DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2004/19

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Diamond identification results, field description and magnetic profiling

Sven Monrad Jensen, Karsten Secher
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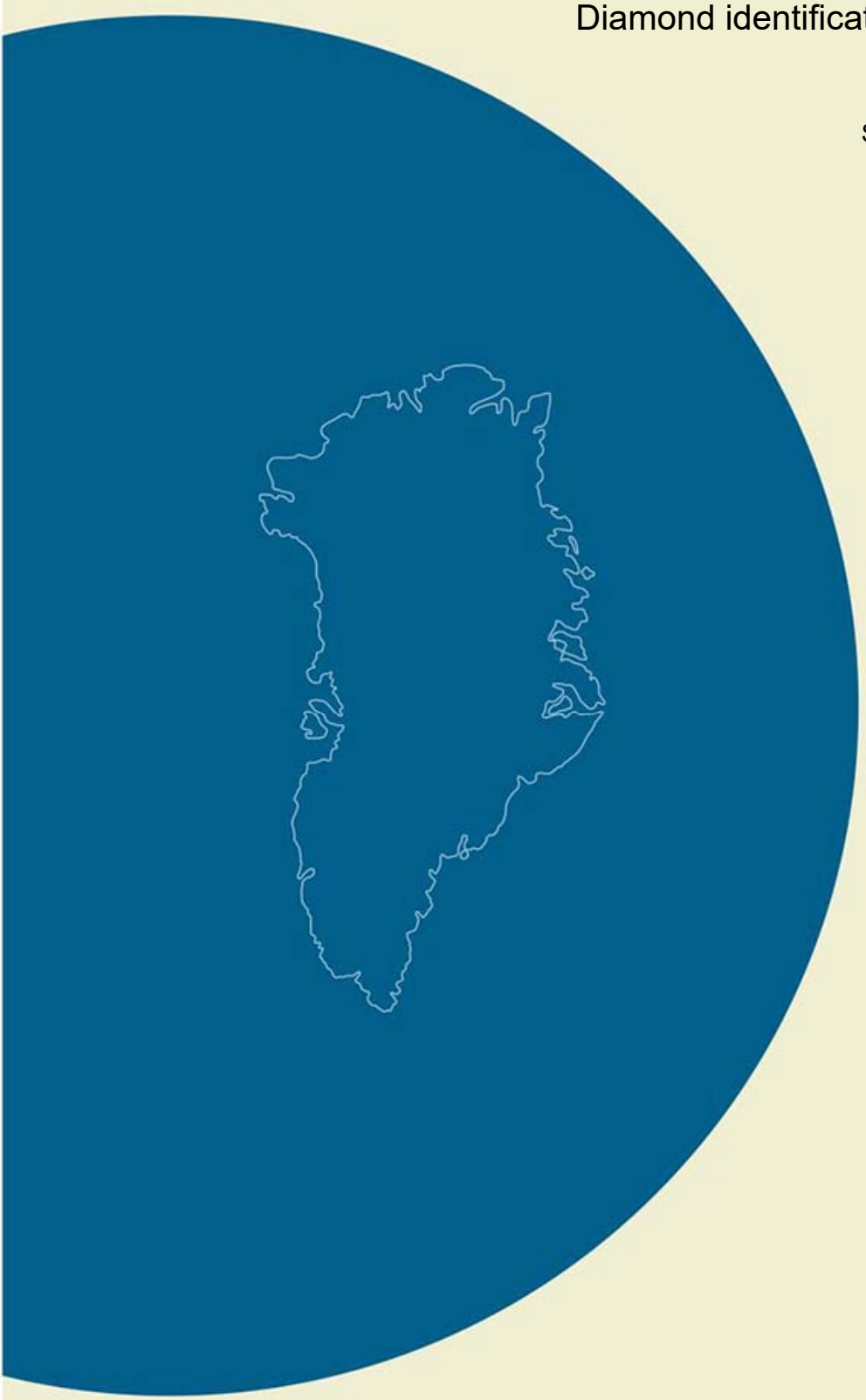

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
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Contents

Summary

The Government of Greenland's Bureau of Minerals and Petroleum (BMP) proposed and financed a field and laboratory programme to test the diamond content of several large kimberlitic occurrences in southern West Greenland. The programme was conducted and co-ordinated by the Department of Economic Geology at the Geological Survey of Denmark and Greenland (GEUS).

In August 2003, a field party of GEUS and BMP staff undertook sampling of three large occurrences of kimberlitic rocks for subsequent testing for diamond content by caustic dissolution. The fieldwork included detailed magnetic mapping using a caesium precession magnetometer and collection of samples for petrography, diamond indicator mineral characterisation and dating.

Criteria for the selection of occurrences for testing for diamond content included size of potential resource, geographical distribution, regional geological setting, previous tests for diamond content or favourable indicator mineral chemistry, and location outside exclusive exploration licence coverage. The selected occurrences belong to two clusters of kimberlitic dykes of the Sarfartoq and Maniitsoq regions of southern West Greenland. The Maniitsoq cluster with Occurrence 1 lies wholly within the Archaean craton. Occurrences 2 and 3 belong to the Sarfartoq cluster, which straddles the border zone between the Archaean craton and the Palaeoproterozoic Nagssugtoqidian orogen.

Two of the occurrences are subvertical dykes with a length of approximately 2500 m and a width of up to 2 m (Occurrences 1 and 3). The third occurrence is a shallow dipping dyke with a length of at least 500 m and a thickness of 1–2 m (Occurrence 2).

Composite rock samples of 1000–1060 kg from the three occurrences have been processed and examined for diamonds by SGS Lakefield Research Ltd., a certified Canadian testing laboratory (ISO 17025).

The test work resulted in a total of 128 diamonds from the three kimberlitic occurrences. All diamonds recovered are less than 1 mm in all dimensions. The approximately 1060 kg of rock processed from Occurrence 1 contained 125 diamonds, of which the five largest fall in the -600/+425 µm grain size fraction. The largest diamond measures 0.74 × 0.63 × 0.54 mm. From Occurrence 2, the processed sample of approximately 1000 kg contained only 2 diamonds: one in the -300/+212 µm size fraction and one in the -150/+100 µm fraction. The approximately 1030 kg of rock processed from Occurrence 3 contained one diamond in the -212/+150 µm fraction.

Most of the diamonds recovered are white (114 stones), and transparent (104) or translucent (24). There are 51 stones described as fragments with no recognisable crystal faces, 47 octahedra, 12 macles, 11 fragments with crystal faces, 4 dodecahedra, 1 cube and 2 irregular stones. Of the 128 diamonds, 79 have minor to significant cleavages, and 30 have graphite inclusions. The estimated preservation of 50 of the 77 diamonds with recognisable crystal faces is 95% or better.

Introduction

In 2003, the Geological Survey of Denmark and Greenland (GEUS) and the Government of Greenland's Bureau of Minerals and Petroleum (BMP) went further in investigating the economic potential of specific sites than has been customary. Four areas were temporarily closed to application for exploration licences, pending sampling and testing for diamond content of large samples of more than one tonne each from significant kimberlitic occurrences.

The occurrences chosen for sampling and testing have previously been reported by exploration companies to be diamondiferous, but documentation of several details of the laboratory procedures employed is not available. The aim of the present investigation is to obtain an independent review of the diamond potential of the occurrences. Consequently, GEUS and BMP undertook sampling of three large occurrences of kimberlitic rocks for subsequent testing for diamond content by caustic dissolution. The locations of the three occurrences are shown in Figure 1.

Indicator minerals from the same three kimberlitic occurrences have been separated, picked, and analysed by electron microprobe. The indicator minerals studied are pyrope, eclogitic garnet, chrome-diopside, chromite, ilmenite and olivine. The mineral chemistry fingerprint of the *in situ* occurrences may have important implications for the interpretation of existing indicator mineral chemistry data from till and stream sediment samples.

Additional characterisation and research initiated on these and other occurrences include detailed magnetic mapping and petrographic studies of the dyke rocks and their mantle xenoliths. An extensive regional age dating programme has also been initiated.

The present report summarises details of sampling and magnetic mapping of the kimberlitic occurrences, and presents the results of the test for diamond content. Petrographic details, indicator mineral chemistry, age determination and additional research activities will be reported separately.

Assessment reports and digital data from previous diamond exploration in Greenland, including the thee sampled kimberlitic occurrences, can be found in a recently published GIS-based compilation on DVD (Jensen *et al.* 2003). The compilation contains scanned text and maps, and selected digital data extracted from company assessment reports submitted to BMP in fulfilment of the standard terms for mineral exploration licences. The data include mineral analyses of heavy minerals recovered from till and stream sediment samples, dyke and boulder distribution maps, airborne and ground geophysical surveys, results of testing for diamond content of mini-bulk sampled dykes, drill logs, etc.

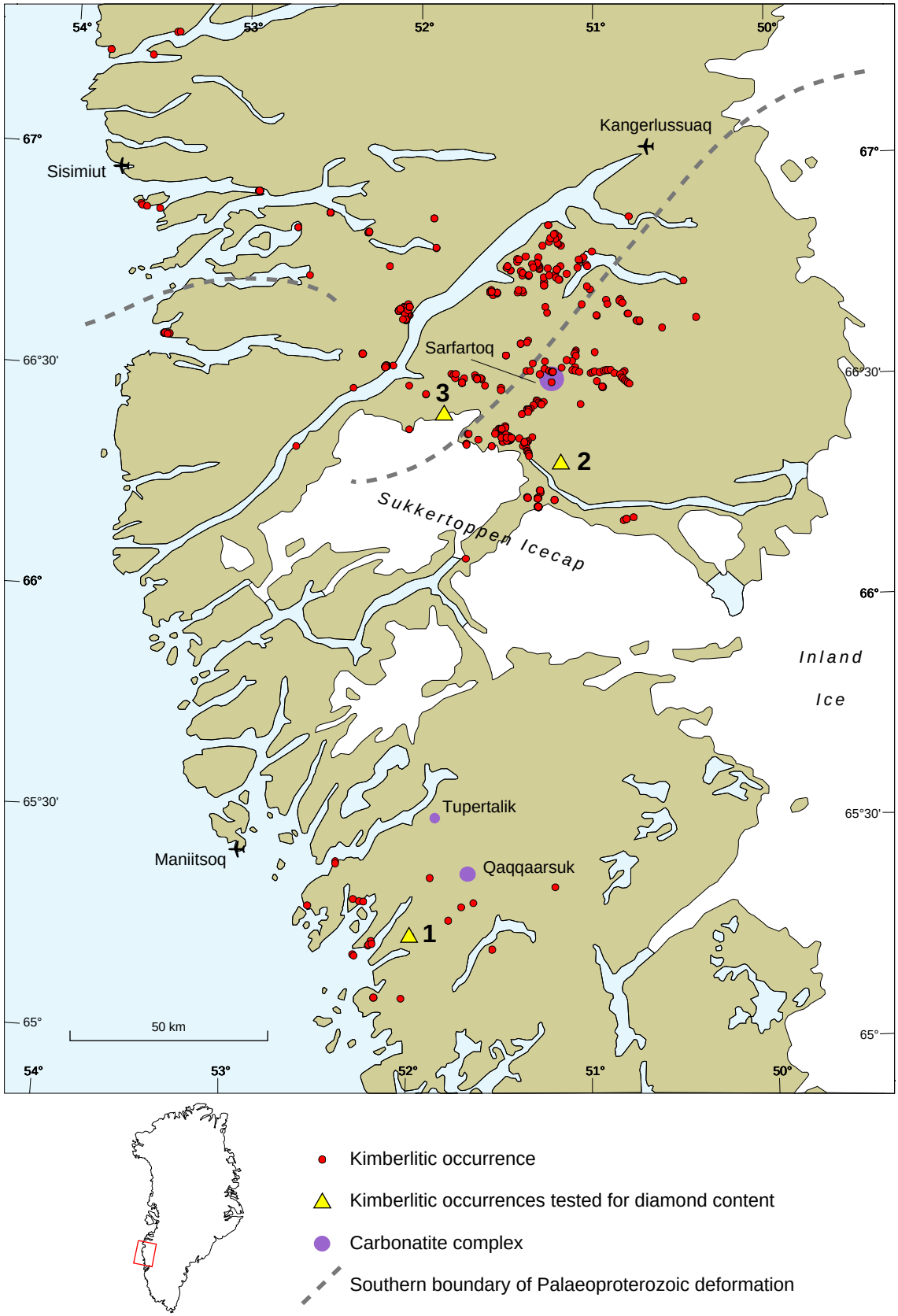

Figure 1. *Map of the Sarfartoq and Maniitsoq regions of southern West Greenland. The kimberlitic occurrences tested for diamond content are numbered 1 to 3.*

Kimberlitic occurrences

Occurrence 1

Brief description

Occurrence 1 lies on a 700 m high ridge named Majuagaa, 25 km south-east of the town of Maniitsoq. The kimberlitic rocks at Occurrence 1 form several dyke segments arranged in an *en echelon* pattern. The dyke system has an overall strike of 080° and a dip of 80–90° N (Figure 2), and is nearly parallel, but clearly discordant to the foliation of the enclosing banded Archaean gneiss. The estimated exposure is only around 10%, but the dyke trend is well defined throughout as a trench-like depression paved with an abundance of kimberlitic boulders. Figure 3 shows an example of a well-exposed part of the occurrence. Kimberlitic outcrop and boulders have been traced over a distance of 2500 m. The width is *c*. 2 m in the westernmost end of the system (locality 1-09), generally 1–1.5 m in the western to central parts (localities 1-08 to 1-01, and 1-10 to 1-18) and generally 0.5–1 m in the eastern parts (localities 1-19 to 1-24). The dyke ends abruptly at a steep stream gully *c*. 50 m beyond locality 1-09, and has not been possible to trace further west. Towards the east the dyke tapers out and disappears *c*. 100 m beyond locality 1-24. From locality 1-09 to the highest point around locality 1-01, a vertical section of *c*. 160 m is accessible.

