806	10.413665		
	В	574185,6804	6936688,773	62.55365	10.442705	2.15	
	С	573729,0203	6935418,355	62.542342	10.433279	2,15	
	D	572223,3399	6935959,582	62.547496	10.404249		
	А	572717	6931186	62.504565	10.411815		
171 - 44	В	573797,168	6930663,279	62.499661	10.432554	1 40	
Kletten	С	573274,4471	6929583,111	62.490072	10.421949	1,43	
	D	572194,2791	6930105,832	62.494974	10.401215		
	А	570876	6918215	62.388527	10.370743		
D 1	В	572239,6287	6917897,956	62.38542	10.396974]	
Røstvangen	С	572001,846	6916875,235	62.376289	10.391952	1,46	
	D	570638,2172	6917192,278	62.379395	10.365728		
	А	569464	6912867	62.340802	10.341299		
	В	570378,307	6912461,978	62.336996	10.358784		
	С	569892,2806	6911364,81	62.327242	10.348962		
0	D	569791,0251	6911136,233	62.32521	10.346916]	
Storboren	Е	569365,7521	6910176,211	62.316674	10.338328	2,5	
	F	568451,4451	6910581,233	62.320477	10.320853		
	G	568876,7182	6911541,255	62.329014	10.329437		
	Н	568977,9737	6911769,832	62.331047	10.331481		
	А	568025	6907471	62.292644	10.31141		
11	В	568821,7955	6907399,467	62.291857	10.326738	1.07	
Haugsvangen	С	568634,022	6905307,879	62.273122	10.322296	1,67	
	D	567837,2265	6905379,412	62.273909	10.306977		
Borsjoho	А	567161,0001	6922000	62,423181	10,300390		
	В	568368,2281	6921109,719	62,414972	10,323404		
	С	567774,7073	6920304,9	62,407859	10,311603	0.50	
	D	567372,2979	6920601,661	62,410595	10,303934	3,53	
	Е	566155,5805	6918951,782	62,396007	10,279760	1	
	F	565350,7617	6919545,303	62,401475	10,264420		
					TOTAL SIZE	12,74	

Table 1: Geographical Coordinates in WGS-84 UTM Zone 32N ETRS89

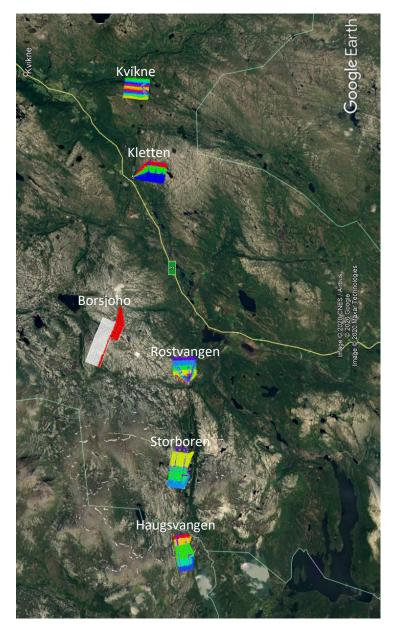


Figure 2: Location Map of the Project Area in Norway

3. SURVEY EQUIPMENT

3.1. MAGNETOMETER

The Digital Fluxgate Magnetometer, that was used in this survey, is a three component, high precision, low noise vector magnetometer. The small-sized, lightweight vector compensated magnetic field sensor is built up of low noise ring cores and a self-supporting Helmholtz coil system. A rigorously design of the circuit boards and the ring cores reduces noise and temperature drift to a minimum and improves long term stability, which makes it superior to other sensor available on the market. The magnetometer is a stand-alone instrument. Tab. 2 shows the main technical specifications.

