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Contribution to the Geo-mapping for Energy and Minerals 2 (GEM-2) program (2014-2017)

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ABSTRACT

This open file reports preliminary results for the 2014 field season of reconnaissance-scale till sampling in the south Core Zone in NTS sheets 23I and 23P. The report also contains data for glacial sediment samples collected 10 to 200 km to the north of the mapping area, in support of focussed bedrock mapping activities in the North Core Zone. All surface sediment sampling was carried out as part of the Geological Survey of Canada's (GSC) Geo-mapping for Energy and Minerals 2 (GEM-2) program, as part of the GEM-2 Core Zone Project (2014–2017).

INTRODUCTION

Bedrock mapping and mineral resource exploration in northern Quebec and Labrador face challenges where the bedrock geology in places is poorly documented and sparsely exposed. Bedrock is mostly covered by surficial (glacial) sediments deposited during a complex sequence of glacial flow related to the migrating Labrador ice centre of the Laurentide Ice Sheet (Dyke and Prest, 1987). For significant parts of northern Quebec and Labrador, there are no surficial geology maps, till geochemical data, or indicator mineral knowledge. This lack of information results in poorly understood drift thickness, glacial history, and dispersal mechanisms, which ultimately hinders mineral exploration.

To address these knowledge gaps and support resource exploration, the Geological Survey of Canada (GSC) as part of its Geo-mapping for Energy and Minerals 2 (GEM-2) program and in collaboration with the Ministère de l'Énergie et des Ressources Naturelles du Québec (MERNQ) and the Geological Survey of Newfoundland & Labrador (GSNL) are conducting new surficial mapping and surficial (till, lake sediments) geochemical studies as part of an integrated regional mapping program centred on Archean "core zone" rocks between the Torngat Orogen to the east and the New Quebec Orogen to the west (Wardle et al., 1997, 2002) (Figs. 1 and 2). These surficial activities will produce new regional geoscience data that will be used to greatly increase geological knowledge and support mineral exploration and responsible resource development.

This open file reports preliminary results for 36 till samples collected in the south Core Zone in NTS maps 23I and 23P in the summer of 2014 (McClenaghan et al., 2014). Additional glacial sediment sampling was carried out 10 to 200 km to the north of the NTS 23I/23P study area, in support of focussed GEM-2 bedrock mapping activities in the north Core Zone area (Corrigan et al., 2015). The data for these 18 till samples are also reported here because the samples were analyzed in the same batch as the till samples from the south Core Zone (NTS maps 23I/23P) area. However, only the south Core Zone till sample data are discussed in this report.

LOCATION AND ACCESS

Straddling the border between Quebec and Newfoundland and Labrador, the south Core Zone study area is located east of the town of Schefferville, Quebec, in the Lac Résolution (NTS 23P) and Woods Lake (NTS 23I) 1:250 000 scale topographic map sheets. The study area is within the Lake Plateau portion of the James Region and the George Plateau and Whale Lowland divisions of the Davis Region within the Canadian Shield (Bostock, 2014). It encompasses the drainage divide used to establish the boundary between Quebec and Labrador, separating northern flow to Ungava Bay, and southern flow to the Churchill River system. Due to the lack of transportation infrastructure, remoteness, and rugged terrain of the study area, field sites were only accessible via helicopter. Site selection was therefore limited to locations allowing for safe helicopter operation, usually treeless highlands, large bedrock outcrops, or open lake shorelines.

PHYSIOGRAPHY

The variation in physiography across the south Core Zone study area is a direct reflection of the differing bedrock lithology and distribution of glacial deposits. The topography varies from high to low relief in the northern map sheet, with more low-lying fens and bogs in the southern map sheet. Elevation ranges from less than 350 m above mean sea level (asl) in the George River valley to a maximum of 668 m (asl). The

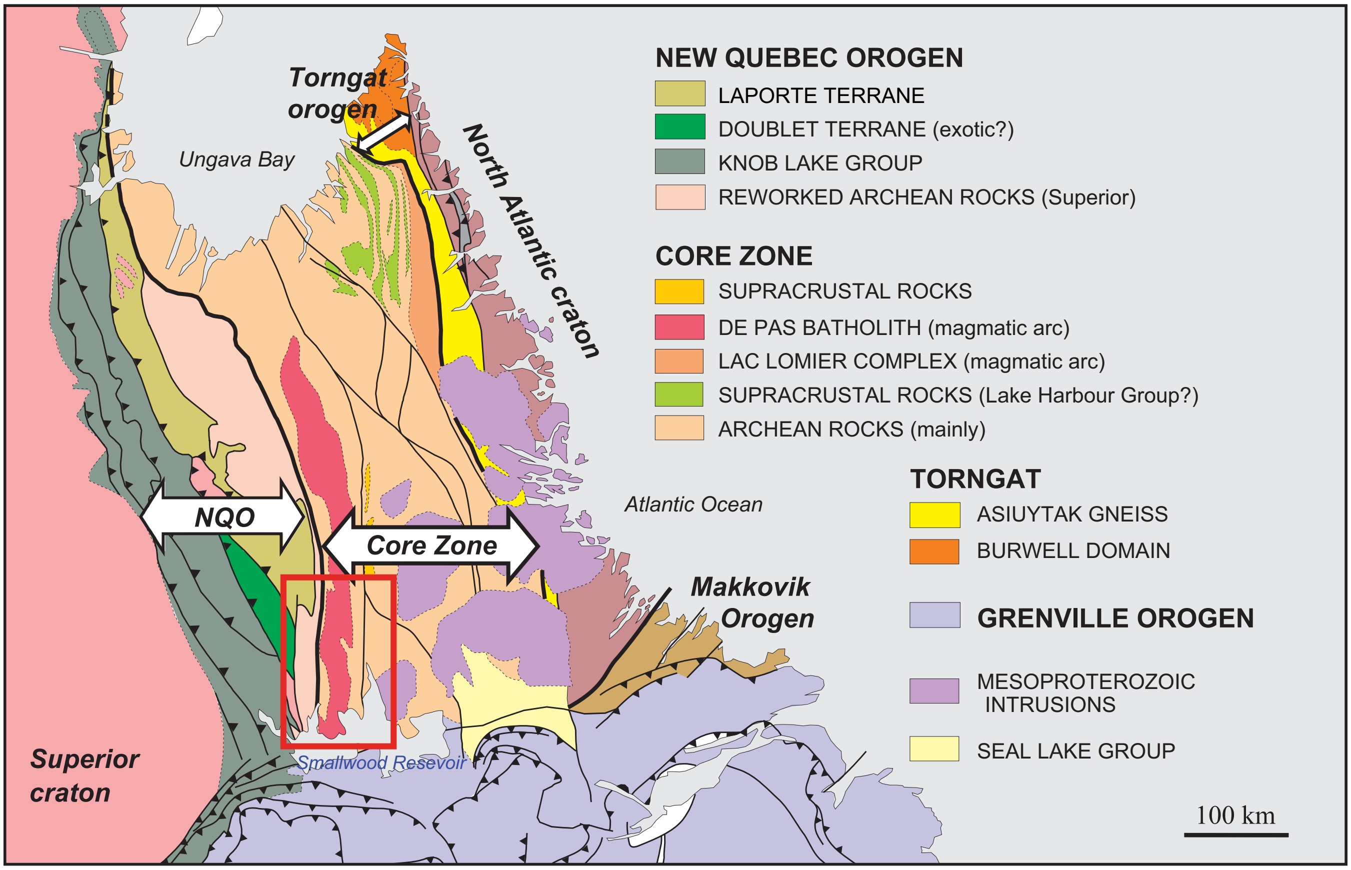

Figure 1. Simplified bedrock geological map of the Core Zone and bounding orogens in Quebec and Labrador. The south Core Zone surficial mapping area (NTS 23P and 23I) is outlined in red. Bedrock geology modified after James et al. (2003). Abbreviation: NQO = New Quebec Orogen.

northern map sheet (NTS map 23P), which has the greatest variation in elevation, is characterized by abundant barren highlands scattered with perched glacial erratics. Lakes are common in the eastern portion of the map sheet, where the presence of elongate lakes appears to be controlled by bedrock joints and faults. The southern portion of the study area (NTS map 23I) is dominated by the Smallwood Reservoir, a large hydroelectric reservoir created through the damming of the Churchill River.

Glacial sediment thickness varies throughout the region, with thin till veneer covering highland areas, thicker till on the flanks of highland areas, and thick glacial sediments infilling many of the lowland areas. North of the reservoir, extensive drift cover results in low-lying swamps, fens, and bog that are confined between a plethora of small lakes. The central portion of the map sheet is dominated by the De Pas Batholith, which is a plutonic unit that is characterized by higher relief with increased occurrence of bedrock outcrops. East of the De Pas Batholith, the terrain is radially punctuated with well defined eskers, several of which continue for tens of kilometres.

Vegetation varies with the topography and elevation across the study area. The southern portion of the south Core Zone study area is representative of Boreal Forest woodlands, with small conifers, interspersed between small bushes and moss floors. The northern portion of the study area reflects forested tundra, with barren highlands covered only in caribou lichen, grasses, and small plants. The entire region has isolated patches of discontinuous permafrost (Heginbottom et al., 1995).