The kimberlitic rock is dark grey, weathering to reddish-brown, with a medium-grained groundmass rich in olivine, ilmenite and carbonate. The marginal parts of the dyke are usually finer-grained and may have a darker colour. Weathered surfaces often show a well-developed flow banding in the dyke. The rock has a high content of ilmenite, olivine, pyrope, eclogitic garnet and chrome-diopside macrocrysts (Figure 4). Garnet macrocrysts are up 5 cm across, and chrome-diopsides up to 15 cm. Rounded mantle xenoliths of peridotitic and eclogitic compositions and angular crustal xenoliths are common (Figure 5). The xenoliths are up to 40 cm in size.

Sampling

Seven sub-samples make up the total of 1084.4 kg of rock collected from Occurrence 1. The distribution of the sub-samples is shown in Figure 2, and details of sub-sample locations are tabulated in Appendix A.

The width of the dyke at individual sample locations has been taken into account, so that the sample weights are roughly proportional to the dyke width. In two sections of the Occurrence 1 dyke system, central and marginal parts of the dyke have been individually tested for diamond content. Thus, sub-samples 3 and 6 represent the central part of the dyke, and sub-samples 4 and 7 represent the corresponding marginal parts (Figure 2).

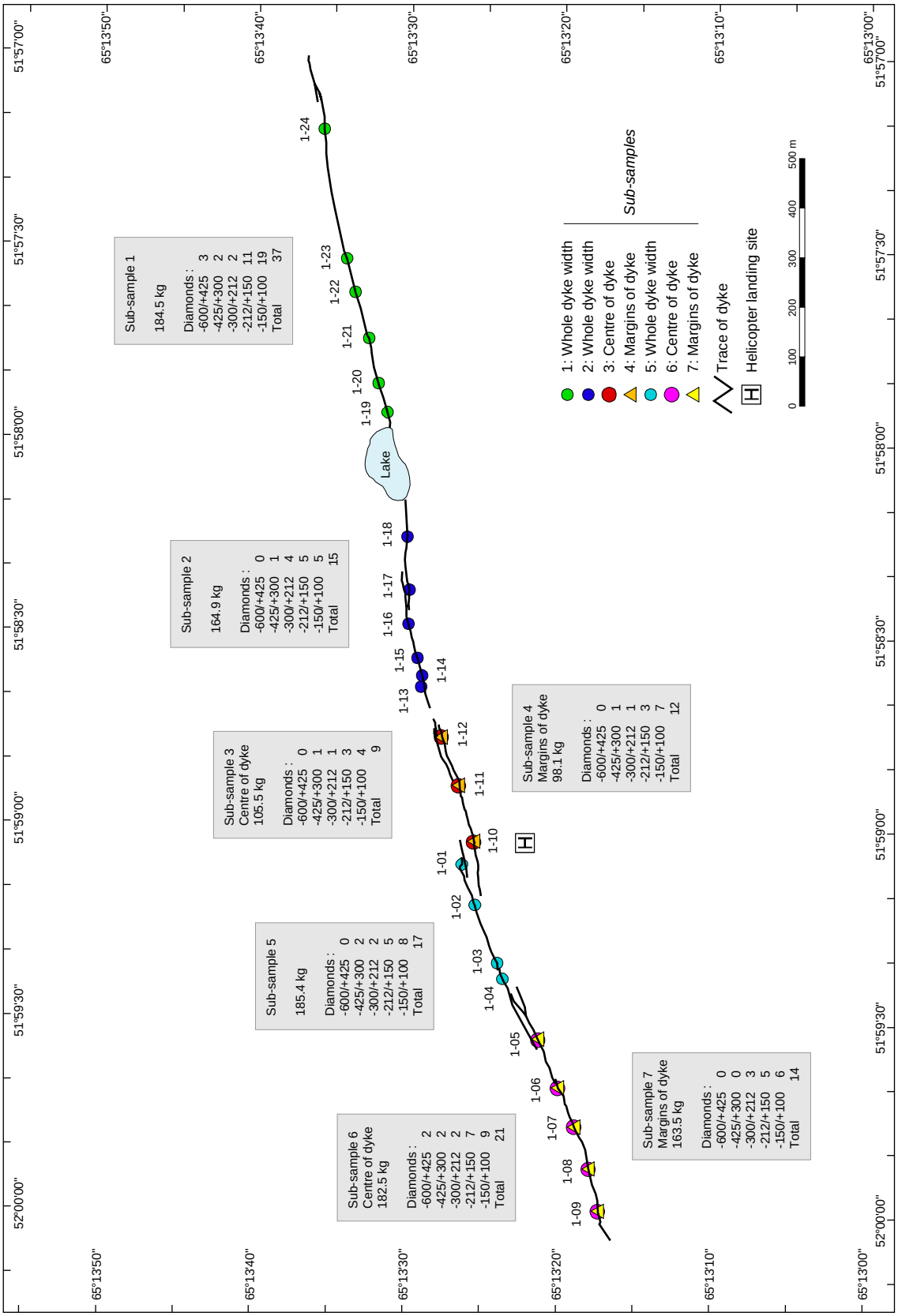

Figure 2. *Map of Occurrence 1 with sub-sample locations and diamond results. The overall dip of the kimberlitic dykes is 80–90° N. Diamond size fractions in µm.*

Previous investigations

The kimberlitic dykes of Occurrence 1 were first reported by Kryolitselskabet Øresund A/S (Juhava 1974). After new investigations in 1997, it became the first occurrence of *in situ* kimberlitic rocks in Greenland to be proven diamondiferous. A first sample of 43 kg yielded two microdiamonds, and a subsequent larger composite sample of 792 kg yielded 25 microdiamonds and 16 macrodiamonds (Chartier 1998). Both samples were processed by caustic dissolution. The definition of macrodiamond reported was 'stones larger than 0.5 mm'. All diamonds were less than 1 mm in all dimensions. Individual descriptions are available for the two first microdiamonds only.

Figure 3. *Large outcrop of kimberlitic dyke at Occurrence 1 (looking SW at locality 1-12, Figure 2). Note a second, parallel dyke on the lakeshore in centre of photograph.*

Figure 4. *Kimberlitic sample from Occurrence 1, locality 1-17, with garnet, ilmenite and olivine macrocrysts, and contact to gneiss. Scale bar is 2 cm.*

Figure 5. *Kimberlitic sample from Occurrence 1 with eclogitic xenolith. Scale bar is 2 cm.*

Occurrence 2

Brief description

Occurrence 2 lies at 1000 m elevation on the high plateau that characterises the area between the Sarfartoq carbonatite complex and Sukkertoppen Icecap (Figure 1). The kimberlitic occurrence is a shallow dipping dyke, or sill, trending E–W to ENE–WSW and dipping around 15° N (Figure 6). The dyke is emplaced into Archaean reddish, banded gneiss and appears to have intruded in a system of shallow dipping faults or joints that are common in the area. The occurrence consists of patches of large boulders on a steep scree slope with a height of around 75 m (Figure 7). Kimberlitic boulders have been traced and sampled over an E–W distance of 500 m. The only 'true' outcrop was found at locality 2-06, where the dyke is around 1 m thick. Judging from the size of numerous large boulders, the dyke is consistently 1–1.5 m thick over much of its indicated extent.

The kimberlitic rock is dark grey, weathering to a dark greenish colour, with a medium-grained olivine- and calcite-rich groundmass. The dyke is relatively uniform throughout, but does have parts rich in olivine-rich mantle xenoliths and serpentinised olivine macrocrysts (Figure 8). Garnet, chrome-diopside, chromite or ilmenite macrocrysts have not been identified in the field.

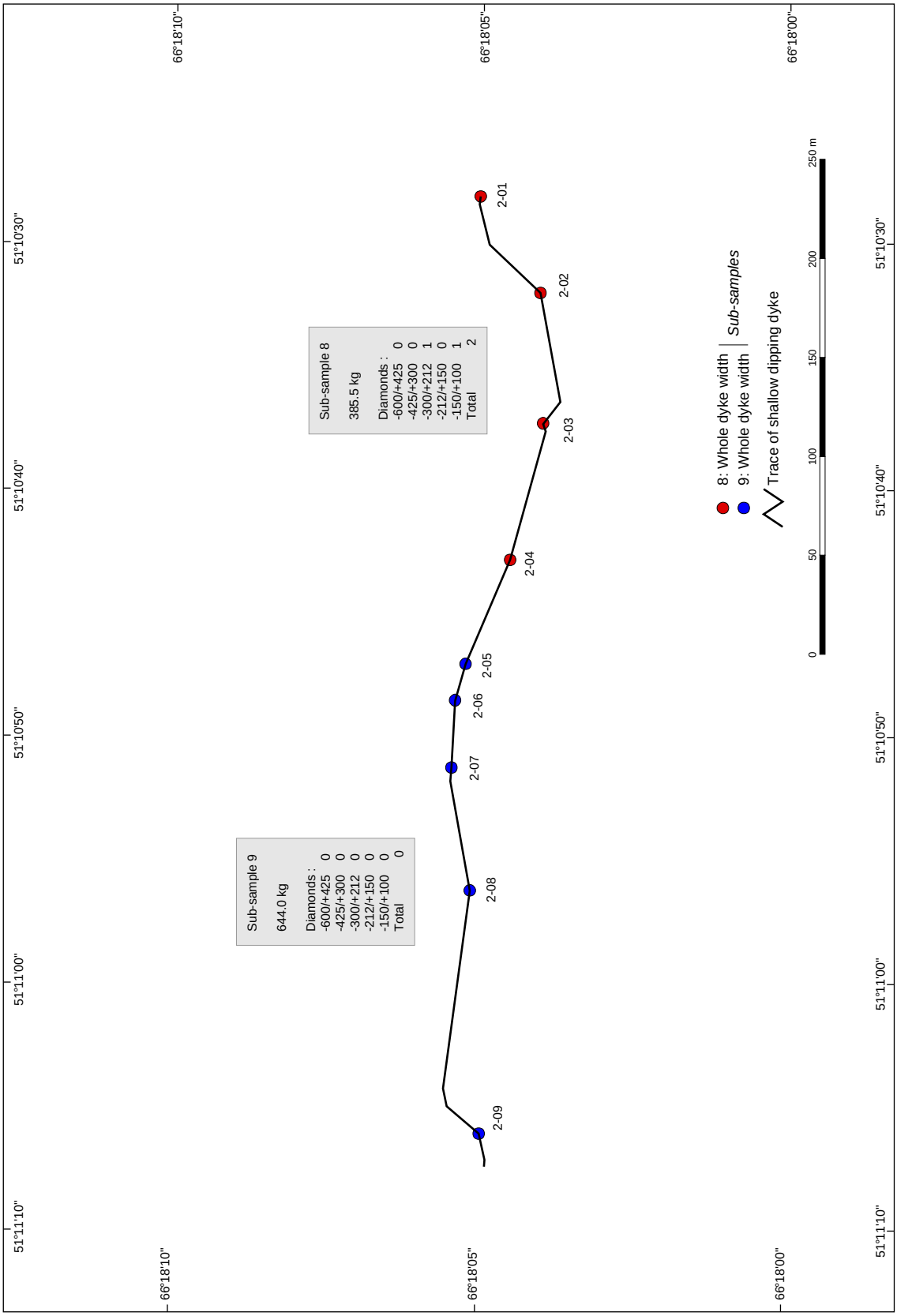

Figure 6. *Map of Occurrence 2 with sub-sample locations and diamond results. The kimberlitic dyke dips c. 15° N to NNW. Diamond size fractions in µm.*

Figure 7. *Panoramic view of Occurrence 2, looking NNE. Dashed line indicates trail of kimberlitic boulders. Another patch of kimberlitic boulders at locality 2-09 lies to the left of the view above. The dyke rock at locality 2-06 is believed to be in situ. Several holes drilled during winter on the lake in the background have intersected thin kimberlitic sheets (Bizzarro & Plouffe 1999). Length of dashed line c. 350 m.*

Sampling

Two sub-samples make up the total of 1029.5 kg of rock collected from Occurrence 2. The distribution of the sub-samples is shown in Figure 6, and details of sub-sample locations are tabulated in Appendix A.