3 AXES FLUXGATE MAGNETOMETER

Sensor construction self-supporting Helmholtz coil

system

Height 40mm Sensor size Ø 50 mm Cover Socket Ø 67 mm Sensor weight 105 g < 10pT/VHz Noise < 10 nT per year Long-term stability

Orientation X, Y, Z Range ±65 μT Orthogonality <0.02° temperature range -20 to +75 ℃



DATA ACQUISITION SYSTEM FOR SINGLE FLUXGATE SENSOR

± 65 µT Field range 2x 16 bitt ADC 10 pT Resolution power supply 5 VDC

Power consumption Minimum: 1.4 W (1 Sensor)

@5VDC

sample rate 1, 10, 50, 100 Hz data storage SD Card (4Gbyte) Data format ASCII, binary Weight

ca. 220 g

Dimensions 16cm X 6cm X 3cm (LWH)

Time and Position **GPS-receiver**

Synchronization Internal high precision clock



Table 2: Technical specifications of the 3-axis fluxgate sensor and data acquisition system

The magnetometer system uses a ublox NEO-M8N GPS receiver, which outputs the latitude, longitude, altitude and a time stamp. During field operations a sample rate of 100 Hz and 10Hz, resp., was used. The octocopter uses an inertial navigation system. It was programmed to fly in the autonomous mode along a set of waypoints. The Global Positioning System (GPS) is the core technology for unmanned aerial vehicle (UAV) localization. UAVs can fly autonomously based on GPS without any pilot intervention. Umanned aerial vehicles (UAVs) are pilotless aircrafts, which depend on a vehicle's ability to autonomously follow a mission path. Flight paths are followed by implementing discrete sets of waypoints that are generated on the remote ground station and then wirelessly relayed to the UAV's autopilot. Fixed-path-following guidance systems using waypoints are typically not capable of avoiding newly discovered obstacles without partially or completely replanning the path. Therefor much care must be taken while planning the flight survey for choosing a flight altitude that is uncritical for potential obstacles, such as trees, steep slopes, poles, etc.

The accuracy of the position critically depends on the number of satellites available at a time. Several tests suggest that the absolute accuracy of the horizontal position derived from the GPS is better than 1m and about 2m for the vertical position.

Fig. 3 shows the complete system, consisting of the octocopter, the GPS receiver, the data acquisition system attached to the frame of the multicopter, and the magnetometer. Last one is suspended about 2m below the drone.

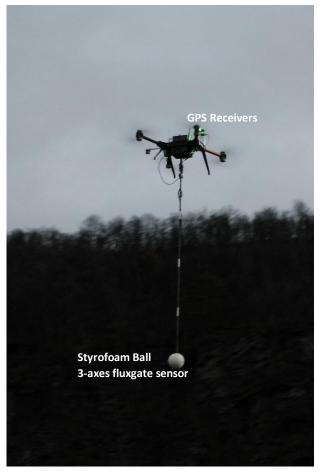


Figure 3: Octocopter and magnetometer, Photo taken on Kletten Area, Nov 7th 2020

3.2.OCTOCOPTER X810 (AERIALIS GBR)

The octocopter is product from Aerialis GbR in Bremerhaven/Germany. The drone was operated by pilots from Aerialis GbR. Following Tab. 3 shows the main technical specifications of the octocopter.

ConfigurationOctocopter (8 engines) in coaxial configuration, battery drivenEnduranceup to 25 min. @ 3,3 kg payload up to 38 min. w/o payload

Max. velocity vertical: -2 m/s and +5 m/s; horizontal: 15 m/s

Battery weight: 4,4 kg; nominal voltage 22,2V max. voltage: 25,2 V; capacity: 710 Wh

Empty weight 4,1 kg (w/o batteries and payload)

Max. payload 8,3 kg (@ 15,0 kg Take-Off Weight) 3,3 kg (@ 10,0 kg Take-Off Weight)

Max. Take-Off weight 15,0 kg, Design Weight: 10 kg

Operating temperature -5°C - +35°C

Humidity 0% - 90%, non condensing **Wind** < 8 m/s (17,9 mph / 28,8 km/h)

Autopilot Functions

Waypoint Navigation, Terrain Following, Fail Safe Procedures, Return to Launch &

Auto Land, ...

Table 3: Technical specifications of the Octocopter from Aerialis GbR

4. SUMMARY OF THE FIELD OPERATIONS

Mobilization of the MGT crew and equipment to the RKV 2020-Project Area began on Oct. 27th. The crew departed or Norway on Oct. 28th. After arriving in Larvik on Oct. 29th the equipment was cleared from customs. The crew arrived in Savalen Hestesenter at 11:00AM on the same day. The field office was set up in a cottage nearby Savalen Hestesenter and mobilization was completed on October 29th. On the following days, Nov 30th tru Nov 2nd we inspected the flight areas, defined take-off sites and prepared for the pilot's exam. On Mon, Nov 2nd, the pilot's exam was taken in Tynset and successfully completed.