BEDROCK GEOLOGY

The region is centred on the Archean cratonic Meta Incognita rocks between the Torngat and the New Quebec orogenic rocks (Corrigan et al., 2015). The northern map sheet (NTS 23P) is dominated by Churchill Province basement rocks overlain by Doublet Group, fine-grained mafic metavolcanic rocks. The De Pas Batholith dominates the central part of the study area, as it is elevated above the surrounding Churchill basement bedrock. Other Churchill Province bedrock within the southern map sheet consists of the Knob Lake Group, Eastern Gneisses (reworked Archean rocks), Archean orthogneiss and granite, Core Zone Paleoproterozoic rocks of the Lac Zeni Complex, and Mesoproterozoic intrusions, such as the Julliet syenite and Michikamau anorthosite (Green, 1974;

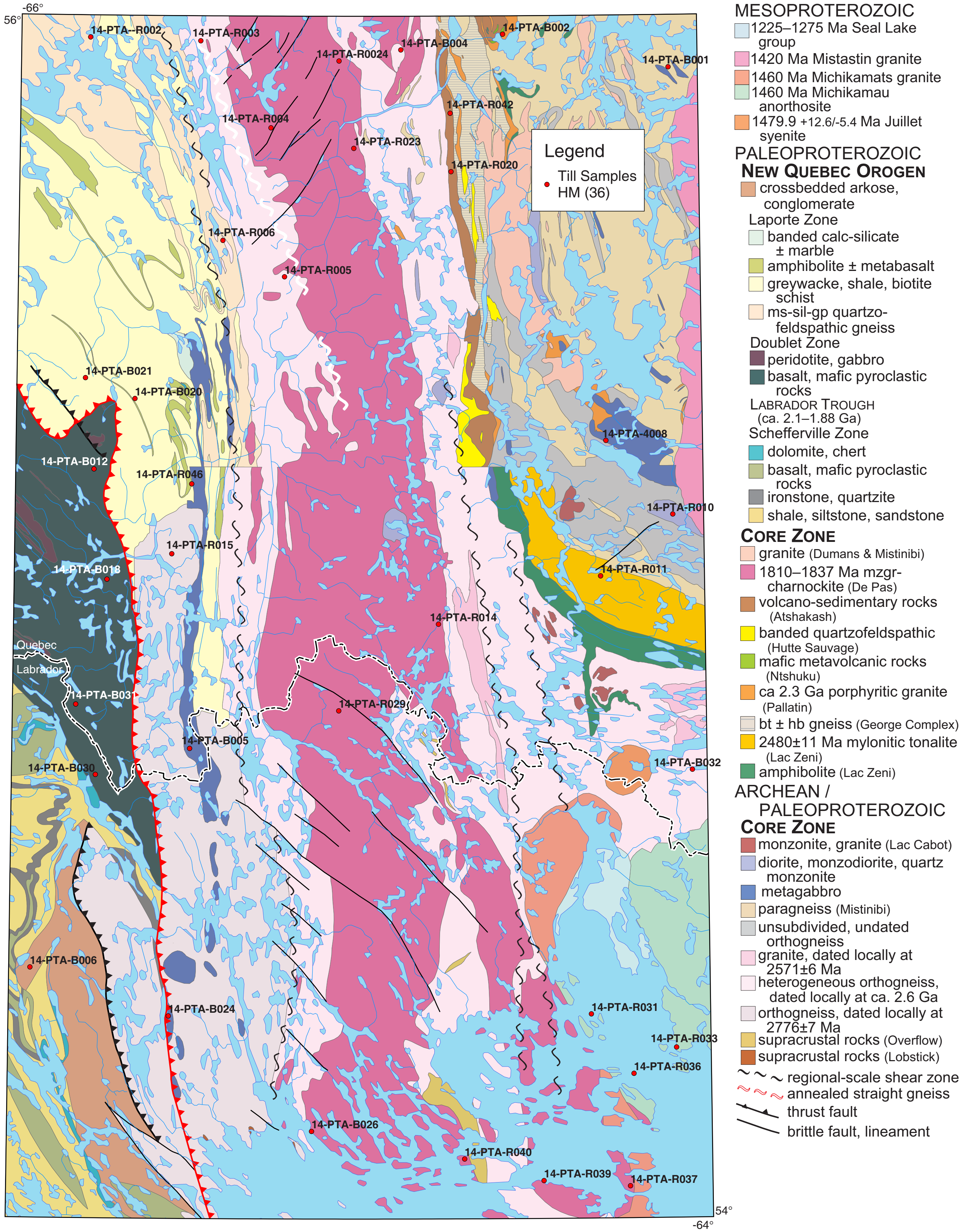

Figure 2. Bedrock geology of the GEM-2 southern Core Zone project area (NTS 23P and 23I) highlighting crustal domains within the New Quebec Orogen and southern Core Zone. Red dots indicate localities where till samples were collected in 2014. Bedrock geology after Wardle et al. (1997).

Wardle et al., 1997). Detailed bedrock geology and economic potential of Labrador was carried out by Greene (1974), and provides a simple summary of the bedrock geology of the southern portion of the map sheet.

SURFICIAL GEOLOGY

The study area has been subjected to multiple glacial events, and remained under continuous ice cover of the Labrador Sector of the Laurentide Ice Sheet throughout the Wisconsin glaciation. Reconstruction of past ice-flow trajectories, their associated landforms, and glacial landsystems are fundamental for successful application of drift prospecting, as it provides information about dispersal characteristics of former Pleistocene ice sheets. The sequence of striation trends, which is inscribed on many outcrops throughout the map area, provides a complete chronology of ice-flow events (Fig. 3).

The oldest documented ice flow was to the northeast and originated in the Quebec Highlands (Veillette et al., 1999). Local glacial landforms, however, do not reflect this oldest ice-flow event. The first and major landform-forming ice-flow phase was from ice flowing radially from the Labrador ice centre, which was roughly centred over the De Pas Batholith. Nucleation of drumlin and other streamlined landform formations may be the related to radial flow around glacially lodged sediments or bedrock outcrops. Eastward migration of the Labrador ice centre, evidence of which was observed in several outcrops in the north-central part of the northern map sheet (McClenaghan et al., 2015b), resulted in a number of areas experiencing a complete reversal of ice flow. In the early stages of deglaciation, ice flowing to the Labrador coast reduced the ice-sheet profile in the eastern section of the Laurentide Ice Sheet (Margold et al., 2015), which remobilized the previously deposited tills and created elongated landforms with high length-to-width ratios, which is indicative of fast flowing ice. After the paleo ice-stream network shut down, a deglacial landsystem prevailed, which was dominated by radial esker systems in the eastern half of the map area, with local deviations that resulted from topographically controlled ice flow.

Three glacial lakes formed in the study area during deglaciation, glacial Lake Smallwood in the southern part of 23I and glacial lakes McLean and Naskaupi in the northern parts of 23P. These glacial lakes, which extended well beyond the study area, are part of ongoing research (cf. McClenaghan et al., 2015a).

PREVIOUS WORK

A reconnaissance till sampling program was carried out by the GSC in the 1980s across western Labrador and northeastern Quebec, including the south Core Zone study area. Data for this previous GSC sampling program were reported in Klassen and Thompson (1987, 1989, 1990, 1993), Klassen (1999), and Klassen and Knight (1995).

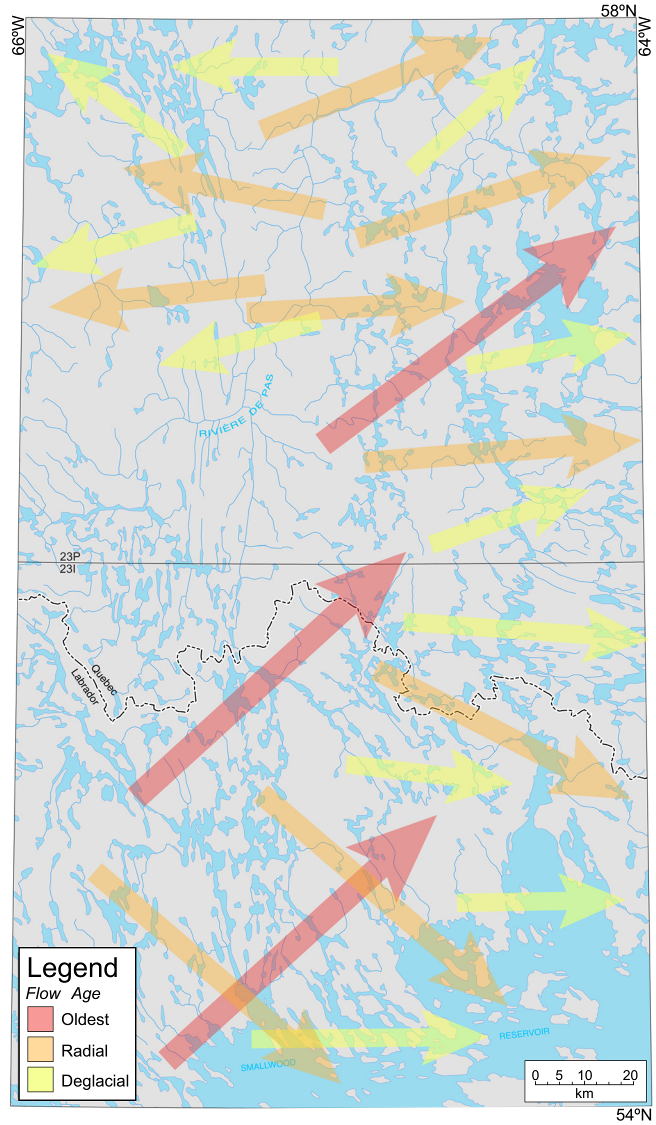

Figure 3. Generalized ice-flow chronology in the study area. Pink arrows indicate the oldest ice flow recorded in the region, which was likely from the Quebec highlands (cf. Veillette et al., 1999). Orange arrows indicate radial ice flow from the Labrador ice centre during the main Wisconsin phase of the Laurentide Ice Sheet. Yellow arrows show radial flow from the ice centre during deglaciation (from McClenaghan et al., 2015b).

METHODS

Till sampling methods

A total of 36 till samples (Fig. 2) were collected in the South Core Zone area during the summer of 2014 following established GSC protocols (Spirito et al., 2011; McClenaghan et al., 2013). Sample site locations are listed in Appendix A1. As this sampling survey was

Figure 4. Example of a typical mudboil targeted for till collection at site 14-PTA-B001.

reconnaissance fieldwork, a bias toward samples from specific regions of interest resulted in uneven geographical spacing of sample sites in 2014. Gaps between field sample sites will be addressed in follow-up field activities based (cf., McClenaghan et al., 2015a,b), partially directed from results of this preliminary fieldwork. Active mudboils were targeted for sample collection (Fig. 4) at a depth between 0.2 and 1.0 m. Samples were collected from hand-dug pits at all locations. At some sites, particularly in the south part of the study area beyond the limit of discontinuous permafrost, till samples were collected by digging through the naturally developed soil profile to sample the C-horizon till (Fig. 5). Great care was taken to limit cross contamination among sites, including cleaning shovels between locations. Additionally, all cobbles (>6 cm) were removed from the till sample to maximize the amount of matrix material being collected. Two samples were collected at each site, a large till sample (7–13 kg) for recovery of indicator minerals and a ~3 kg sample for geochemical analysis, textural determinations, Munsell colour determination, and archiving. These sampling protocols were also followed for the collection of an additional 18 samples, which were collected 10 to 200 km to the north in support of the GEM-2 bedrock mapping activities by Corrigan et al. (2015).

Sample processing and analysis

The 3 kg till samples were submitted to the GSC Sedimentology Laboratory, Ottawa, where each sample was oven dried at 105°C for 15 to 30 minutes, then laid out on dry Kraft paper and disaggregated using a rubber mallet (Girard et al., 2004). For each dried sample, an ~800 g split was archived and the remainder was subjected to matrix grain-size analysis, Munsell colour determination, and sieving to recover the <0.063 mm fraction following GSC protocols as outlined by Spirito et al. (2011) and McClenaghan et al. (2013), and shown in the flowchart in Figure 6.