The width of the dyke estimated from the size of boulders at individual sample locations has been taken into account, so that the sample weight is roughly proportional to the dyke width.

Previous investigations

A 187 kg sample from this occurrence was tested for diamond content by caustic dissolution in 1998, returning 474 microdiamonds and 5 macrodiamonds, all smaller than 1 mm in size (Boucher 2000). The diamonds were described as graphite-coated fragments without recognisable crystal faces. A later test for macrodiamonds by dense media separation of a 10790 kg sample returned no diamonds (Boucher 2000).

Six diamond drill holes within a distance of 600–2000 m N and NE of the kimberlitic occurrence have intersected thin kimberlitic sheets with a combined thickness of 0.1–2.62 m in each hole (Bizzarro & Plouffe 1999).

Figure 8. *Kimberlitic boulders from Occurrence 2.*

Occurrence 3

Brief description

Occurrence 3 lies a few kilometres from the margin of Sukkertoppen Icecap on a 1200 m high plateau with broad, rolling hills. The occurrence consists of thousands of frost-heaved kimberlitic boulders confined to narrow trends that outline underlying dykes. Kimberlitic boulders can be followed over a distance of approximately 2500 m. For at least half of its length the occurrence consists of two parallel dykes, and in its easternmost part even three (Figure 9). There are few 'true' outcrops along the trace of the dyke, but there is no doubt that the kimberlitic boulders lie directly above the dykes. This has been confirmed by magnetic profiling. Hardly any kimberlitic boulders are found outside the trace of the dykes.

West of the centrally located lake, between localities 3-10A and 3-13A, the occurrence consists of two parallel *en echelon* segments, the westernmost segment being displaced 25–30 m to the north. The dyke width is here 0.5–1 m. East of the lake, a main dyke (localities 3-01C to 3-06B) with a width of 0.5–1 m and two narrower dykes (localities 3-01B to 3-06A, and locality 3-01A) with a width of 0.1–0.5 m constitute the dyke segments. The three dykes taper out rapidly towards the east and disappear 50–100 m beyond locality 3-01A. Likewise, the dyke tapers out towards the west and can only be traced as scattered boulders beyond locality 3-15A.

The Archaean gneiss basement of the area has a high density of massive dolerite dykes referred to the Palaeoproterozoic Kangâmiut swarm. The younger kimberlitic dykes of Occurrence 3, presumably around 600 Ma old, are partly hosted in dolerite, partly on the contact between dolerite and gneiss, but follow the overall 080° dolerite dyke trend. A younger carbonatitic dyke may cut the main kimberlitic dyke at locality 3-13A (Figure 9).

The kimberlitic rock has a uniform, greenish appearance, with marginal zones that are often of a more brownish colour. The groundmass is fine to medium-grained, and has relatively few macrocrysts. Garnet, chrome-diopside, chromite or ilmenite macrocrysts have not been identified in the field. Well-rounded, olivine-rich mantle xenoliths are common throughout, but occur in particularly high numbers in the westernmost part of the dyke system.

Sampling

Six sub-samples make up the total of 1051.7 kg of rock collected from Occurrence 3. The distribution of the sub-samples is shown in Figure 9, and details of sub-sample locations are tabulated in Appendix A.

The width of the dyke at individual sample locations has been taken into account, so that the sample weights are roughly proportional to the dyke width. In two sections of Occurrence 3 dyke, central and marginal parts of the dyke have been separated and individually tested for diamond content. Thus, sub-sample 12 represents the central part of the dyke, and sub-sample 13 represents the corresponding marginal parts (Figure 9).

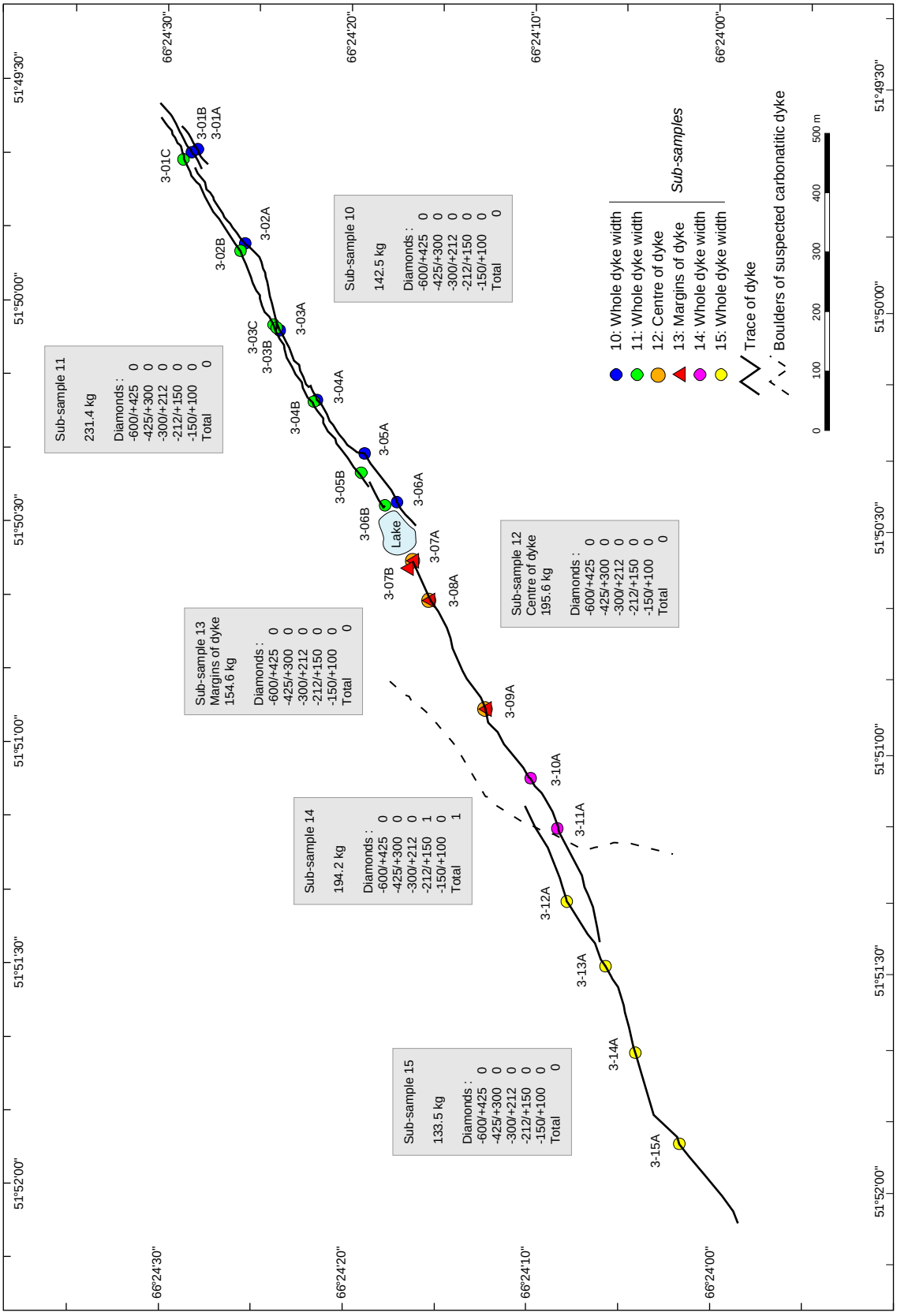

Figure 9. *Map of Occurrence 3 with sub-sample locations and diamond results. The kimberlitic dykes are subvertical. Diamond size fractions in µm.*

Previous investigations

Kimberlitic dykes in the Occurrence 3 area were first studied by Scott (1977). The described occurrences have later been difficult to locate with certainty, however.

A sample of 160 kg from this area – a precise location is not available – has been tested for diamond content by caustic dissolution, but did not contain any diamonds (Boucher 2000). A large field of xenolith-rich kimberlitic boulders, lying about 10 km SSW of Occurrence 3, precisely in its projected continuation, has yielded two diamonds from a 3.3 kg sample, the largest stone being 1.18 × 1.00 × 0.94 mm in size (Pirie 2000).

There is good coverage of till samples processed for indicator minerals in the area north of Occurrence 3. Analyses of 5560 ilmenites, 453 chromites, 252 garnets (including G10 and G9 garnets) and 4 chrome-diopsides picked from till samples are reported in Bizzarro (1998) and tabulated in Jensen *et al.* (2003).

Figure 10. *Frost-heaved kimberlitic boulders at Occurrence 3, locality 3-07A. The trace of the dyke continues below the tent.*

Diamond identification results

Testing laboratory

The Canadian testing laboratory SGS Lakefield Research Ltd. was contracted to process the approximately 3.2 t of kimberlitic samples. The samples were subjected to coarse crushing, caustic dissolution, screening, washing, drying, magnetic separation, and diamond identification using a binocular microscope. This laboratory also sized, weighed and described the diamonds recovered.

Prior to processing for diamond identification, SGS Lakefield Research took out samples for diamond indicator mineral separation, picking and analysis: grab samples amounting to approximately 20 kg for each of the three kimberlitic occurrences. The indicator mineral chemistry will be reported separately.

The results summarised below are based on SGS Lakefield Research's reports to GEUS.

Diamonds recovered

The results of the diamond identification work are summarised in Table 1 and are also incorporated in brief in the three occurrence maps (Figures 2, 6 and 9). A total of 128 diamonds have been recovered, with 125 stones from Occurrence 1, two stones from Occurrence 2 and one stone from Occurrence 3.

Sub-samples 3 and 6 from Occurrence 1 represent central parts of the dyke, and sub-samples 4 and 7 represent corresponding marginal parts. Likewise, sub-samples 12 and 13 from Occurrence 3 represent central and marginal parts of the dyke, respectively.

There is an insufficient number of diamonds to determine whether the central parts of the dykes are significantly more diamondiferous than the marginal parts.

All seven sub-samples from Occurrence 1 contain diamonds. The number of diamonds per kg of rock tested ranges from 0.09 to 0.20, with an average ratio of 0.12.

Diamond size distribution

The grain size distribution of the 128 recovered diamonds is summarised in Table 2 and shown graphically in Figure 11. The largest diamond recovered, from Occurrence 1, sub-sample 1, measures 0.74 × 0.63 × 0.54 mm. The total weight of the 128 diamonds is 3.251 mg, or 0.016 carats.