Flight operations commenced on Nov 3rd on the Kvikne area. The survey areas along with the personnel (2 Pilots, 1 Geophysicist) and the equipment were accessed by a 4X4 truck (Toyota Hillux). Exept for Kvikne all areas were not accessible by car. Therefor all take-off sites laid outside the areas. It required long transfer flights to get to the production lines.

In order to allow full coverage of a survey area, all take-off sites must be within a range of 1 kilometer to the edge of an area. Except for Borsjoho take-off and landing sites that were closer than 1 km to the survey area, could be found.

The take-off and landing locations were chosen in a way to minimize the number of flights required to cover an area. The number of production lines on an area, which can be completed in one flight, varied with respect to the length of the transfer flights. The number of flight lines, that are achievable in one day, depends on the distance between the take-off site and the closest edge of the survey area. About 5 up to 15 flights were conducted in one day.

Each survey flight departed and returned to the same location. It was selected for each flight block aiming to optimize the flight range and the maximum size of the block that can be covered from this location.

Significant consideration was put to safety and ruggedness of the terrain due to the possibility of collision with a variety of objects (trees, power lines, slopes).

Since SRTM data are not provided at high latitude, we used a digital surface model from "open data portal" that bases on airborne LiDAR measurements (http://data.opendataportal.at/dataset/dtm-norway). Its vertical accuracy is in the order of 1m. But considerable deviations from the true topography are assumed due to the ruggedness of the terrain. Therefor we decided to choose a flight altitude of 50 m above ground to allow enough clearance between ground and vegetation (trees).

Following flight pattern was applied.

Traverse Line Spacing	50 m
Tie Line Spacing	500 m
Traverse Line Heading	90° - 270°
Tie-Line Heading	0° - 180°
Flying Height	100 m; subject to pilot's discretion
Projection / Datum	UTM Zone 36N (WGS-84)

Table 4: Flight characteristics and survey pattern

Due to the ruggedness of the terrain at some sites we lost track of the multicopter beyond certain distances. On all flights the multicopter was operated in autonomous mode. The flight operations were completed on Nov 10^{th} .

The weather conditions varied between days. The temperature ranged between -5°C to 5°C. Most days were cloudy with temperatures around 0°C. On most days the weather was clear, with some fog in the morning, but low wind speeds. Only on Nov 5th rain started in the late morning. We decided to stop operations and continue with site inspection for the rest of the day.

On Nov 10th the multicopter crashed as a result of a gap of terrain data in the digital terrain model. The drone as well as the magnetometer was recovered. This crash occurred on the 4th flight on this day on the Borsjoho area. Due to the ruggedness of the terrain, the large size of this area, and the large distance between ground station and the flight area our backup multicopter could not be deployed on this site. Since it was the last site to be surveyed we decided to stop the whole project at this point. On Nov 11th we started demobilization and on Nov 12th we departed for Germany

Following Tab. 5 summarizes the course of events of the project:

WED 28.10.	Mobilize for Norway. Ferry from Hirtshals to Larvik (departure at 22:15).
THU 29.10.	@11:00AM Arrival in Savalen Hestesenter
FRI 30.10.	Preparation for pilot exam
SAT 31.10	Preparation for exam, site inspection of Kvikne and Kletten
SUN 1.11.	site inspection Rostvangen, Borsjoho, define take-off and landing sites and check accessibility
MON 2.11.	pilot exam in Tynset at 12:00AM, flight planning
TUE 3.11.	Flight operations on Kvikne area
WED 4.11.	Flight operations on Kvikne area completed, site inspection Haugsvangen
TRU 5.11.	Flight operations on Haugsvangen, $\frac{1}{2}$ rain day, site inspection Storboren and Borsjoho
FRI 6.11.	Flight operations on Rostvangen
SAT 7.11.	Flight operations on Kletten
SUN 8.11.	Flight operations on Storboren
MON 9.11.	Flight operations on Haugsvangen
TUE 10.11.	Flight operations on Borsjoho, crash of multicopter at ca. 11-05-00 CET
WED 11.11.	Organizing return to Germany
TRU 12.11.	11:00AM mobilizing for Germany
FRI 13.11.	Arrival at 5:00AM in Bremen/Germany and 6:30AM in Celle

Table 5: Project summary

Following Tab. 6 summarizes the produced line kilometers of each day.