Figure 5. Sample hole showing the soil profile (orange B horizon) that was developed on till at site 14PTA-R039. The till sample was collected from the lower grey till (C horizon), below the orange B horizon.

The <0.063 mm fraction of each till sample was isolated by dry sieving in a stainless steel US standard 230 mesh sieve and was then submitted to a commercial laboratory for geochemical analysis. Grain-size analysis of the sediment matrix was conducted on a separate aliquot using a combination of wet and dry methods (Girard et al., 2004). The size classes for the >0.063 mm material were determined by wet sieving in a stack of sieves, and the size classes for the <0.063 mm material were determined using a Lecotrac LT-100 Particle Size Analyzer. Sediment classification was determined based on the Shepard (1954) system for determining sand-silt-clay ratios. Data from the reported grain-size distribution are listed in Appendix A2. Munsell colour (dry) was determined for each dry till-matrix sample using a Spectrophotometer linked to IQC colour software. Munsell colour determinations are also reported in Appendix A2.

Geochemical analysis

Total carbon, organic and inorganic carbon contents, and loss on ignition (LOI) were determined for the

<0.063 mm fractions using the LECO® RC-412 Carbon Analyzer at the GSC, Ottawa. Samples were heated to 1350ºC to determine percentages of total inorganic carbon and total carbon through infrared detection of liberated CO_2. Samples were then heated for 1 hour at 500ºC to determine the LOI. Data are reported in Appendix B1. An additional portion of the <0.063 mm fraction was used for determination of calcite and dolomite contents using the UIC CM5015 Coulometer/Acid Evolution Method following the method described by Girard et al. (2004). Data for all till samples are reported in Appendix B2.

The <0.063 mm fraction of each till sample was submitted to ACME Labs (now Bureau Veritas Commodities Canada Ltd.), Vancouver, for analysis of a suite of major, minor, and trace elements using a modified aqua regia leach ($HCl:HNO_3$ in a 1:1 ratio) followed by an ICP-MS determination (ACME AQ250 package on 0.5 g), and lithium metaborate/tetraborate fusion followed by nitric acid digestion/ICP-ES, -MS (LF200 package on 0.2 g) that includes the determination of Cu, Pb, Zn, and Mo. Total sulphur and carbon was determined by LECO. Detection limits and geochemical data for all samples are reported in Appendix B3.

Three silicic acid (silica sand) blanks (samples 14-PTA-R001, 14-PTA-R012, and 14PTA-B043) were inserted into the sample batch and then sieved and analyzed along with routine till samples to monitor potential cross contamination from metal-rich samples during sieving and instrumental memory effect during analytical procedures. Analytical data for the three blanks are reported in Appendix B3. Two blind (lab prep) duplicates (sample 14-PTA-R023A is a duplicate of sample 14-PTA-R023; 14-MPB-1014B is a duplicate of and 14-MPB-1014) were prepared and inserted into the batch by the GSC Sedimentology Laboratory, to monitor analytical precision. Data for the GSC blind duplicates are reported in Appendix B4. CANMET certified reference standard TILL-4 was inserted into the batch (samples 14PTA-R059A and 14PTA-B024A) prior to geochemical analysis to monitor analytical accuracy. The certificate of analysis for this reference material is available at: http://www.nrcan.gc.ca/mining-materials/certified-reference-materials/certificate-price-list/8137. TILL-4 was originally collected from a trench dug in till near the Sisson W-Mo deposit (Lynch, 1996). Data reported for standards inserted into the batch are reported in Appendix B5. Bureau Veritas' in-house quality assurance and quality control data (in-house standard, replicate, and blank samples) are reported in Appendix B3.

Pebble counts

The >2.0 mm clast fraction was obtained from the large (7–13 kg) till samples collected for indicator minerals, during the sample processing at Overburden Drilling Management Limited. The pebble fraction was washed with oxalic acid to remove iron and manganese staining and coatings on the surfaces of the pebbles. The 0.56 to 2.5 cm fraction of each till south Core Zone till sample was examined (>150 pebbles) and pebbles were classified into the following 12 lithological categories: mafic intrusive; felsic intrusive, ultramafic intrusive, metasedimentary, red sediment, carbonate, vein quartz, quartzite, iron formation, leucogranite, Makuach rhyolite (referred to as Martin Lake rhyolite by Klassen and Thompson, 1993), and other. Data are listed in Appendix C1.

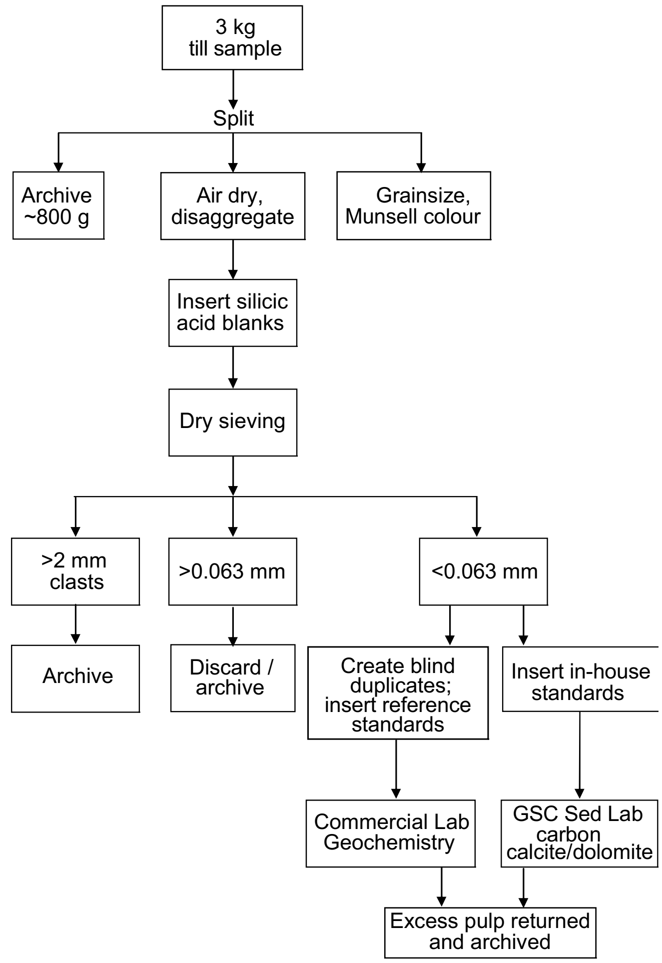

Figure 6. Flow chart outlining sample processing and preparation of till samples at the Geological Survey of Canada's Sedimentology Lab, Ottawa (modified from McClenaghan et al., 2013).

RESULTS

Till characteristics

Despite being sampled from a large geographical region with till derived from various bedrock lithologies, the samples in the south Core Zone have a relatively uniform grain-size distribution (Fig. 7) with an average content of 55.1% sand, 41.5% silt, and 3.5%

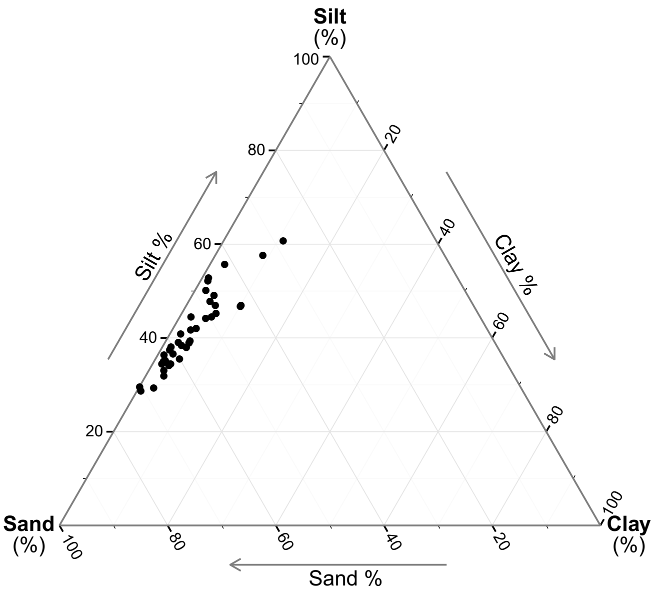

Figure 7. Ternary diagram of percentage of sand, silt, and clay in the 2014 till samples from NTS sheets 23I and 23P.

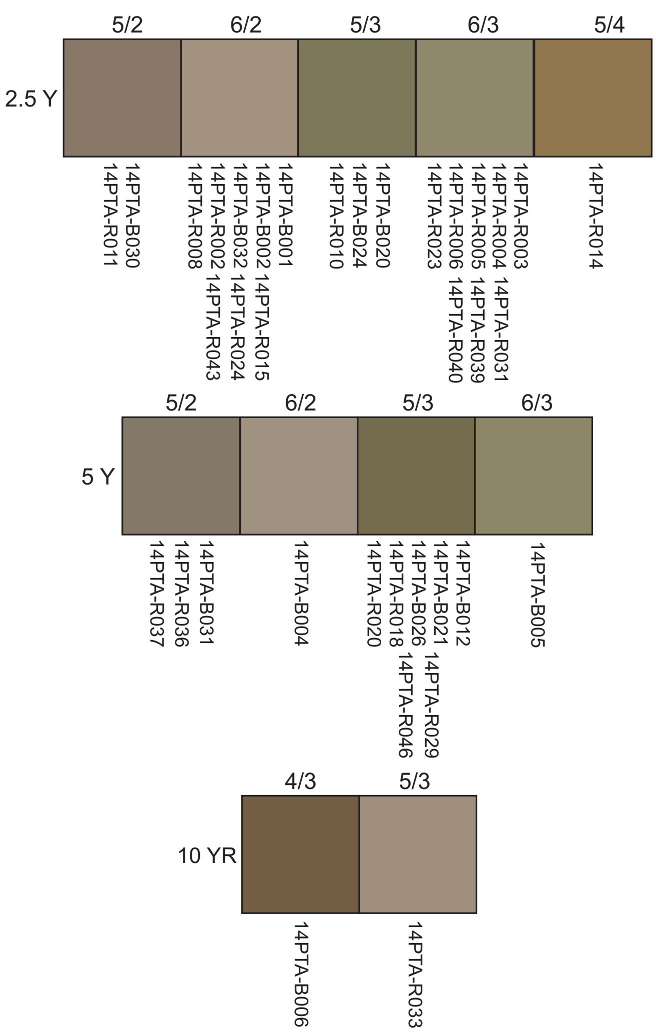

Figure 8. Graphical display of Munsell colour results for the 2014 till samples from NTS maps 23I and 23P.

clay. The majority of the till sampled has a sandy-silt matrix, with some samples being slightly more silt-rich, and only two samples containing more than 10% clay. Munsell colour yielded similar results with all samples ranging from olive (5Y 5/3) to light brownish grey (2.5Y 6/2) (Fig. 8).