Table 1. *Summary of diamond determination results.*

Occurrence no.	Sub-sample no.	Sub-sample mass (kg)	No. of diamonds per size fraction (μm)					Total no. of diamonds	Total diamond weight (mg)	Total diamond weight (carats)
			-600/+425	-425/+300	-300/+212	-212/+150	-150/+100			
1	1	184.5	3	2	2	11	19	37	1.284	0.006
1	2	164.9	0	1	4	5	5	15	0.328	0.002
1	3	105.5	0	1	1	3	4	9	0.181	0.001
1	4	98.1	0	1	1	3	7	12	0.158	0.001
1	5	185.4	0	2	2	5	8	17	0.293	0.001
1	6	182.5	2	2	1	7	9	21	0.793	0.004
1	7	163.5	0	0	3	5	6	14	0.183	0.001
1	***Sub-total***	*1084.4*	*5*	*9*	*14*	*39*	*58*	*125*	*3.220*	*0.016*
2	8	385.5	0	0	1	0	1	2	0.018	0.000
2	9	644.0	0	0	0	0	0	0	0.000	0.000
2	***Sub-total***	*1029.5*	*0*	*0*	*1*	*0*	*1*	*2*	*0.018*	*0.000*
3	10	142.5	0	0	0	0	0	0	0	0
3	11	231.4	0	0	0	0	0	0	0	0
3	12	195.6	0	0	0	0	0	0	0	0
3	13	154.6	0	0	0	0	0	0	0	0
3	14	194.2	0	0	0	0	1	1	0.013	0.000
3	15	133.5	0	0	0	0	0	0	0	0
3	***Sub-total***	*1051.7*	*0*	*0*	*0*	*0*	*1*	*1*	*0.013*	*0.000*
All	***Grand total***	*3165.6*	*5*	*9*	*15*	*39*	*60*	*128*	*3.251*	*0.016*

Table 2. *The number of diamonds recovered classified by sieve size fractions.*

Diamond size fraction (μm)	Number of diamonds
-600/+425	5
-425/+300	9
-300/+212	15
-212/+150	39
-150/+100	60

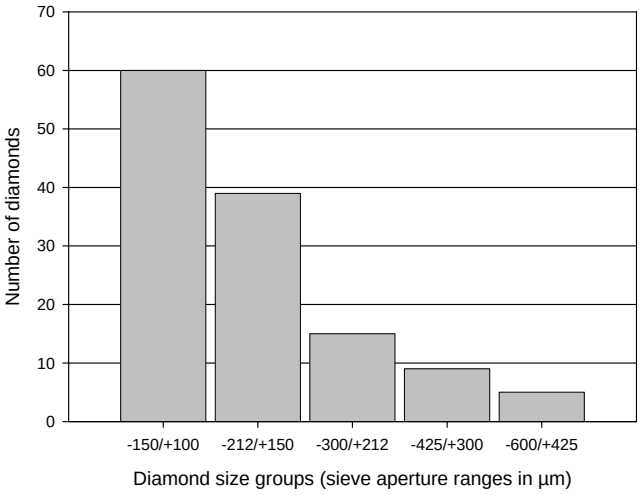

Figure 11. *Diamond size distribution of all 128 stones recovered.*

Summary of diamond descriptions

The colours of the recovered diamonds are described as white (114 stones), off-white (7), grey (1) or brown (6). The clarity is described as transparent (104 stones) or translucent (24). Morphologies include: fragment with no recognisable crystal faces (51 stones), fragment with crystal faces (11), octahedron (47), macle (12), dodecahedron (4), cubic (1) or irregular (2).

Of the 128 diamonds in total, 79 stones have cleavages as follows: significant (25 stones), minor (37) or very minor (17). Graphite inclusions are present in 30 stones.

The estimated preservation of the 77 diamonds *not* described as fragments with no recognisable crystal faces have the following distribution: 99+% (16 stones), 95% (34), 85% (15), 75% (5), 62.5% (4) and 1–55% (3).

Magnetic mapping

Geophysical data are available from the three areas with kimberlitic occurrences. The geophysical data are from ground profiling with a magnetic gradiometer with recordings of the magnetic total field and associated vertical gradient, and from combined electromagnetic and magnetic airborne surveys. *In situ* magnetic susceptibility measurements are available along the ground profiles. The ground profiling was carried out as part of the field project presented in this report, whereas exploration companies carried out the airborne surveys from 1996 to 1998.

Appendix B contains results from the ground magnetic profiling and includes magnetic data from the airborne surveys for comparison.

Magnetic susceptibilities for the kimberlitic rocks are high (0.01–0.1 SI units) for all three occurrences, whereas the gneiss shows considerably larger variations. The most clear magnetic response from the kimberlitic rocks is found at Occurrence 3, where the gneiss generally has low susceptibility. At this occurrence, the magnetic data are very useful for tracing the kimberlitic rocks.

Conclusions

1. Previous diamond determination results from Occurrence 1 were reproduced and the number of microdiamonds per kg of rock was improved by the new test. The seven sub-samples that make up the approximately 1060 kg of rock tested all contain diamonds, and the 125 stones detected are distributed fairly evenly along the whole extent of the dyke. The largest stone recovered is 0.74 × 0.63 × 0.54 mm. The five largest stones fall in the -650/+425 µm sieve fraction.

2. Previous microdiamond determination results from Occurrence 2 were not reproduced by the new test. The low diamond content of two microdiamonds in approximately 1000 kg of rock processed is in stark contrast to the 474 microdiamonds and 5 macrodiamonds from 187 kg of rock reported earlier from this occurrence.

3. The approximately 1030 kg of rock tested from Occurrence 3 only contained one microdiamond.

4. The dyke occurrences are not distinguishable in airborne magnetic survey data, but ground profiling using a caesium precession magnetometer readily detects and maps covered sections of the dykes at Occurrence 3. The profiles from Occurrence 3 show the dykes as well-defined, symmetric magnetic maxima. At Occurrence 1 the kimberlitic dyke can be observed in some of the profiles as weak maxima of short wavelength in the magnetic field and in the vertical gradient. The response from the kimberlitic dyke is superimposed on a broader negative anomaly caused by topographic variations. At Occurrence 2, a weak contrast in magnetic susceptibility between kimberlitic rocks and gneiss, the shallow dipping nature of the dyke, and its location on a steep scree slope make this dyke difficult to distinguish in both airborne and ground magnetic survey data.

5. Lakes lying on the trend of the dykes of Occurrences 1 and 3 are possible locations of blows, but the magnetic measurements made on land as near to the lakes as possible do not show clear evidence of widening of the dyke fissures. Ground magnetic profiles should be measured directly over the lakes at a time when there is ice cover in order to test the possibility of blows here.

Acknowledgements

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Appendix A: Co-ordinates of sample locations and details of sub-sample compositions

Occurrence no.	Sub-sample no.	Locality no.	Part of dyke sampled	GEUS sample no.	Individual sample mass (kg)	Mass per locality (kg)	Sub-sample mass (kg)	Latitude	Longitude	UTM zone	UTM easting	UTM northing	Elevation (m)
1	1	1-19	Whole dyke width	491738	16.5	16.5	184.5	65.2255292	-51.96545114	22W	454858	7233935	638
1	1	1-20	Margins	491739	9.7	67.4	184.5	65.2257002	-51.96418539	22W	454918	7233953	656
1	1	1-20	Centre	491740	39.0	67.4	184.5	65.2257002	-51.96418539	22W	454918	7233953	656
1	1	1-20	Margins	491741	18.7	67.4	184.5	65.2257002	-51.96418539	22W	454918	7233953	656
1	1	1-21	Whole dyke width	491742	15.8	32.4	184.5	65.2258794	-51.96227046	22W	455007	7233972	644
1	1	1-21	Whole dyke width	491743	16.6	32.4	184.5	65.2258794	-51.96227046	22W	455007	7233972	644
1	1	1-22	Whole dyke width	491744	16.9	16.9	184.5	65.2261447	-51.96027054	22W	455101	7234000	617
1	1	1-23	Whole dyke width	491745	17.6	17.6	184.5	65.2263059	-51.95883103	22W	455169	7234017	593
1	1	1-24	Whole dyke width	491746	33.7	33.7	184.5	65.2267464	-51.95326486	22W	455430	7234062	555
1	2	1-13	Whole dyke width	491730	16.7	16.7	164.9	65.2248501	-51.97727792	22W	454304	7233868	632
1	2	1-14	Whole dyke width	491731	18.1	18.1	164.9	65.2248289	-51.97676227	22W	454328	7233865	630
1	2	1-15	Whole dyke width	491732	18.5	18.5	164.9	65.2249154	-51.97602072	22W	454363	7233874	632
1	2	1-16	Whole dyke width	491733	20.4	20.4	164.9	65.2250952	-51.97455473	22W	454432	7233893	635
1	2	1-17	Margins	491734	20.0	71.8	164.9	65.2250871	-51.97308915	22W	454500	7233891	642
1	2	1-17	Centre	491735	33.7	71.8	164.9	65.2250871	-51.97308915	22W	454500	7233891	642
1	2	1-17	Margins	491736	18.1	71.8	164.9	65.2250871	-51.97308915	22W	454500	7233891	642
1	2	1-18	Whole dyke width	491737	19.4	19.4	164.9	65.2251383	-51.97080793	22W	454607	7233895	638
1	3	1-10	Centre	491722	41.2	68.7	105.5	65.2238429	-51.98392067	22W	453992	7233760	636
1	3	1-11	Centre	491725	30.7	64.4	105.5	65.2241369	-51.98150877	22W	454105	7233792	623
1	3	1-12	Centre	491728	33.6	70.5	105.5	65.2244557	-51.97942847	22W	454203	7233826	624
1	4	1-10	Margins	491723	27.5	68.7	98.1	65.2238429	-51.98392067	22W	453992	7233760	636
1	4	1-11	Margins	491724	16.8	64.4	98.1	65.2241369	-51.98150877	22W	454105	7233792	623
1	4	1-11	Margins	491726	16.9	64.4	98.1	65.2241369	-51.98150877	22W	454105	7233792	623
1	4	1-12	Margins	491727	18.3	70.5	98.1	65.2244557	-51.97942847	22W	454203	7233826	624
1	4	1-12	Margins	491729	18.6	70.5	98.1	65.2244557	-51.97942847	22W	454203	7233826	624
1	5	1-01	Margins	491701	32.2	56.6	185.4	65.2240632	-51.98489397	22W	453947	7233786	639
1	5	1-01	Centre	491702	24.4	56.6	185.4	65.2240632	-51.98489397	22W	453947	7233786	639
1	5	1-02	Margins	491703	24.8	57.1	185.4	65.2238089	-51.98664185	22W	453864	7233759	627
1	5	1-02	Centre	491704	32.3	57.1	185.4	65.2238089	-51.98664185	22W	453864	7233759	627
1	5	1-03	Whole dyke width	491705	24.2	24.2	185.4	65.2233943	-51.98913371	22W	453747	7233714	611
1	5	1-04	Whole dyke width	491706	31.2	47.5	185.4	65.2232852	-51.98981826	22W	453715	7233703	607
1	5	1-04	Whole dyke width	491707	16.3	47.5	185.4	65.2232852	-51.98981826	22W	453715	7233703	607
1	6	1-05	Centre	491709	45.9	67.9	182.5	65.2226266	-51.99243542	22W	453591	7233631	594
1	6	1-06	Centre	491711	32.2	64.9	182.5	65.2222541	-51.99450190	22W	453494	7233591	582