	03.11.2020	04.11.2020	05.11.2020	06.11.2020	07.11.2020	08.11.2020	09.11.2020	10.11.2020	Total distance
Transfer Flights [km]	10,94	9,96	1,64	20,92	17,34	11,45	8,35	9,69	90,29
Production Flights [km]	30,02	21,77	10,44	35,73	37,62	59,64	26,19	8,47	229,87
Total distance [km]	40,96	31,73	12,08	56,65	54,96	71,10	34,54	18,16	320,17

Table 6: Produced line kilometers

Following graphs display the productivity of each day and the total distance flown on each site.

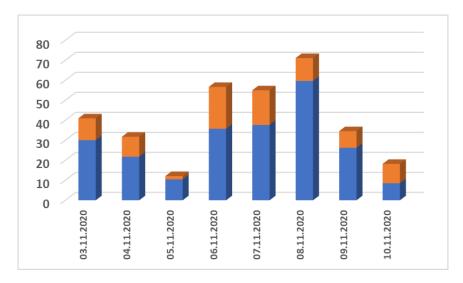


Figure 4: Productivity per day in [km]

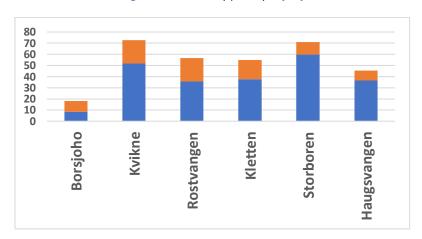


Figure 5: Total Distance in [km] flown on each site

5. DATA PROCESSING

5.1.SYNCHRONIZATION

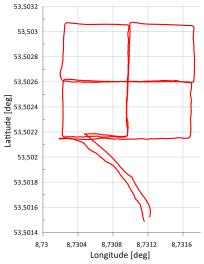
The data acquisitions system reads and records the magnetic field of the three components of the fluxgate sensors and the GNSS (GPS) data simultaneously and stores the values in the mass memory after the data is transmitted via the serial port with 100 Hz (magnetic field data) and 5 Hz (GNSS data). The internal clock, which is triggered every second by the GPS time pulse, provides a time stamp for both the magnetic data and the GPS position. The internal time stamp as well as the GPS time is recorded and enables synchronization of the magnetic and position data.

5.2.SENSOR CALIBRATION AND SYSTEM TEST

Three component fluxgate magnetometers allow measuring the vector magnetic field. But several difficulties must be resolved to use them. The main difficulty is the attitude of the magnetometer against the Earth's Reference Frame: offset and scaling errors and the violation of the orthogonality condition between the fluxgate components generate large variations of the total magnetic intensity depending on its orientation in space. This difficulty is overcome through calibration which makes the three-components equal.

MGT applies an *in-flight calibration procedure* that can be facilitated in a very short time on each site.

A 'figure-of-merit' (FOM) test applies a cloverleaf-shaped flight pattern, which is typically flown between 50-100m above ground (Fig. 6). This flight pattern systematically generates rotations of the horizontal components of the fluxgate sensors, whereas the vertical component is only slightly deviated. The EM interference and the magnetic signatures of the octocopter superpose with the readings of the Earth' magnetic field. Fig. 7 below show the results of the FOM test. The FOM was flown on Fri Oct, 23rd 2020 prior to the mobilization for Norway. Calibration achieved nearly total elimination of the directional dependence of the total magnetic intensity. The standard deviation of the residual noise was estimated to 0.49nT. All data is unfiltered. The residual noise is mainly generated by the eight electric motors of the octocopter.



ocation 53:503493* 8:7320

Figure 6A: Cloverleaf shaped flight pattern of the octocopter performing the Figure of Merit Test