Total carbon, inorganic and organic carbon, and LOI results varies little among the samples. Total carbon values are relatively low, ranging from 0.1 to 1.3%. Inorganic carbon values are below detection limit for every sample except 14-PTA-R002 for which it was not detected. Organic carbon values are also low, ranging from 0.2 to 1.3%. LOI values are relatively low, ranging from 1.0 to 5.3%.

All values for calcite and dolomite, as indicated by CO_2 content generated, are below the detection limit (Appendix B2).

Geochemical results

Geochemical data for the <0.063 mm fraction of the 36 till samples from the south Core Zone and the 18 samples from the area to the north are listed in Appendix B3. Proportional dot maps showing geochemical distributions for selected major oxides or elements for the south Core Zone samples are shown in Appendix D (maps 1 to 20). Sample spacing in the early stage of this reconnaissance sampling program is too broad to interpret regional patterns or trends. However, it is noteworthy that aqua regia values for Au, Co, Cr, Cu, Ni, Sb, and Zn are highest in three areas: the west part of the study area in tills overlying; the Doublet Zone mafic volcanic rocks; Laporte Zone sedimentary rocks immediately north of the Doublet Zone; and metagabbro in the Core Zone.

FUTURE WORK

Surficial mapping and reconnaissance-scale till sampling, which was completed in 2015 and will continue through the summer of 2016, will result in the production of eight 1:100,000 surficial geology maps of the area covered by NTS sheets 23I and 23P. Through this work, a better understanding of both the complex ice history and the provenance of glacial sediments in this region will be obtained. This improved Quaternary geological framework will aid mineral exploration activities in the region.

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REFERENCES

Bostock, H.S., 2014. Physiographic regions of Canada; Geological Survey of Canada, "A" Series Map 1254A, scale 1:5 000 000.

Corrigan, D., Brouillette, P., Morin, A., Van Rooyen, D., Wodicka, N., Houlé, M.G., Douma, S., and Robillard, K., 2015. Report of activities for the Core Zone and bounding orogens: Tectonic framework and mineral potential; Geological Survey of Canada, Open File 7706. doi:10.4095/296141

Dyke, A.S. and Prest, V.K., 1987. Late Wisconsin and Holocene history of the Laurentide Ice Sheet; Géographie physique et Quaternaire, v. 41, p. 237–263.

Girard, I., Klassen, R.A., and Laframboise, R., 2004. Sedimentology laboratory manual, Terrain Sciences Division; Geological Survey of Canada, Open File 4823.

Greene, B.A., 1974. An outline of the geology of Labrador; Province of Newfoundland Information Circular No. 15, p. 1–61.

Heginbottom, J.A., Bureuil, M.A., and Harker, P.T., 1995. Permafrost: National Atlas of Canada Fifth Edition; Natural Resources Canada, MCR 4177. doi:10.4095/205314

James, D.T., Nunn, G.A.G., Kamo, S., and Kwok, K., 2003. The southeastern Churchill Province revisited: U-Pb geochronology, regional correlations, and the enigmatic Orma Domain, *In:* Current Research; Newfoundland Department of Mines and Energy, Geological Survey Report 03-1, p. 35–45.

Jansson, K.N., 2003. Early Holocene glacial lakes and ice marginal retreat pattern in Labrador/Ungava, Canada; Palaeography, Palaeoclimatology, Palaeoecology, v. 193, p. 473–501.

Klassen, R.A., 1999. The application of glacial dispersal models to the interpretation of till geochemistry in Labrador, Canada; Journal of Exploration Geochemistry, v. 67, p. 245–269.

Klassen, R.A. and Thompson, F.J., 1987. Ice flow history and glacial dispersal in the Labrador trough, *In:* Exploration Technology and Glacial Dispersal Studies; Geological Survey of Canada, Current Research Part A. 87-1, p. 61–71.

Klassen, R.A. and Thompson, F.J., 1989. Ice flow history and glacial dispersions, Labrador, In: Drift Prospecting, (ed.) R.N.W. DiLabio and W.B. Coker; Geological Survey of Canada, Paper 89-20, p. 21–29.

Klassen, R.A. and Thompson, F.J., 1990. Glacial history, drift composition, and till geochemistry, Labrador; Geological Survey of Canada, Open File 2170.

Klassen, R.A. and Knight, R.D., 1995. Till geochemistry of central Labrador; Geological Survey of Canada, Open File 3213.

Klassen, R.A. and Thompson, F.J., 1993. Glacial history, drift composition, and mineral exploration, central Labrador; Geological Survey of Canada, Bulletin 435, p. 84.

Lynch, J.J., 1996. Provisional elemental values for four new geochemical soil and till reference materials, TILL-1, TILL-2, TILL-3, and TILL-4; Geostandards Newsletter 20, p. 227–287.

Margold, M., Stokes, C.R., and Clark, C.D., 2015. Ice streams in the Laurentide Ice Sheet: Identification, characteristics and comparison to modern ice sheets; Earth-Science Reviews, v. 143, p. 117–146.

McClenaghan, M.B., Plouffe, A., McMartin, I., Campbell, J.E., Spirito, W.A., Paulen, R.C., Garrett, R.G., and Hall, G.E.M., 2013. Till sampling and geochemical analytical protocols used by the Geological Survey of Canada; Geochemistry: Exploration, Environment, Analysis, v. 13, p. 285–301.

McClenaghan, M.B., Paulen, R.C., Rice, J.M., Sanborn-Barrie, M., McCurdy, M.W., Spirito, W.A., Adcock, S.W., Veillette, J.J., Garrett, R.G., Grunsky, E.C., Pickett, J., Layton-Matthews, D., and Corrigan, D., 2014. GEM 2 Hudson-Ungava Project: southern Core Zone surficial geology, geochemistry, and bedrock mapping activities in Northern Quebec and Labrador; Geological Survey of Canada, Open File 7005. doi:10.4095/292138

McClenaghan, M.B., Paulen R.C., and Rice, J.M., 2015a. Indicator mineral abundance data for till samples from the south Core Zone, Quebec and Labrador (NTS 23P and 23I): samples collected in 2014; Geological Survey of Canada, Open File 7968.

McClenaghan, M.B., Paulen, R.C., Rice, J.M., McCurdy, M.W., Fortin, R., Spirito, W.A., Adcock, S.W., Ross, M., Pyne, M., Dubé-Loubert, H., and Lion, A.J., 2015b. Geochemistry, and Gamma-Ray M.B. Spectrometry Studies in northern Quebec and Labrador; Geological Survey of Canada, Open File 7946.

Rice, J.M., Paulen, R.C., Ross, M., McClenaghan, M.B., Pyne, M., Dubé-Loubert, H., and Lion, A.J., 2015. Surficial mapping, Chapter 2 *In:* Report of Activities for the Core Zone: 2015 Gurficial Geology, Geochemistry, and Gamma-Ray M.B. Spectrometry Studies in northern Quebec and Labrador, (ed.) McClenaghan, R.C. Paulen, J.M. Rice, M.W. McCurdy, R. Fortin, W.A. Spirito, S.W. Adcock, M. Ross, M. Pyne, H. Dubé-Loubert, and A.J. Lion; Geological Survey of Canada, Open File 7946, p. 9–14.

Shepard, F.P., 1954. Nomenclature based on sand-silt-clay rations; Journal of Sedimentary Petrology, v. 24, p. 151–158.

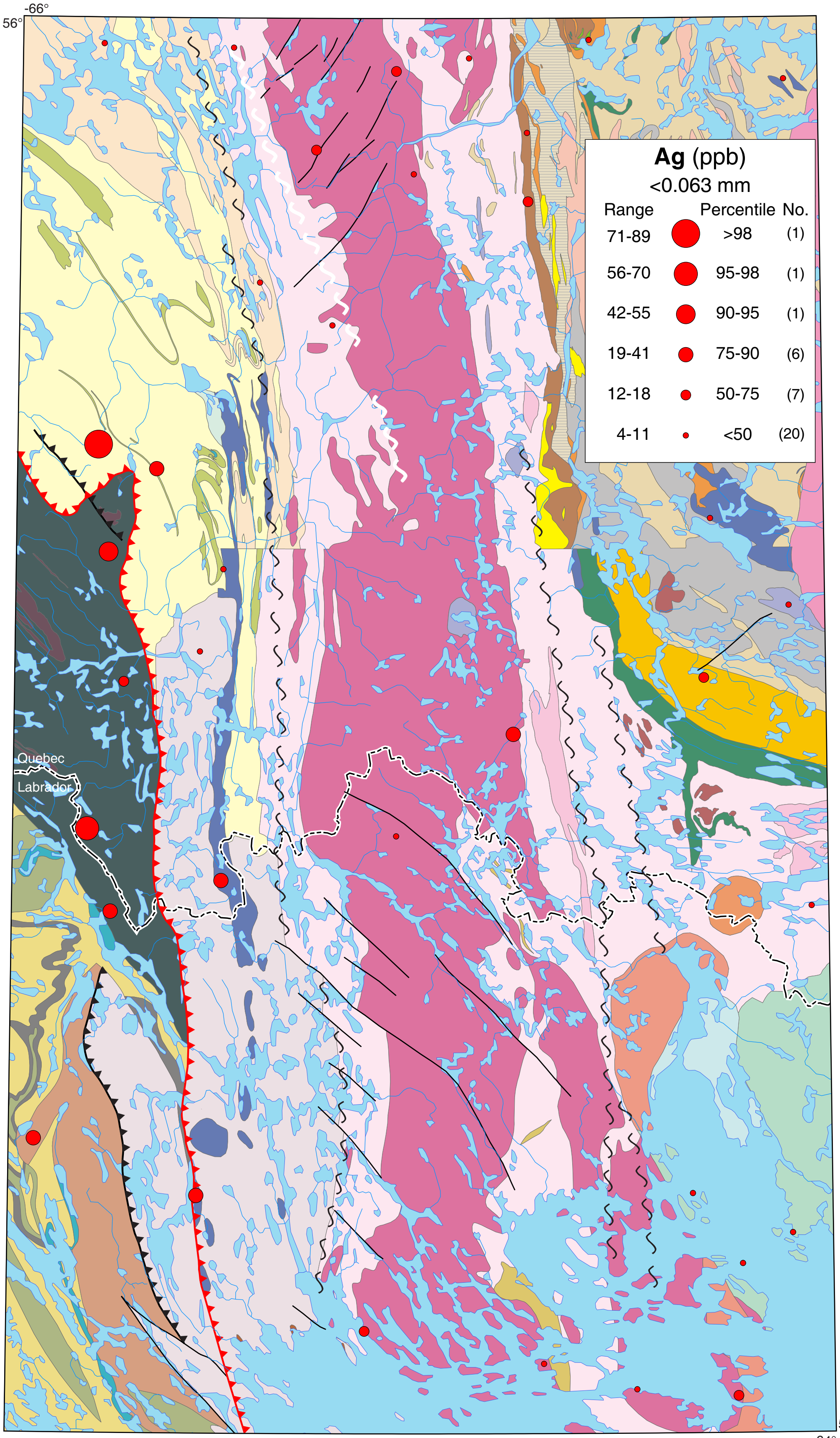
Spirito, W.A., McClenaghan, M.B., Plouffe, A., McMartin, I., Campbell, J.E., Paulen, R.C., Garret, R.G., and Hall, G.E.M., 2011. Till sampling and analytical protocols for GEM Projects: from field to Archive; Geological Survey of Canada, Open File 6850. doi:10.4095/288752

Veillette, J.J., Dyke, A.S., and Roy, M., 1999. Ice-flow evolution of the Labrador Sector of the Laurentide Ice Sheet: a review, with new evidence from northern Quebec; Quaternary Science Reviews, v. 18, p. 993–1019.