Occurrence no.	Sub-sample no.	Locality no.	Part of dyke sampled	GEUS sample no.	Individual sample mass (kg)	Mass per locality (kg)	Sub-sample mass (kg)	Latitude	Longitude	UTM zone	UTM easting	UTM northing	Elevation (m)
1	6	1-07	Centre	491714	34.0	66.5	182.5	65.2219465	-51.99618951	22W	453415	7233558	561
1	6	1-08	Centre	491717	30.0	51.2	182.5	65.2216755	-51.99797276	22W	453331	7233529	532
1	6	1-09	Centre	491720	40.4	95.5	182.5	65.2214971	-51.99982776	22W	453244	7233511	502
1	7	1-05	Margins	491708	22.0	67.9	163.5	65.2226266	-51.99243542	22W	453591	7233631	594
1	7	1-06	Margins	491710	16.7	64.9	163.5	65.2222541	-51.99450190	22W	453494	7233591	582
1	7	1-06	Margins	491712	16.0	64.9	163.5	65.2222541	-51.99450190	22W	453494	7233591	582
1	7	1-07	Margins	491713	16.0	66.5	163.5	65.2219465	-51.99618951	22W	453415	7233558	561
1	7	1-07	Margins	491715	16.5	66.5	163.5	65.2219465	-51.99618951	22W	453415	7233558	561
1	7	1-08	Margins	491716	21.2	51.2	163.5	65.2216755	-51.99797276	22W	453331	7233529	532
1	7	1-09	Margins	491718	23.3	95.5	163.5	65.2214971	-51.99982776	22W	453244	7233511	502
1	7	1-09	Margins	491719	13.6	95.5	163.5	65.2214971	-51.99982776	22W	453244	7233511	502
1	7	1-09	Margins	491721	18.2	95.5	163.5	65.2214971	-51.99982776	22W	453244	7233511	502
2	8	2-01	Whole dyke width	491801	56.4	103.6	385.5	66.3018616	-51.17447097	22W	492175	7353568	1091
2	8	2-01	Whole dyke width	491801	47.2	103.6	385.5	66.3018616	-51.17447097	22W	492175	7353568	1091
2	8	2-02	Whole dyke width	491802	54.6	103.5	385.5	66.3015891	-51.17555316	22W	492126	7353538	1096
2	8	2-02	Whole dyke width	491802	48.9	103.5	385.5	66.3015891	-51.17555316	22W	492126	7353538	1096
2	8	2-03	Whole dyke width	491803	41.9	128.3	385.5	66.3015756	-51.17703022	22W	492060	7353536	1093
2	8	2-03	Whole dyke width	491803	37.6	128.3	385.5	66.3015756	-51.17703022	22W	492060	7353536	1093
2	8	2-03	Whole dyke width	491803	48.7	128.3	385.5	66.3015756	-51.17703022	22W	492060	7353536	1093
2	8	2-04	Whole dyke width	491804	50.0	50.0	385.5	66.3017251	-51.17855841	22W	491992	7353553	1099
2	9	2-05	Whole dyke width	491805	53.4	105.0	644.0	66.3019243	-51.17974059	22W	491939	7353576	1098
2	9	2-05	Whole dyke width	491805	51.6	105.0	644.0	66.3019243	-51.17974059	22W	491939	7353576	1098
2	9	2-06	Whole dyke width	491806	51.1	106.4	644.0	66.3019704	-51.18014938	22W	491920	7353581	1101
2	9	2-06	Whole dyke width	491806	55.3	106.4	644.0	66.3019704	-51.18014938	22W	491920	7353581	1101
2	9	2-07	Whole dyke width	491807	43.4	210.1	644.0	66.3019851	-51.18089956	22W	491887	7353583	1100
2	9	2-07	Whole dyke width	491807	57.1	210.1	644.0	66.3019851	-51.18089956	22W	491887	7353583	1100
2	9	2-07	Whole dyke width	491807	55.7	210.1	644.0	66.3019851	-51.18089956	22W	491887	7353583	1100
2	9	2-07	Whole dyke width	491807	53.8	210.1	644.0	66.3019851	-51.18089956	22W	491887	7353583	1100
2	9	2-08	Whole dyke width	491808	57.1	57.1	644.0	66.3019028	-51.18229095	22W	491824	7353574	1080
2	9	2-09	Whole dyke width	491809	52.9	165.4	644.0	66.3018570	-51.18501725	22W	491702	7353569	1084
2	9	2-09	Whole dyke width	491809	54.4	165.4	644.0	66.3018570	-51.18501725	22W	491702	7353569	1084
2	9	2-09	Whole dyke width	491809	58.0	165.4	644.0	66.3018570	-51.18501725	22W	491702	7353569	1084
3	10	3-01A	Whole dyke width	491901	16.4	16.4	142.5	66.4083333	-51.82756817	22W	463042	7365670	1110
3	10	3-01B	Whole dyke width	491902	16.5	16.5	142.5	66.4084204	-51.82767872	22W	463037	7365680	1104

Occurrence no.	Sub-sample no.	Locality no.	Part of dyke sampled	GEUS sample no.	Individual sample mass (kg)	Mass per locality (kg)	Sub-sample mass (kg)	Latitude	Longitude	UTM zone	UTM easting	UTM northing	Elevation (m)
3	10	3-02A	Whole dyke width	491904	24.6	24.6	142.5	66.4075986	-51.83109024	22W	462884	7365590	1146
3	10	3-03A	Whole dyke width	491906	24.4	24.4	142.5	66.4070546	-51.83433898	22W	462738	7365531	1162
3	10	3-04A	Whole dyke width	491909	22.0	22.0	142.5	66.4064776	-51.83695263	22W	462620	7365469	1179
3	10	3-05A	Whole dyke width	491911	14.5	14.5	142.5	66.4057471	-51.83893470	22W	462530	7365388	1192
3	10	3-06A	Whole dyke width	491913	24.1	24.1	142.5	66.4052509	-51.84078291	22W	462447	7365334	1193
3	11	3-01C	Whole dyke width	491903	16.5	16.5	231.4	66.4085457	-51.82794225	22W	463026	7365694	1110
3	11	3-02B	Whole dyke width	491905	26.4	26.4	231.4	66.4076632	-51.83136601	22W	462871	7365597	1144
3	11	3-03B	Whole dyke width	491907	27.1	27.1	231.4	66.4071012	-51.83422809	22W	462743	7365536	1158
3	11	3-03C	Whole dyke width	491908	32.8	32.8	231.4	66.4071486	-51.83414494	22W	462746	7365542	1158
3	11	3-04B	Whole dyke width	491910	30.6	30.6	231.4	66.4065246	-51.83701960	22W	462617	7365474	1178
3	11	3-05B	Whole dyke width	491912	48.1	48.1	231.4	66.4057936	-51.83966736	22W	462498	7365394	1188
3	11	3-06B	Whole dyke width	491914	49.9	49.9	231.4	66.4054332	-51.84089698	22W	462442	7365355	1192
3	12	3-07A	Centre	491916	48.5	72.3	195.6	66.4049967	-51.84297452	22W	462349	7365307	1198
3	12	3-08A	Centre	491919	48.6	147.9	195.6	66.4047422	-51.84444831	22W	462283	7365280	1205
3	12	3-08A	Centre	491919	49.3	147.9	195.6	66.4047422	-51.84444831	22W	462283	7365280	1205
3	12	3-09A	Centre	491921	49.1	97.8	195.6	66.4038704	-51.84851747	22W	462100	7365185	1219
3	13	3-07A	Margins	491915	23.8	72.3	154.6	66.4049967	-51.84297452	22W	462349	7365307	1198
3	13	3-07B	Margins	491917	32.1	32.1	154.6	66.4050759	-51.84327149	22W	462336	7365316	1199
3	13	3-08A	Margins	491918	49.9	147.9	154.6	66.4047422	-51.84444831	22W	462283	7365280	1205
3	13	3-09A	Margins	491920	48.7	97.8	154.6	66.4038704	-51.84851747	22W	462100	7365185	1219
3	14	3-10A	Whole dyke width	491922	48.6	97.5	194.2	66.4031737	-51.85111033	22W	461983	7365109	1242
3	14	3-10A	Whole dyke width	491922	48.9	97.5	194.2	66.4031737	-51.85111033	22W	461983	7365109	1242
3	14	3-11A	Whole dyke width	491923	48.3	96.6	194.2	66.4027609	-51.85300238	22W	461898	7365064	1240
3	14	3-11A	Whole dyke width	491923	48.3	96.6	194.2	66.4027609	-51.85300238	22W	461898	7365064	1240
3	15	3-12A	Whole dyke width	491924	49.1	49.1	133.5	66.4025993	-51.85572298	22W	461776	7365048	1227
3	15	3-13A	Whole dyke width	491925	29.9	29.9	133.5	66.4019984	-51.85814602	22W	461667	7364982	1199
3	15	3-14A	Whole dyke width	491926	26.5	26.5	133.5	66.4015374	-51.86140348	22W	461521	7364933	1166
3	15	3-15A	Whole dyke width	491927	28.0	28.0	133.5	66.4008514	-51.86481684	22W	461367	7364858	1151

Positions have been determined by integrating at least 100 GPS measurements at each locality using a Garmin GPSmap 76S hand-held unit. Geodetic datum: WGS 84

Appendix B: Magnetic mapping

Magnetic gradiometer profiling

The GSM858 magnetic gradiometer manufactured by Geometrics Inc. records the magnetic total field simultaneously by two caesium vapour precession magnetometers. Magnetic variations caused by diurnal activity are removed from the data by subtracting the field recorded by a GSM856 proton precession base magnetometer located at a fixed position within the surveyed area.

The two GSM858 sensors are placed at each end of a vertically oriented aluminium rod and in the present study sample the magnetic field 10 times per second. During surveying, the top and bottom sensors are approximately 1.7 m and 1.2 above ground, respectively. The measurements are taken while walking along profiles defined by pre-selected and marked points placed at suitable intervals. In the present work, locations of the marked points along the profiles were measured with a Garmin GPSmap 76 instrument. When georeferencing the recorded magnetic data, a constant walking speed between two adjacent marks is assumed.

Magnetic measurements are performed twice along each profile by walking in opposite directions with the instrument. Quality checks of the measurements are conducted by comparing data obtained from measurements along the two directions, and in most cases, the two data sets show good agreement. The differences that arise mainly reflect that the distance from sensor to the ground is dependent on the walking direction in places with rough topography. Furthermore, the path between two adjacent marks may differ slightly from straight lines. The field recorded by the bottom sensor usually shows larger differences than the top-sensor. The reason for this is that the vertical gradient increases with smaller distance to the ground. We therefore focus mainly on the field measured by the top sensor.

Magnetic susceptibility measurements

In situ measurements of the magnetic susceptibility are made along the magnetometer profiles at suitable locations, i.e. usually at the profile markers and at places with observed anomalous magnetic fields. The instrument used was a GMS-2 manufactured by Geo-Instruments Pty. Ltd. The magnetic susceptibility usually shows considerable spatial variation and 10 recordings within a few square metres are used to describe the susceptibility at each site.

Combined airborne magnetic and electromagnetic surveys

Frequency domain electromagnetic data from the helicopter-borne Dighem^{V} system and recordings of the magnetic total field are available from two surveys that cover Occurrences 1 and 3. For Occurrence 2, data from the Eagle 5 frequency domain electromagnetic system are available together with magnetic total field data. Selected system parameters for the three surveys are listed in Table B1. Geoterrex-Dighem Ltd. measured the data covering Occurrence 1 for Platinova A/S (Chung 1998). High-Sense Ltd. flew the survey at Occurrence 2 for Monopros Ltd. (Andrews 1998), and Geoterrex-Dighem flew the area that includes Occurrence 3 for Softrock Petroleums Ltd. (Chung 1996).

Table B1. *Parameters for the helicopter-borne combined electromagnetic and magnetic surveys that cover the three sampled dykes.*

Location	Occurrence 1	Occurrence 2	Occurrence 3
Geophysical contractor	Geoterrex-Dighem Ltd.	High-Sense Ltd.	Geoterrex-Dighem Ltd.
Exploration company	Platinova A/S	Monopros Ltd.	Softrock Petroleums Ltd.
Number of frequencies	5	5	5
Frequency 1	900 Hz	915 Hz	900 Hz
Configuration, frequency 1	Coaxial	Coaxial	Coaxial
Frequency 2	900 Hz	4450 Hz	900 Hz
Configuration, frequency 2	Coplanar	Coaxial	Coplanar
Frequency 3	5500 Hz	850 Hz	5500 Hz
Configuration, frequency 3	Coaxial	Coplanar	Coaxial
Frequency 4	7200 Hz	4800 Hz	7200 Hz
Configuration, frequency 4	Coplanar	Coplanar	Coplanar
Frequency 5	56000 Hz	33500 Hz	56000 Hz
Configuration, frequency 5	Coplanar	Coplanar	Coplanar
Nominal altitude of EM loops	30 m	30 m	30 m
Nominal altitude of magnetometer	30 m	30 m	40 m
Nominal line spacing	125 m	50 m	200 m

Data presentation

The magnetic field at each location is presented in the following figures as coloured dots with class values chosen individually for the ground and airborne line data. The ground anomaly data are relative to the values obtained for the base station magnetometer and the airborne data are relative to the mean value within the displayed area. Thus, the ground and airborne data are not levelled to a common reference value. The dot plots only show values measured by the top sensor for the ground profiling.

Magnetic susceptibility is presented as median values at each site.

Magnetic signatures: Occurrence 1

Magnetic fields measured from the ground profiling and the airborne survey are shown in Figure B1. The magnetic susceptibility is shown in Figure B2. Figure B3 shows the magnetic field measured by the top and bottom sensors of the gradiometer, as well as the gradient for profile 10.