Figure 6B: 3D plot of the cloverleaf test

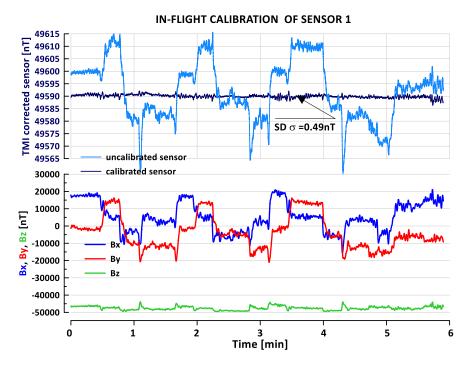


Figure 7: Result of the cloverleaf test. The test was flown about 40m above ground. The lower panel shows the three components of the fluxgate sensor. A change of the flight direction also changes the sign of the horizontal components. The upper panel shows the Total Magnetic intensity of the uncorrected fluxgate data (light blue) and after calibration (dark blue).

Without calibration the TMI strongly depends on the sensor orientation and flight direction (light blue line in upper panel). The TMI is strongly correlated with the change in the flight direction exhibiting an unacceptable heading error.

After calibration the TMI exhibits a straight line (dark blue line in upper panel) and is independent from the flight direction and orientation of the fluxgate sensor. All data is unfiltered. The sample rate is 100Hz. The peak-to-peak noise amplitude is 1nT. The standard deviation is 0.49nT (490pT).

A fluxgate magnetometer does not obtain the absolute value of the magnetic field. In order to obtain the absolute value of the Earth's magnetic field it is subject to calibration. We use a so-called scalar calibration. It means we compare the readings of the fluxgate magnetometer with the readings of a second scalar magnetometer, e.g. Cs-vapor, or the IGRF intensity obtained for the geographic coordinate of the site. The difference between both is mathematically minimized using a least square approach. Opposing to a vector calibration a scalar calibration delivers the intensity of the magnetic field, but not its direction in space. The calibration process outputs coefficients which are used to correct each fluxgate component and makes them mathematically equal. All data were processed using the calibration coefficients from 23/10/2020.

5.3. INTERNATIONAL GEOMAGNETIC REFERENCE FIELD (IGRF)

The IGRF is a standard mathematical description of the large-scale structure of the Earth's main magnetic field and its secular variation. It was created by fitting parameters of a mathematical model of the magnetic field to measured magnetic field data from surveys, observatories and satellites across the globe. The IGRF has been produced and updated under the direction of the International Association of Geomagnetism and Aeronomy (IAGA) since 1965. Following magnetic intensities were obtained from an IGRF calculator from the Geoscience Center in Potsdam/Germany (Tab. 7):

Datum: November 2020 Location Kvikne/Norway

Elevation masl: 750 m Latitude: 62° 33' Longitude: 10° 25'

Component	Value	Secular Variation		
Declination*	4° 3'	14.4 arcmin/year		
Total Intensity	51865.6 nT	53.5 nT/year		
Inclination	74° 23'	1.1 arcmin/year		
Horizontal Intensity	13960.6 nT	-2.2 nT/year		
North-Component	13925.9 nT	-6.5 nT/year		
East-Component	984.0 nT	58.2 nT/year		
Vertical Component	49951.4 nT	56.1 nT/year		

Table 7: Intensities derived from IGRF for the RKV-2020 Project area valid for Nov 2020

5.4. Data Compilation

Following procedure was applied to obtain the residual magnetic field intensity:

Step 1	Application of calibration coefficients to the raw data to eliminate the effect of movement from the fluxgate sensor readings
Step 2	Estimation of Total Magnetic Intensity from the three components Bx, By, Bz
Step 3	Reduction of the mean value from the total magnetic intensity. 51,865 nT
Step 4	Cleaning from outlies and spikes
Step 5	interpolation of 20Hz GPS data using a cubic spline to fill the data to 100 Hz
Step 6	Synchronization of magnetic data with GPS position data
Step 7	Gridding the magnetic data and creating a mesh. Creating an isoline plot of the residual magnetic field intensity, the Reduction To Pole, and estimation of the Analytic Signal

At this stage no diurnal correction, levelling and height correction are made to produce the 2D isoline plot of the Total Magnetic Intensity (TMI). The isoline maps of the residual magnetic field intensities are shown in Figs. 8-13 in section 6 *Final Products*.