Wardle, R.J., Gower, C.F., Ryan, B., Gunn, G.A.G., James, D.T., and Kerr, A., 1997. Geological map of Labrador; Geological Survey of Newfoundland and Labrador, Map 97-07, scale 1:1 000 000.

Wardle, R.J., James, D.T., Scott, D.J., and Hall, J., 2002. The southeastern Churchill Province: synthesis of a Paleoproterozoic transpressional orogeny; Canadian Journal of Earth Sciences, v. 39, p. 639–663.

APPENDIX D. Proportional dot maps of geochemical data in the <0.063 mm fraction of till samples from the south Core Zone



Map 1. Proportional dot map of Ag (aqua regia/ICP-MS) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.

MESOPROTEROZOIC
- 1225–1275 Ma Seal Lake group
- 1420 Ma Mistastin granite
- 1460 Ma Michikamats granite
- 1460 Ma Michikamau anorthosite
- 1479.9 +12.6/-5.4 Ma Juillet syenite

PALEOPROTEROZOIC

NEW QUEBEC OROGEN
- crossbedded arkose, conglomerate

Laporte Zone
- banded calc-silicate ± marble
- amphibolite ± metabasalt
- greywacke, shale, biotite schist
- ms-sil-gp quartzo-feldspathic gneiss

Doublet Zone
- peridotite, gabbro
- basalt, mafic pyroclastic rocks

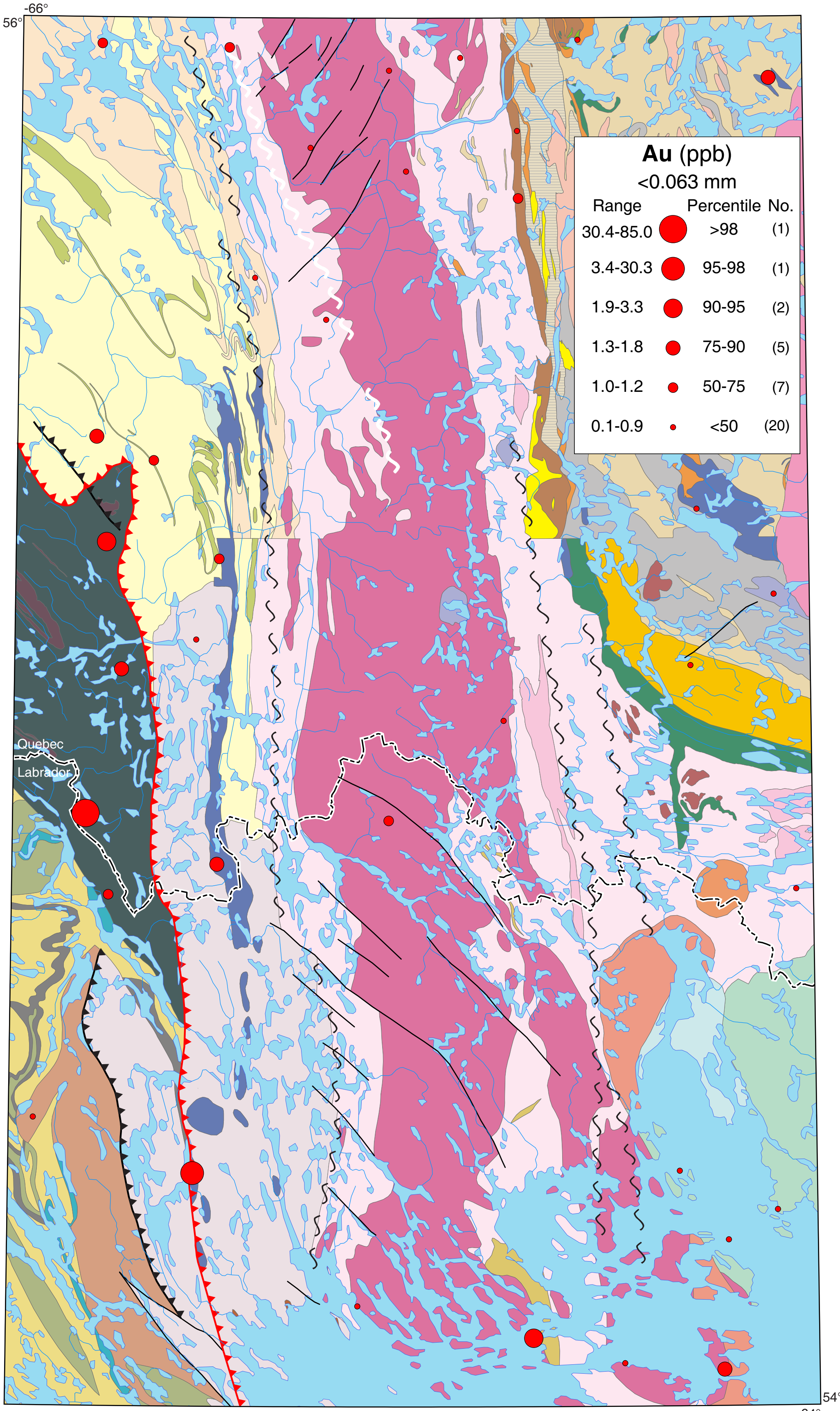
LABRADOR TROUGH (ca. 2.1–1.88 Ga)

Schefferville Zone
- dolomite, chert
- basalt, mafic pyroclastic rocks
- ironstone, quartzite
- shale, siltstone, sandstone

CORE ZONE
- granite (Dumans & Mistinibi)
- 1810–1837 Ma mzgr-charnockite (De Pas)
- volcano-sedimentary rocks (Atshakash)
- banded quartzofeldspathic (Hutte Sauvage)
- mafic metavolcanic rocks (Ntshuku)
- ca 2.3 Ga porphyritic granite (Pallatin)
- bt ± hb gneiss (George Complex)
- 2480±11 Ma mylonitic tonalite (Lac Zeni)
- amphibolite (Lac Zeni)

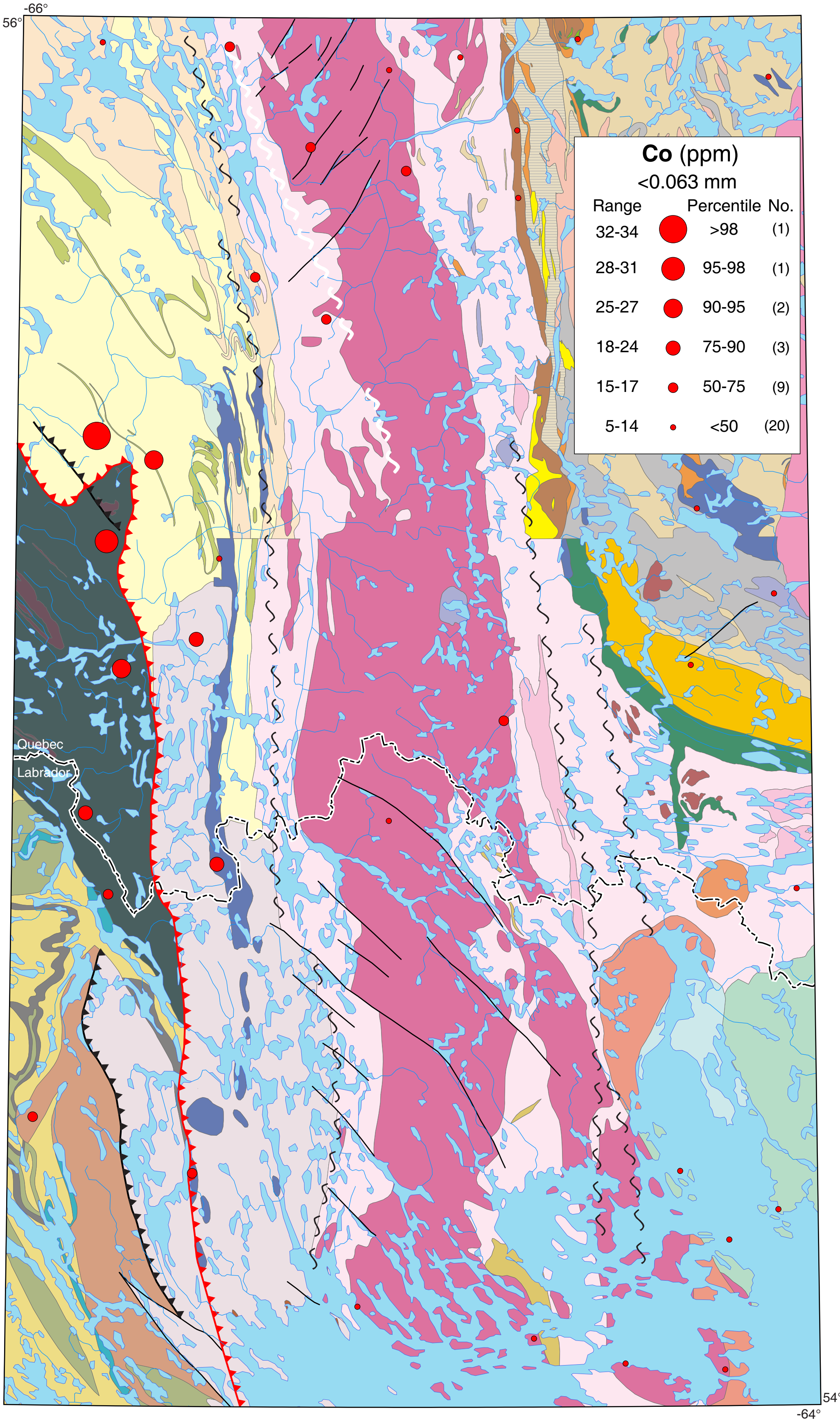
ARCHEAN / PALEOPROTEROZOIC

CORE ZONE
- monzonite, granite (Lac Cabot)
- diorite, monzodiorite, quartz monzonite
- metagabbro
- paragneiss (Mistinibi)
- unsubdivided, undated orthogneiss
- granite, dated locally at 2571±6 Ma
- heterogeneous orthogneiss, dated locally at ca. 2.6 Ga
- orthogneiss, dated locally at 2776±7 Ma
- supracrustal rocks (Overflow)
- supracrustal rocks (Lobstick)
- regional-scale shear zone
- annealed straight gneiss
- thrust fault
- brittle fault, lineament