The most pronounced feature of the magnetic field variations is a minimum found in all profiles crossing the sampled dyke. The minimum is in most cases at the northern boundary of the dyke or shifted a few metres towards north from the edge. The magnetic susceptibilities of the kimberlitic rocks are on average higher than the average obtained for the surrounding rocks. Furthermore, the magnetic low is broader than the width of the dyke. Thus, the kimberlitic rocks cannot be the cause of the minimum. Instead, it is likely that topographic variations cause the minimum. In the case of profiles 1, 2 and 3, the kimberlitic dyke is located at the northern termination of a gently northward sloping surface, and its southern limit is a *c*. 1.5 m high, steep wall. This topographic variation in combination with the measured susceptibilities is sufficient to generate anomalies of the measured amplitudes and to explain the asymmetric anomaly in relation to the position of the dyke.

Along profile 10, the kimberlitic dyke is discriminated by a narrow peak in the measured field and in the vertical gradient (Figure B3). Anomalies with similar wavelength can be observed for profile 14 at locations where kimberlitic boulders were found in an area covered with gneiss boulders. The trace of the kimberlitic boulders crosses the magnetometer profile. In this particular case, a thin unexposed kimberlitic dyke is a plausible interpretation of the anomaly. However, similar anomalies can be observed at other locations without any indications of kimberlitic rocks. Thus, in general, local magnetic maxima are not conclusive with respect to the location of kimberlitic rocks within the area.

The magnetic responses from the mapped kimberlitic rocks cannot be discriminated in the airborne data.

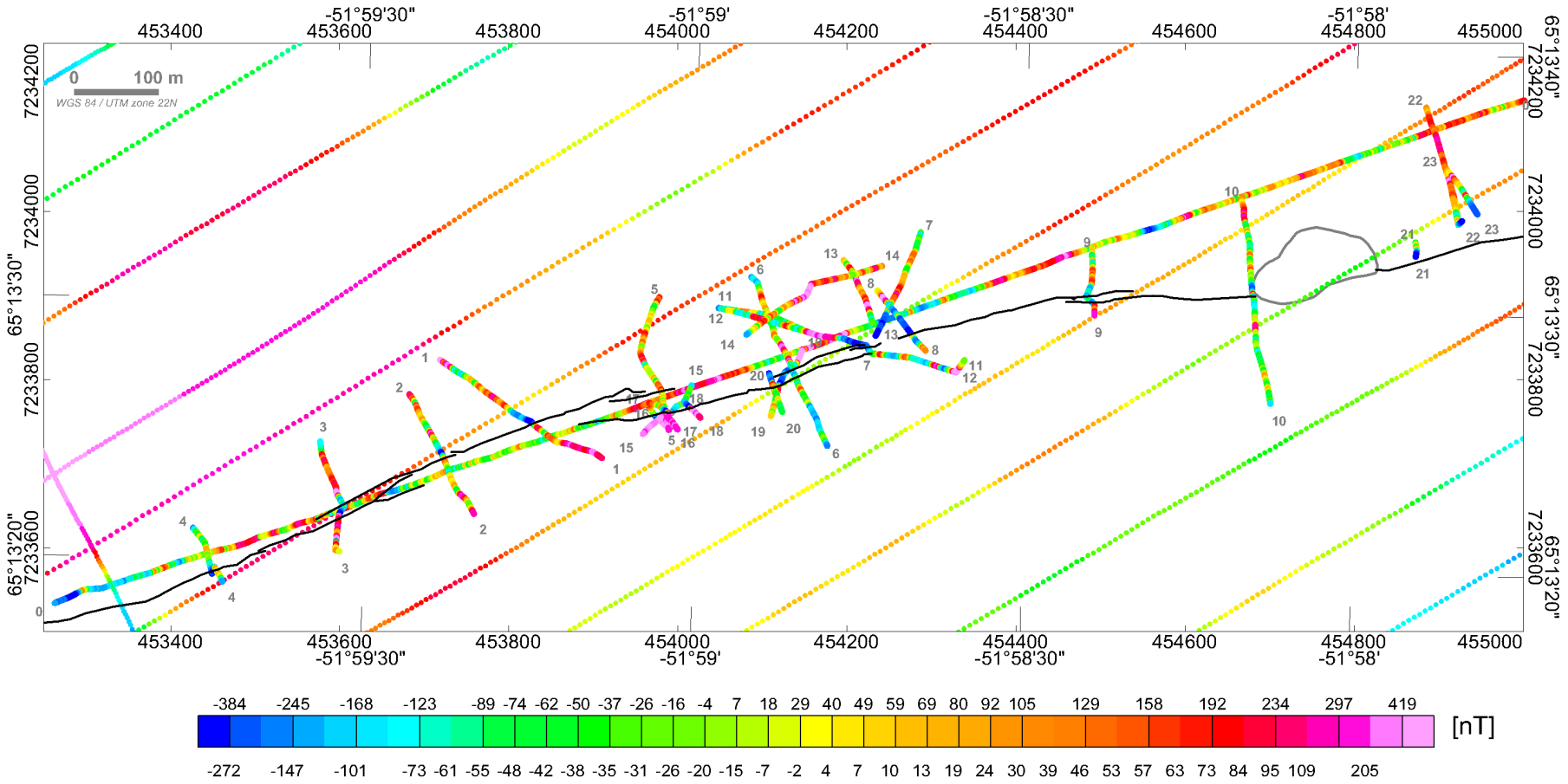

Figure B1. *Magnetic total field anomaly at Occurrence 1 measured at the top-sensor (large coloured dots) along the ground profiles numbered 0–23 and magnetic total field anomaly from the airborne survey (small coloured dots). The class limit annotations above the legend bar are for the ground survey data and the annotations below are for the airborne survey data. Black lines mark the trace of the kimberlitic dykes. The grey line marks the location of a lake.*

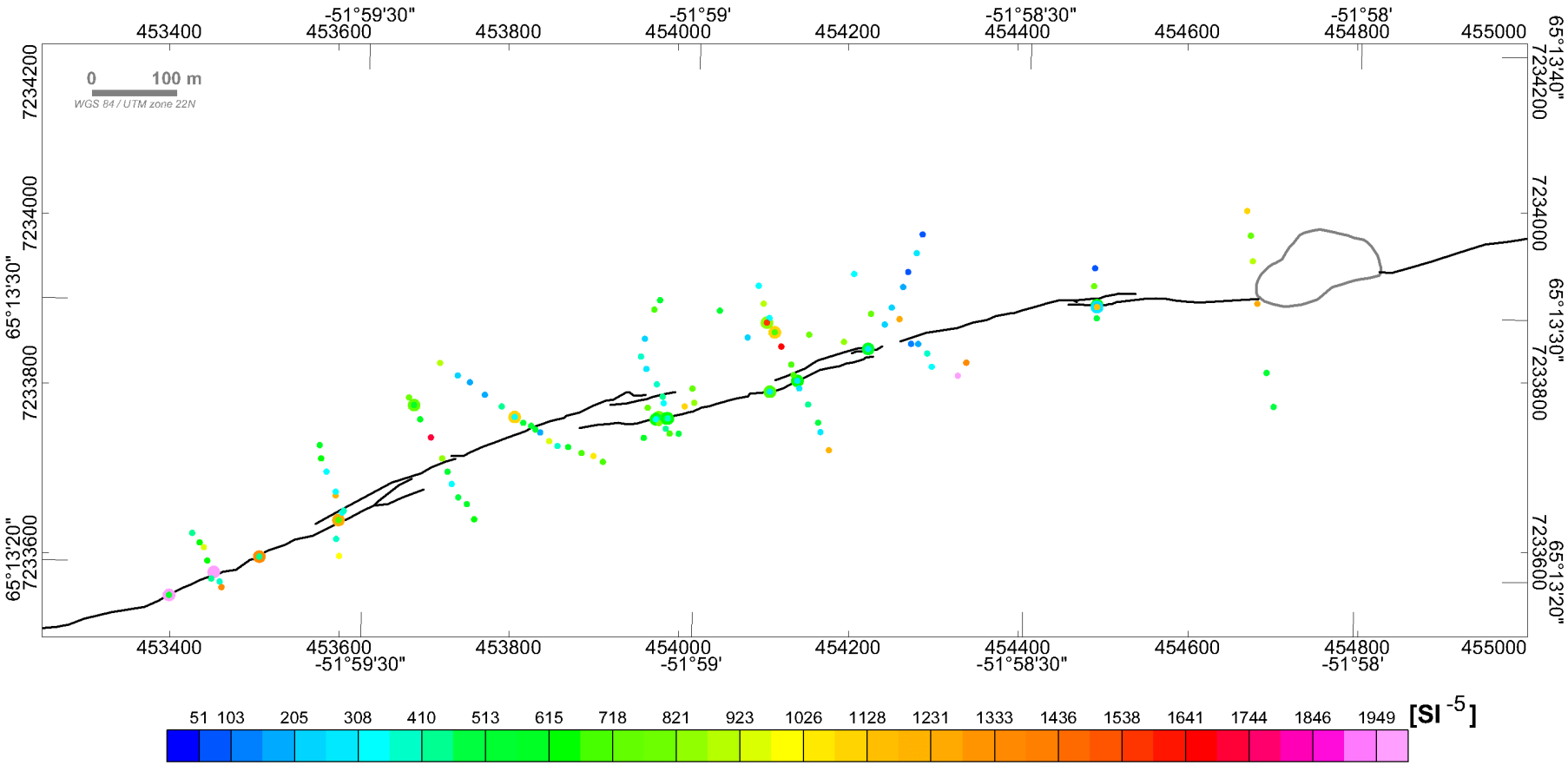

Figure B2. *Magnetic susceptibility values in the area of Occurrence 1. Coloured dots represent median values of 10 measurements at each site. Large dots represent kimberlitic rocks (boulders and dyke) and small dots represent gneiss. Black lines mark the trace of the kimberlitic dykes. The grey line marks the location of a lake.*

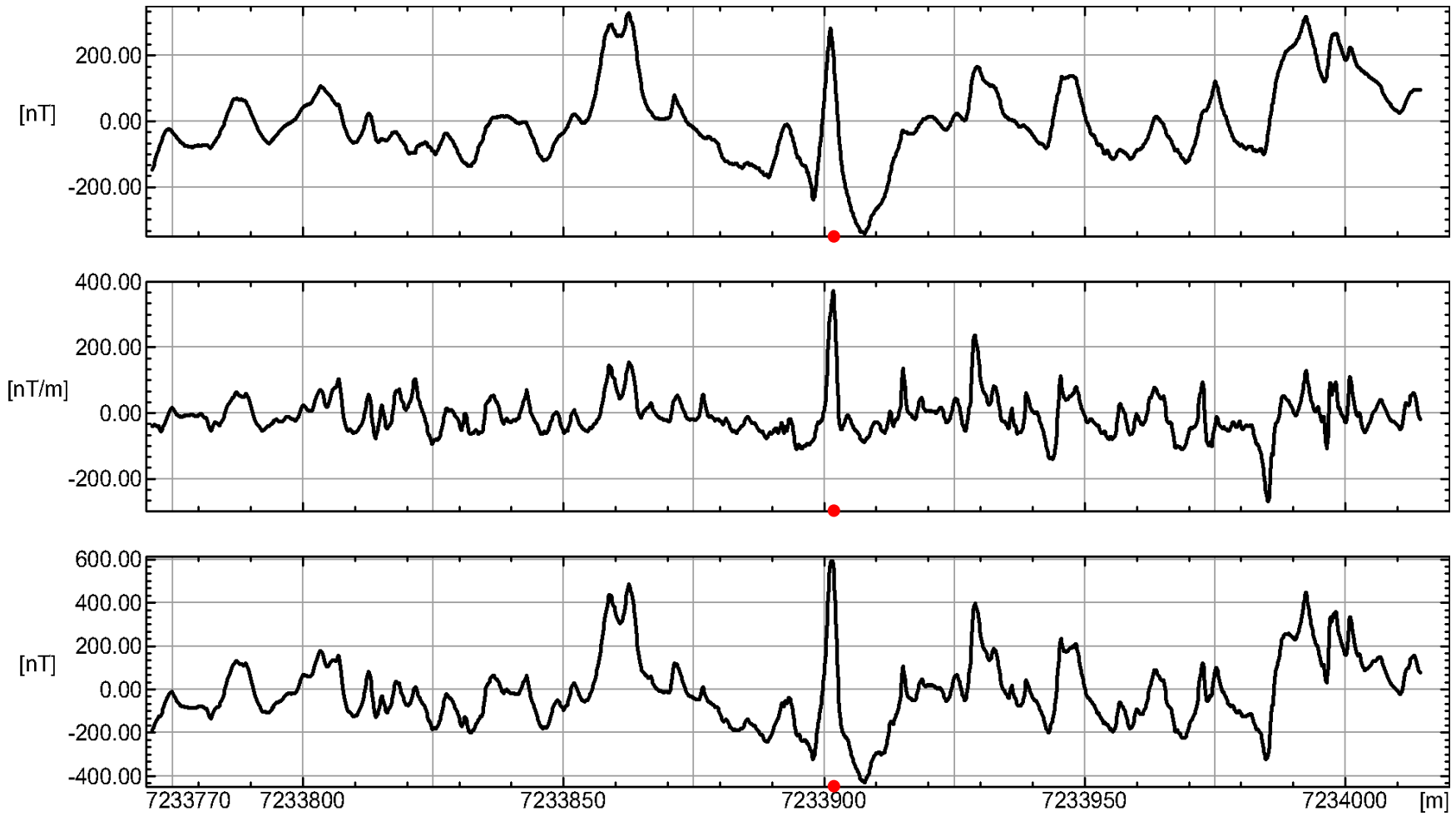

Figure B3. *Magnetic total field anomaly at the top sensor (upper panel), vertical gradient (middle panel) and total field anomaly at bottom sensor (lower panel) along profile 10 at Occurrence 1. The horizontal axis is the north co-ordinate in zone UTM22. The kimberlitic dyke is at co-ordinate 7233901 m (red dots).*

Magnetic signatures: Occurrence 2

The magnetic field measured from the ground profiling and the airborne survey is shown in Figure B4. The magnetic susceptibility is shown in Figure B5. Figure B6 shows the magnetic field measured by the top and bottom sensors of the gradiometer, as well as the gradient for profile 3.