5.5. REDUCTION-TO-POLE AND ANALYTIC SIGNAL

Pole reduction (RTP) takes the anomaly, as measured at any latitude, and transforms it into that which would have been measured if the magnetized ore body had been laid at the magnetic pole i.e. the area where the field inclination is vertical and the anomalies from symmetrical bodies are symmetrical. It removes the effect of induced magnetization and strike while preserving dip information. In practice, the standard RTP transform is difficult to apply at very low latitudes and produces poor quality maps

dominated by declination parallel artefacts. Additionally, the transform cannot completely reconstruct NS-trending anomalies.

Another approach to interpret magnetic anomalies is called the Analytic Signal. The 3D Analytic Signal is a function of magnetic gradients and is easy to compute at all latitudes. It is almost but not entirely independent of magnetization direction. It can be computed easily and accurately for any ambient and source magnetization. The idea is to present magnetic anomaly information stripped of the dependence on the inclination of the earth's inducing field so that anomalies are positive and sit directly above their sources. This can be achieved also through Reduction-To-Pole (RTP). While this latter approach suffers difficulties of directional noise amplification in surveys flown at low magnetic inclinations, the analytic signal approach offers some independence from the effect of strike direction.

The magnetic signature of magnetized bodies is at high magnetic latitudes, a circular anomaly. At lower magnetic latitudes, it becomes asymmetric; and at the magnetic equator, the anomaly is mostly negative. The shape of the anomaly is also influenced by the presence of remanent magnetization. For a vertical cylindric ore body, the shape of the analytic signal of the magnetic field is nearly independent of field orientation and remanence and always results in a compact, almost circular anomaly. Maxima in the analytic signal indicate positions of magnetic contrasts.

6. FINAL PRODUCTS

Following Figs. 8 - 13 display the 2D-isoline plots of

- A) the Total Magnetic Intensity
- B) Reduction-To-Pole, and
- C) Analytic Signal

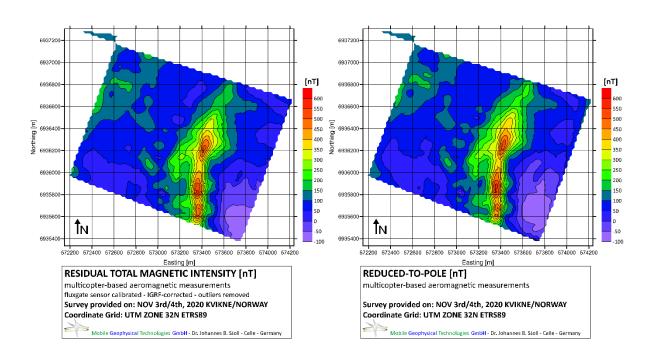
Provided for the following survey areas:

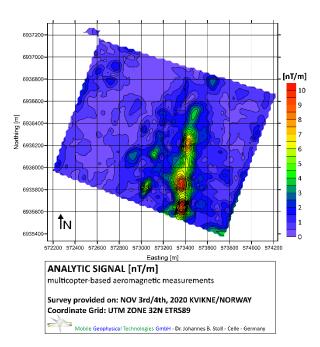
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- 2. KLETTEN
- 3. ROSTVANGEN
- 4. STORBOREN
- 5. HAUGSVANGEN
- 6. BORSJOHO

DELIVERABLES

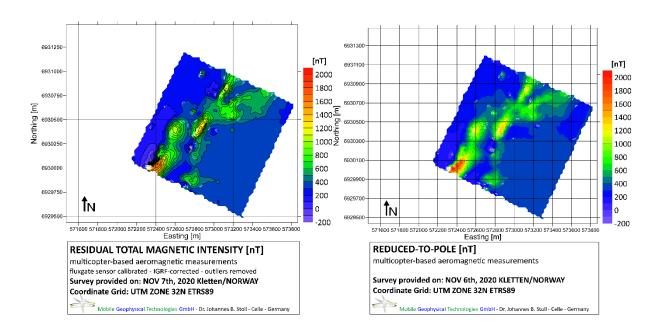
- 1. Report
- 2. Isoline Plots of TMI, RTP, and Analytic Signal in PNG-format and SHP-format