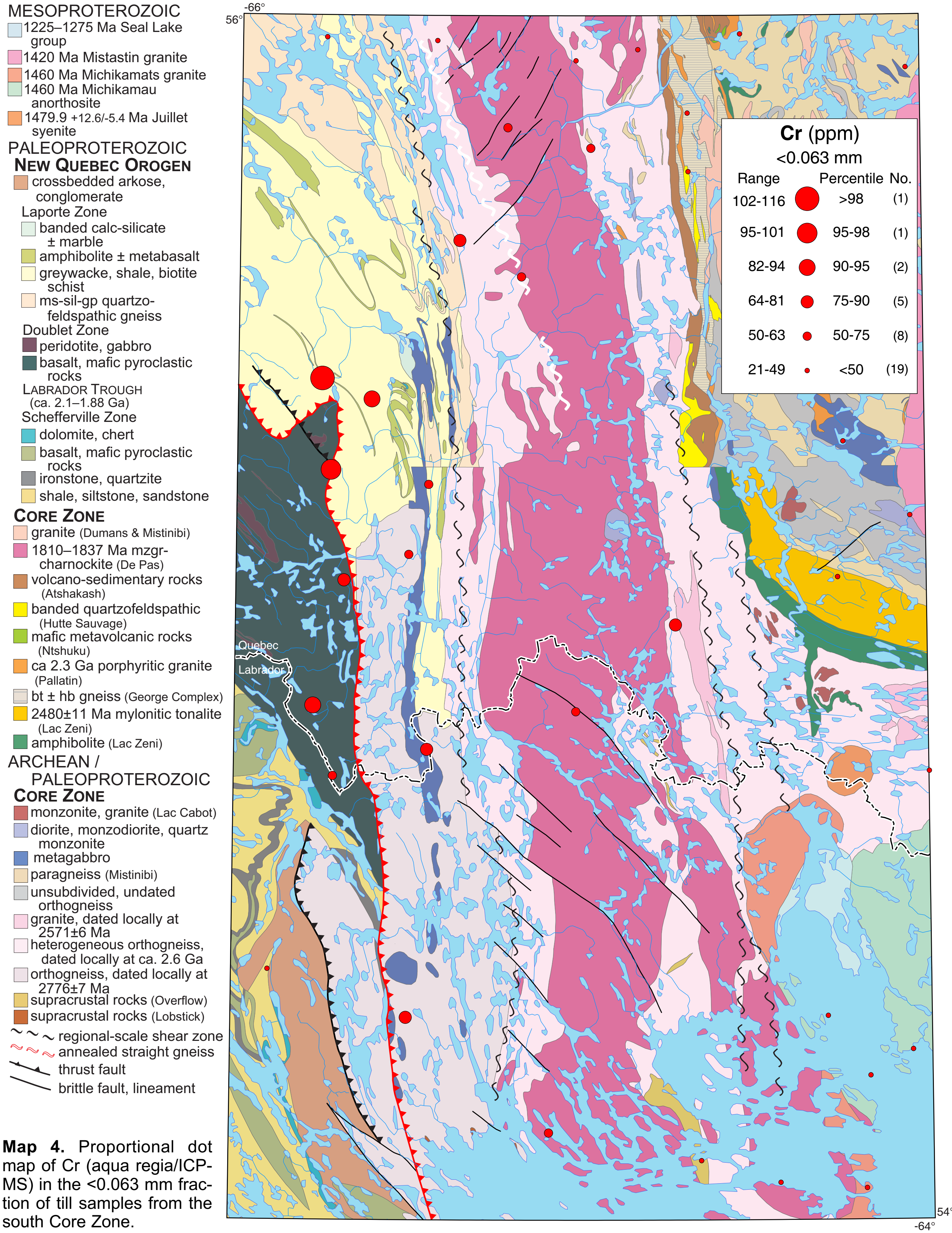
Map 2. Proportional dot map of Au (aqua regia/ICP-MS) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



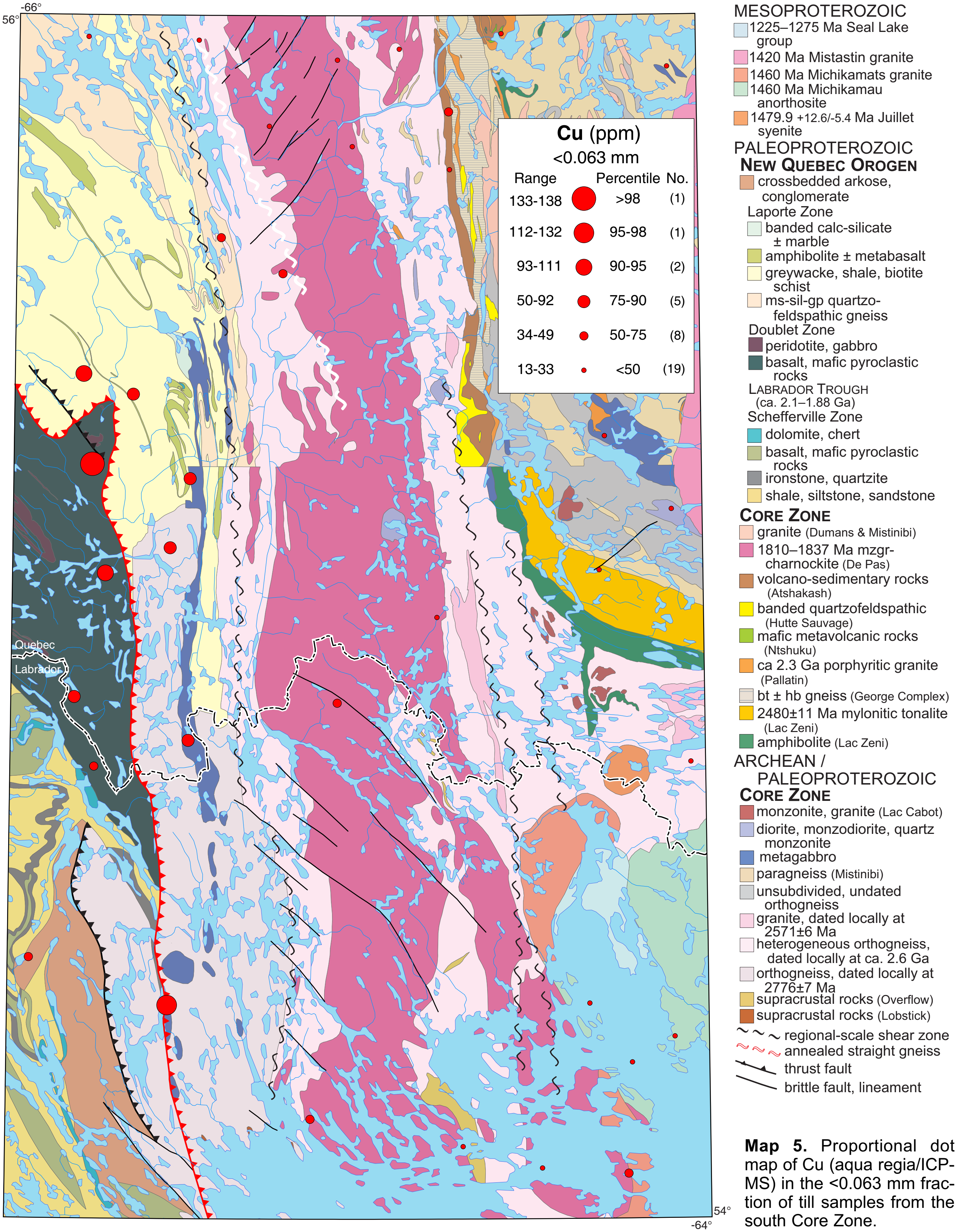
Map 3. Proportional dot map of Co (aqua regia/ICP-MS) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