The contrast in magnetic susceptibility between the kimberlitic rocks and the gneiss combined with the rough topography of the area of Occurrence 2 impose severe limitations on the use of magnetic profiling in this area.

The responses from the mapped kimberlitic rocks cannot be discriminated in the airborne data.

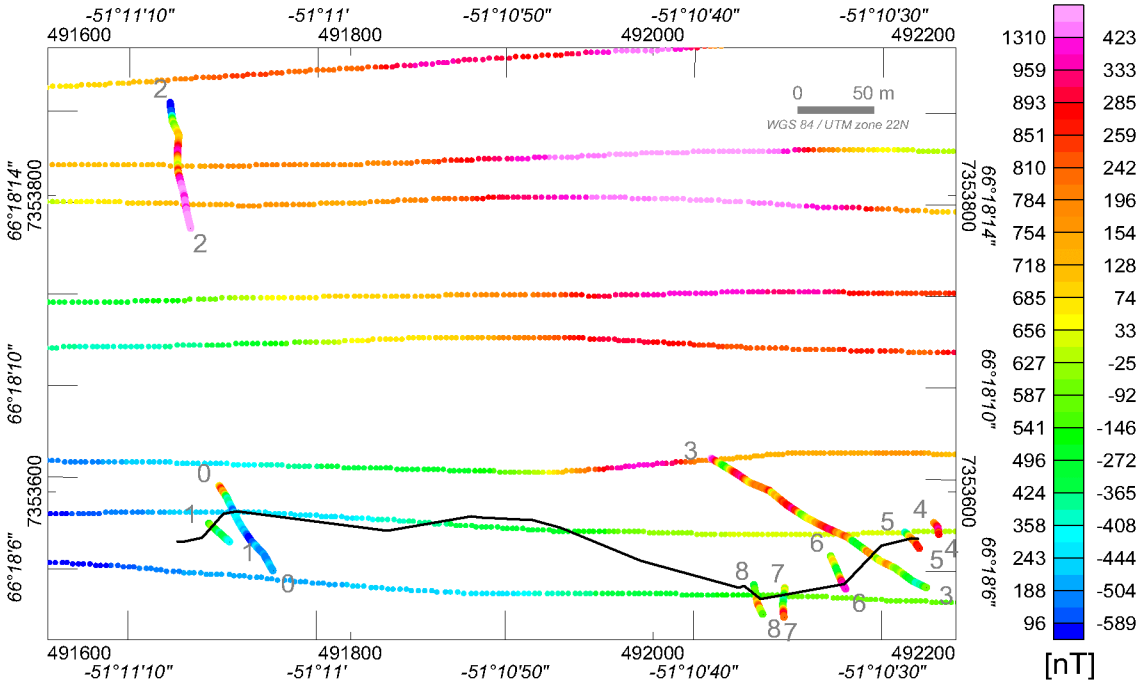

Figure B4. *Magnetic total field anomaly at Occurrence 2 measured at the top-sensor (large coloured dots) along the ground profiles numbered 0–8 and magnetic total field anomaly from the airborne survey (small coloured dots). The class limit annotations on the left side of the legend bar are for the ground survey data and the annotations to the right are for the airborne survey data. The black line marks the trace of the kimberlitic dyke.*

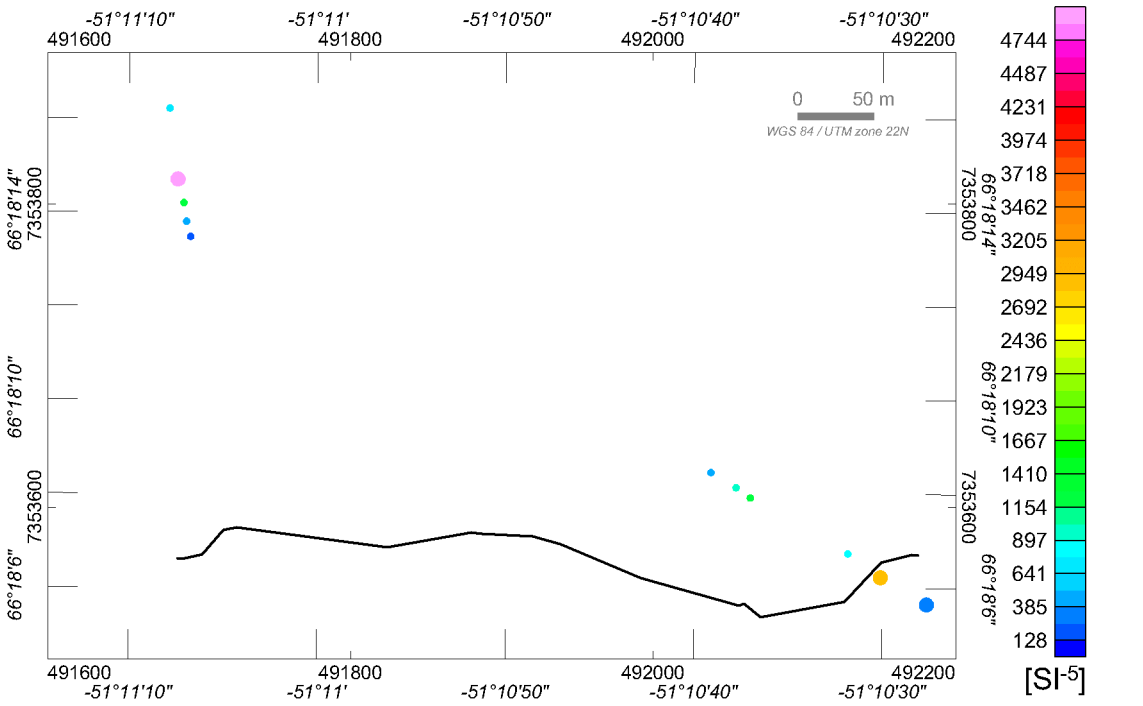

Figure B5. *Magnetic susceptibility values in the area of Occurrence 2. Coloured dots represent median values of 10 measurements at each site. Large dots represent kimberlitic rocks (boulders and dyke) and small dots represent gneiss. The black line marks the trace of the kimberlitic dyke.*

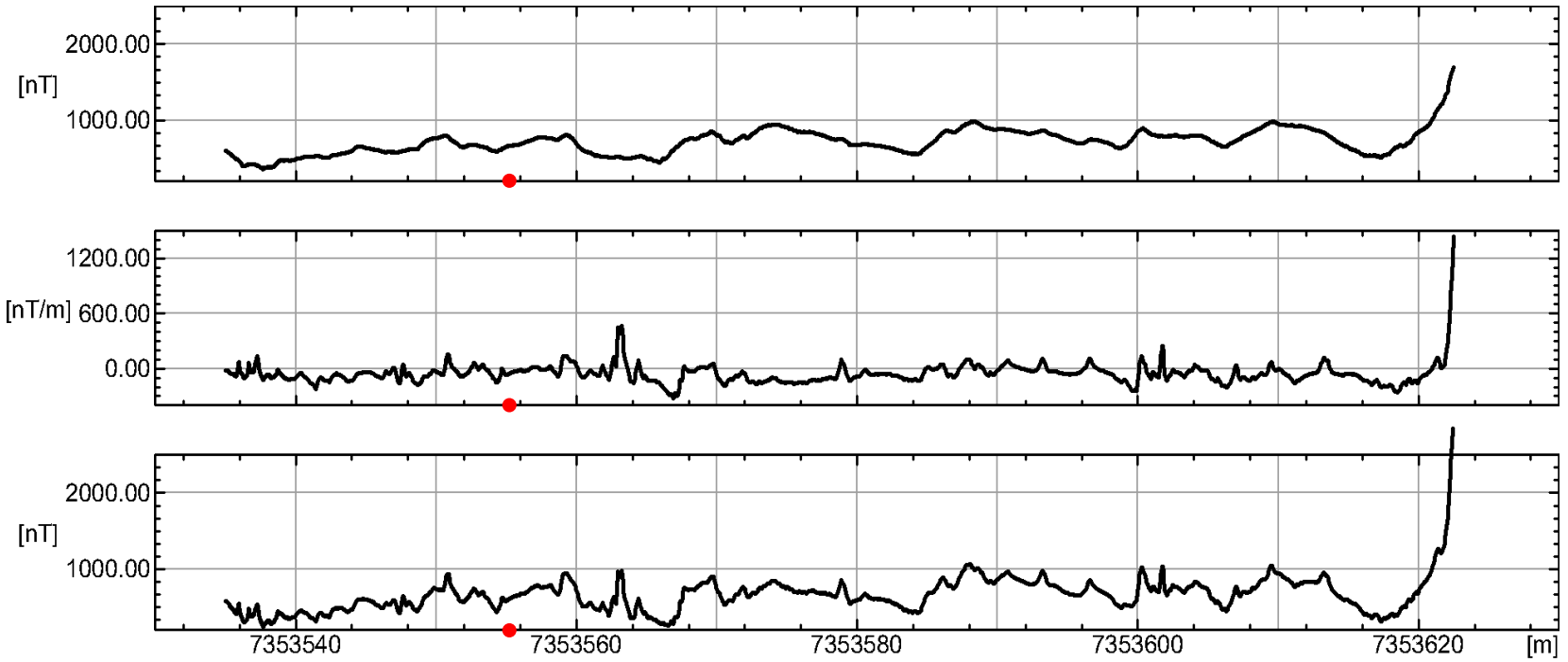

Figure B6. *Magnetic total field anomaly at the top sensor (upper panel), vertical gradient (middle panel) and total field anomaly at the bottom sensor (lower panel) along profile 3 at Occurrence 2. The horizontal axis is the north co-ordinate in zone UTM22. The trace of the kimberlitic dyke is at co-ordinate 7353555 m (red dots).*

Magnetic signatures: Occurrence 3

The magnetic field measured from the ground profiling and the airborne survey is shown in Figure B7. The magnetic susceptibility is shown in Figure B8. Figure B9 shows the magnetic field measured by the top and bottom sensors of the gradiometer, as well as the gradient for profile 3.

The kimberlitic rocks have a clear magnetic signature with a positive peak directly above the kimberlitic dykes. The magnetic susceptibilities of the kimberlitic rocks are high compared to the surrounding gneiss and Kangâmiut dolerite dykes. However, high magnetic susceptibilities of the gneisses are also observed at several locations. This is illustrated in Figure B9, which shows anomalies of similar amplitude caused by kimberlitic rocks and by gneiss with high susceptibilities. Both the kimberlitic rocks and the gneiss with high susceptibilities contribute to the high magnetic anomaly above the trace of the kimberlitic dykes.