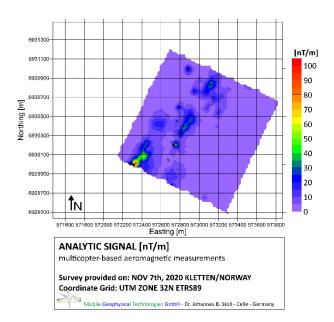
KVIKNE



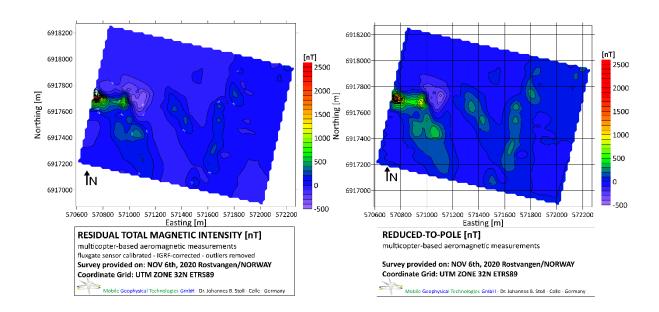


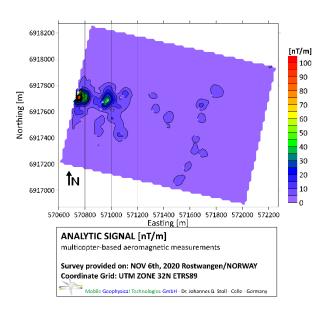
KLETTEN



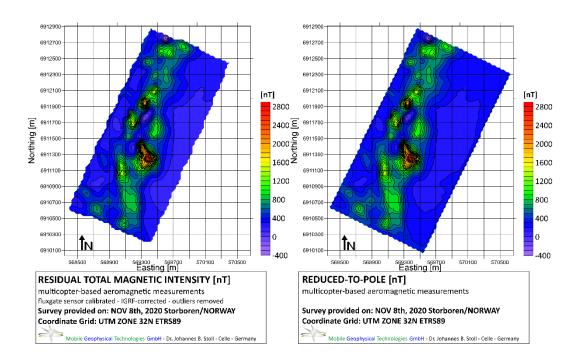


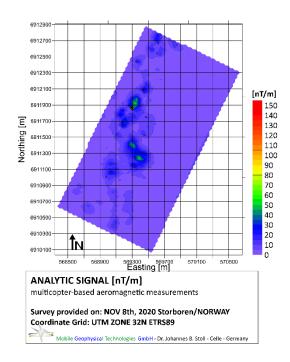
ROSTVANGEN



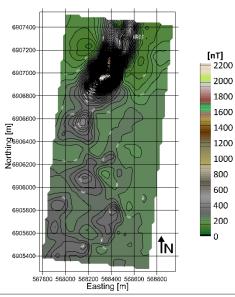


STORBOREN





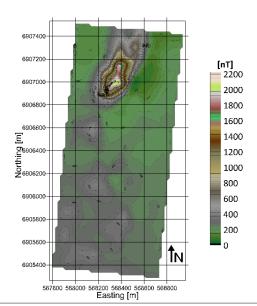
HAUGSVANGEN





multicopter-based aeromagnetic measurements fluxgate sensor calibrated - IGRF-corrected - outliers removed Survey provided on: NOV 9th, 2020 Hausvangen/NORWAY Coordinate Grid: UTM ZONE 32N ETRS89

Mobile Geophysical Technologies GmbH - Dr. Johannes B. Stoll - Celle - Germany

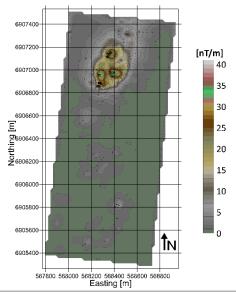


REDUCED-TO-POLE [nT]

multicopter-based aeromagnetic measurements

Survey provided on: NOV 8th, 2020 Storboren/NORWAY Coordinate Grid: UTM ZONE 32N ETRS89

Mobile Geophysical Technologies GmbH - Dr. Johannes B. Stoll - Celle - Germany



ANALYTIC SIGNAL [nT/m]

multicopter-based aeromagnetic measurements

Survey provided on: NOV 8th, 2020 Storboren/NORWAY Coordinate Grid: UTM ZONE 32N ETRS89

Mobile Geophysical Technologies GmbH - Dr. Johannes B. Stoll - Celle - Germany

BORSJOHO