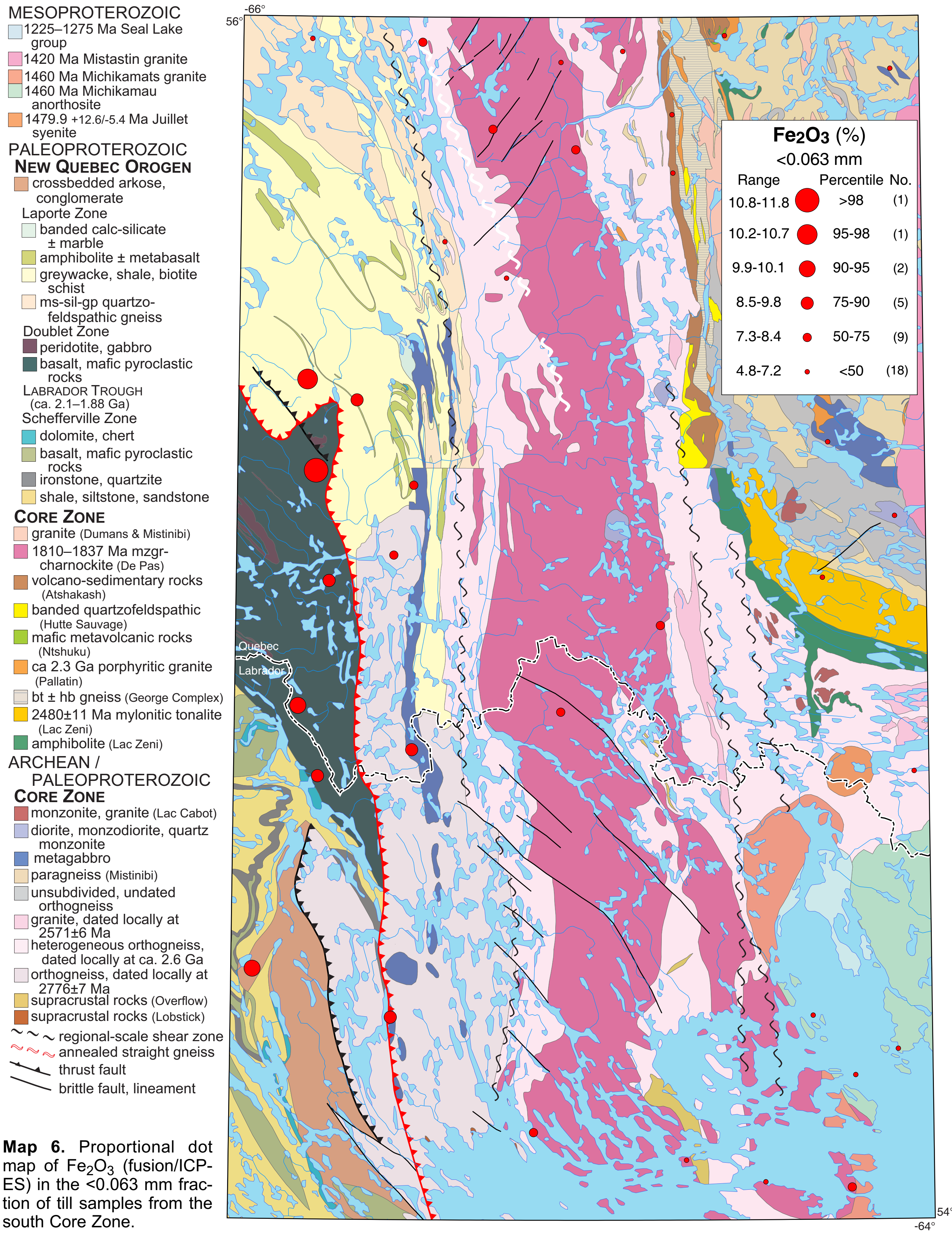
Map 4. Proportional dot map of Cr (aqua regia/ICP-MS) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



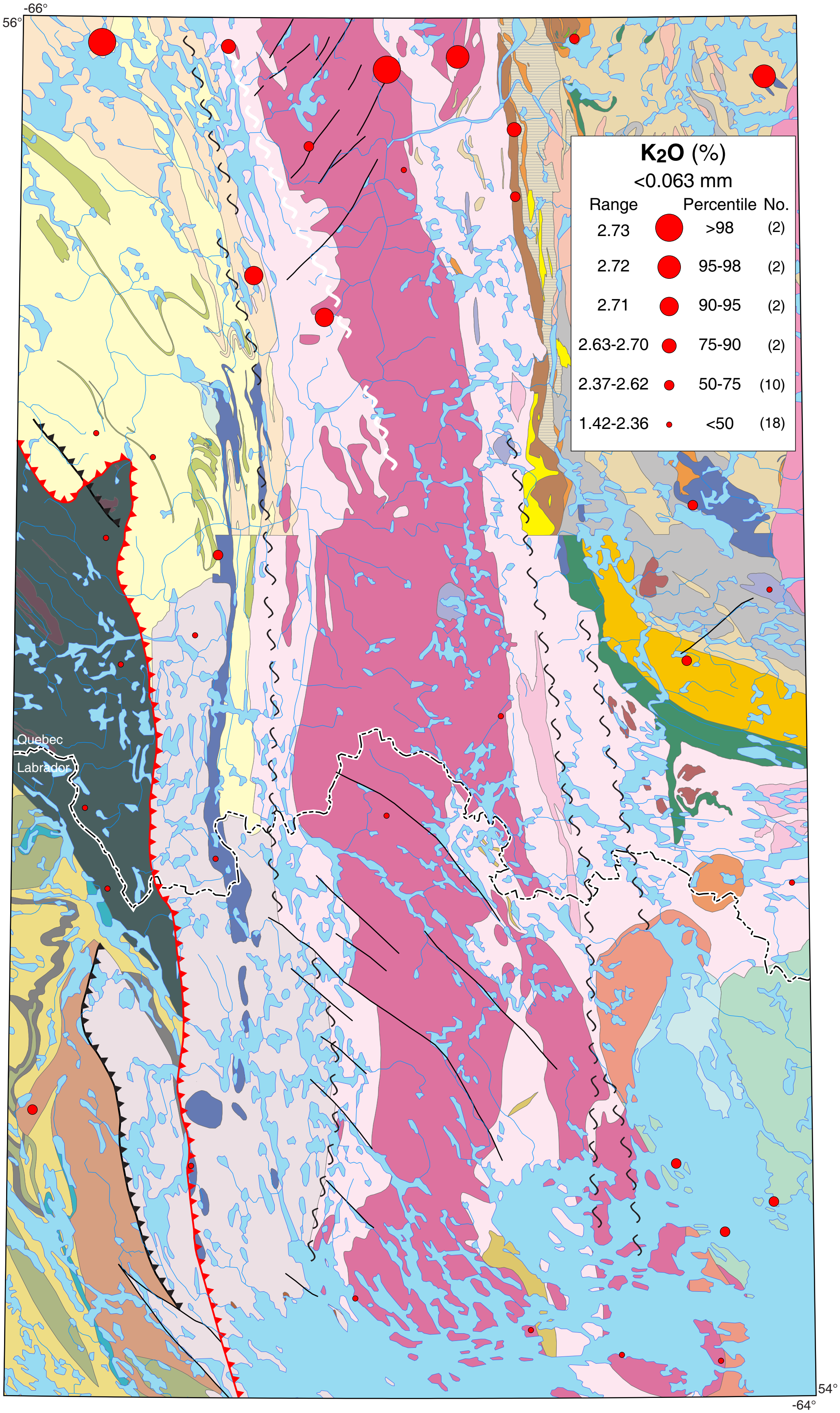
Map 5. Proportional dot map of Cu (aqua regia/ICP-MS) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



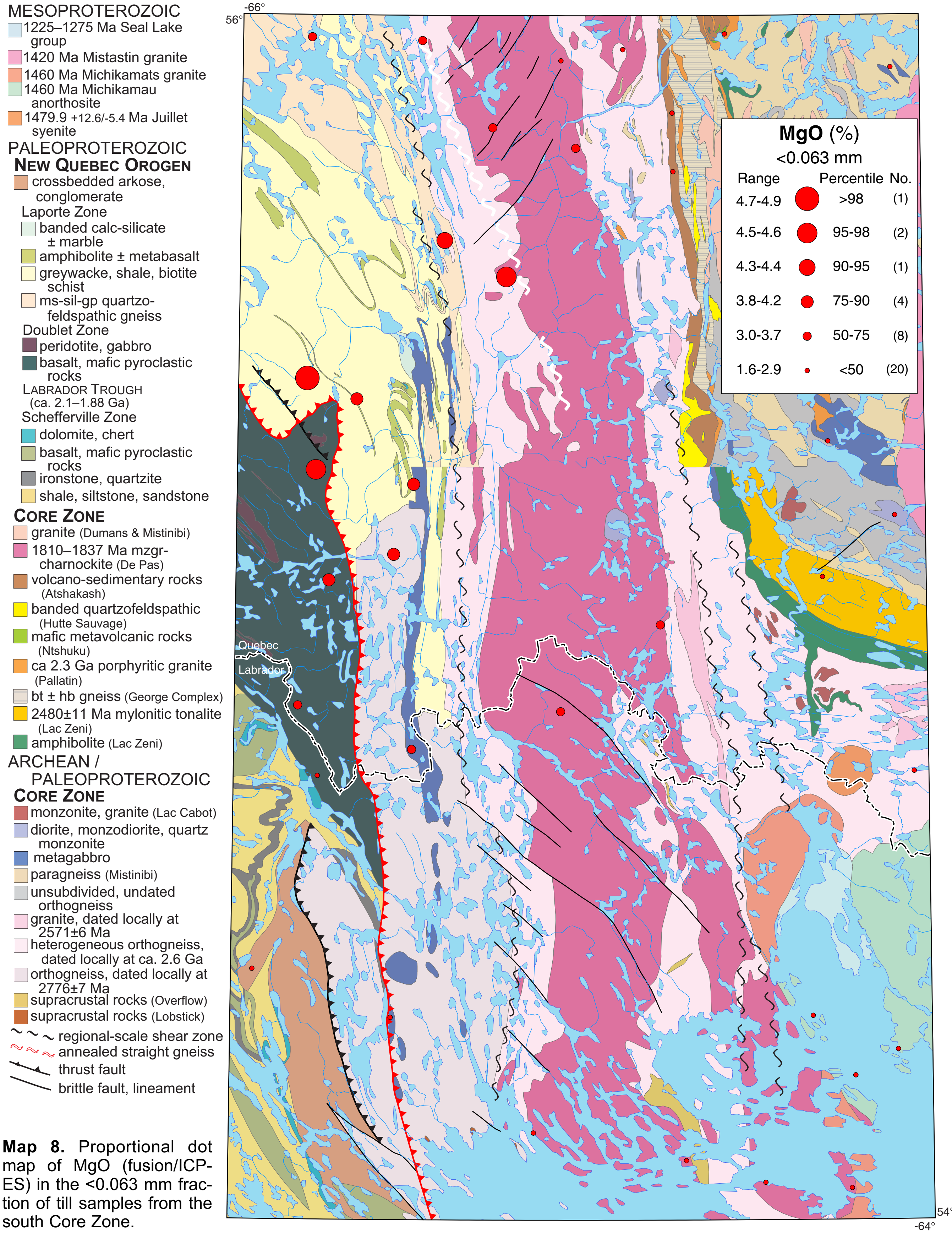
Map 6. Proportional dot map of Fe_2O_3 (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