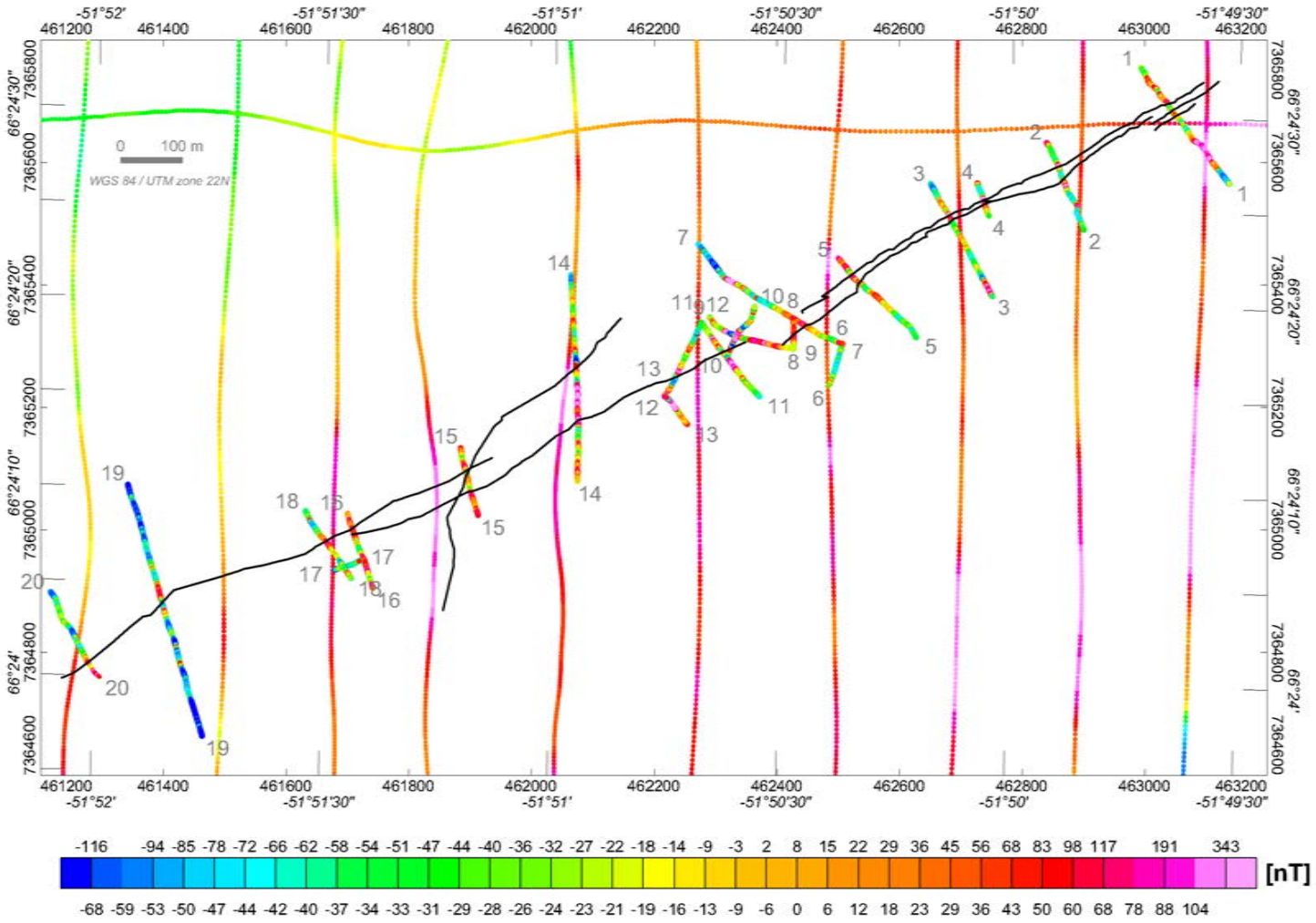

Figure B7. *Magnetic total field anomaly at Occurrence 3 measured at the top-sensor (large coloured dots) along the ground profiles numbered 1–20 and magnetic total field anomaly from the airborne survey (small coloured dots). The class limit annotations above the legend bar are for the ground survey data and the annotations below are for the airborne survey data. Black lines mark the trace of the kimberlitic dykes.*

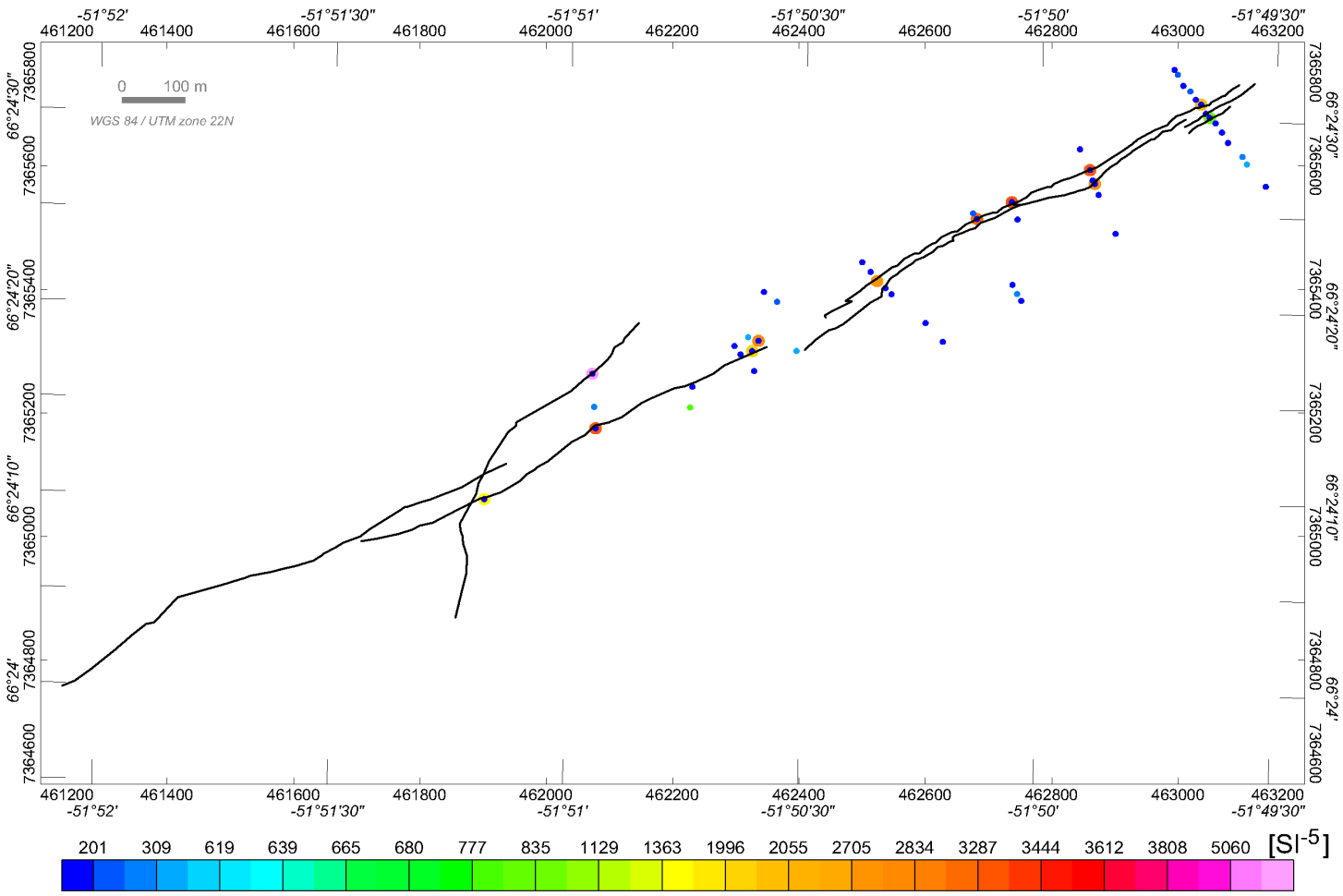

Figure B8. *Magnetic susceptibility values in the area of Occurrence 3. Coloured dots represent median values of 10 measurements at each site. Large dots represent kimberlitic rocks (boulders and dykes) and small dots represent gneiss. Black lines mark the trace of the kimberlitic dykes.*

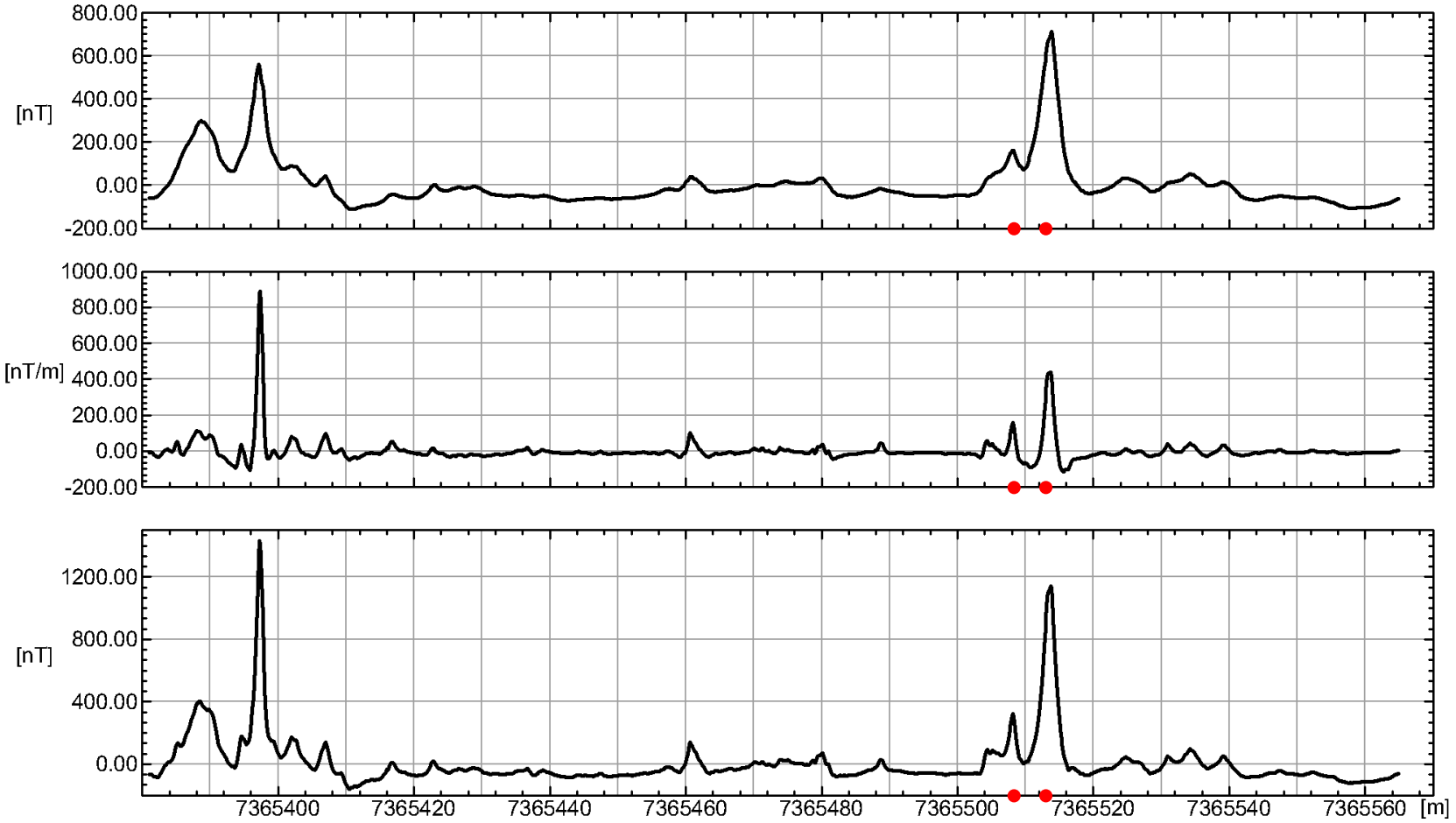

Figure B9. *Magnetic total field anomaly at the top sensor (upper panel), vertical gradient (middle panel) and total field anomaly at bottom sensor (lower panel) along profile 3 at Occurrence 3. The horizontal axis is the north co-ordinate in zone UTM22. The kimberlitic dykes are at co-ordinate 7365508 m and 7365513 m (red dots). The peaks around co-ordinate 7365397 m are caused by gneiss with high magnetic susceptibilities.*