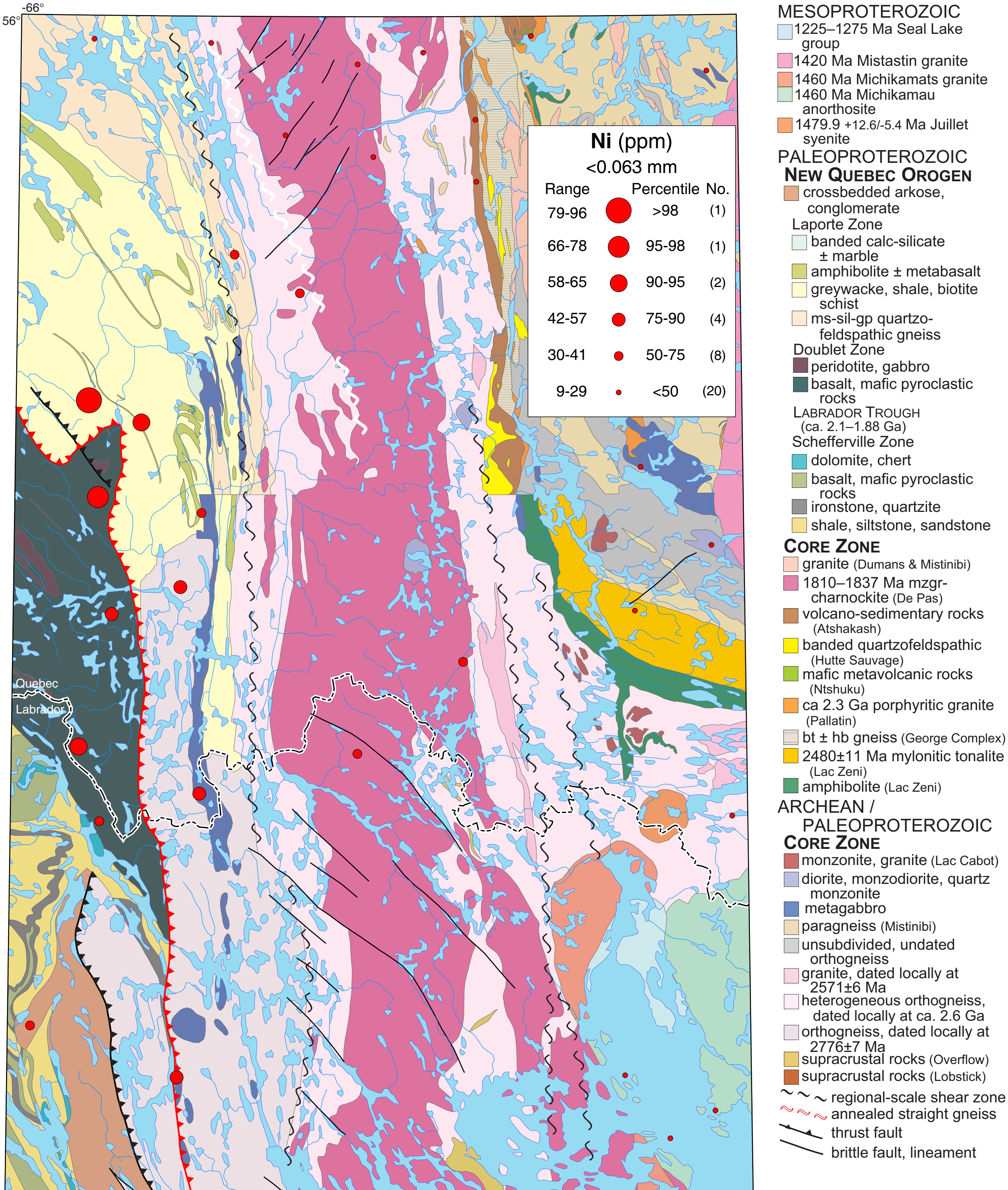
Map 7. Proportional dot map of K_2O (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



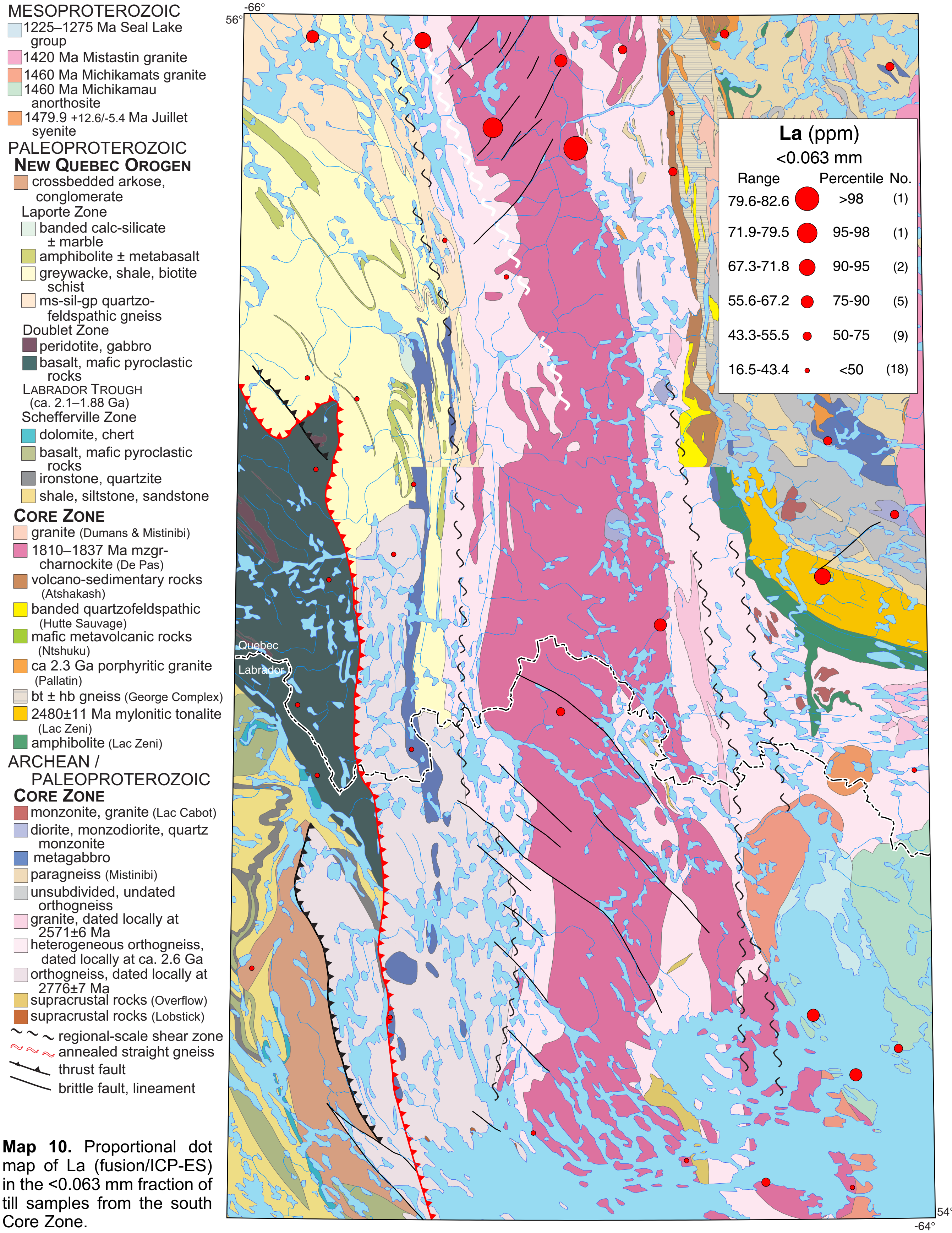
Map 8. Proportional dot map of MgO (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



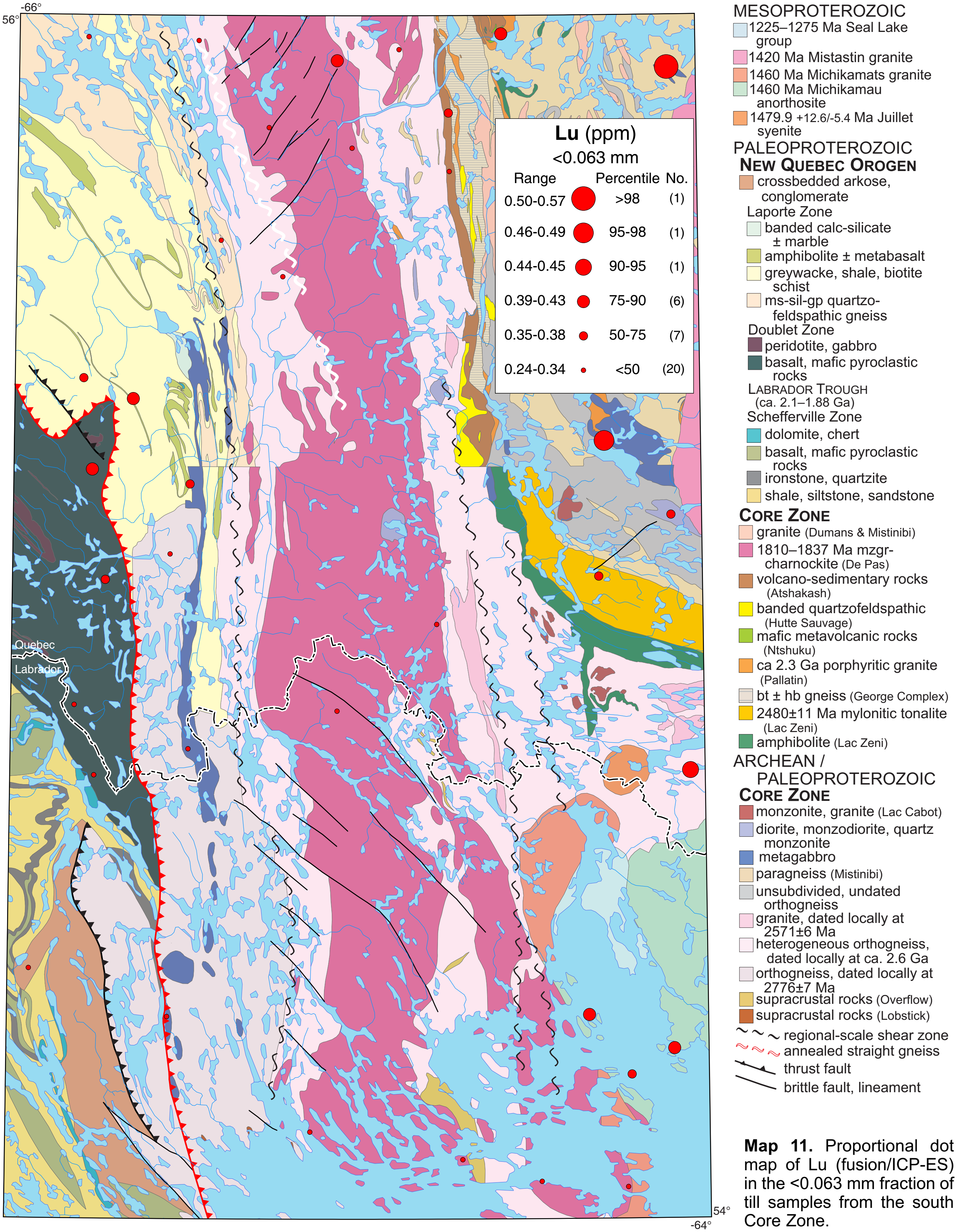
Map 9. Proportional dot map of Ni (aqua regia/ICP-MS) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



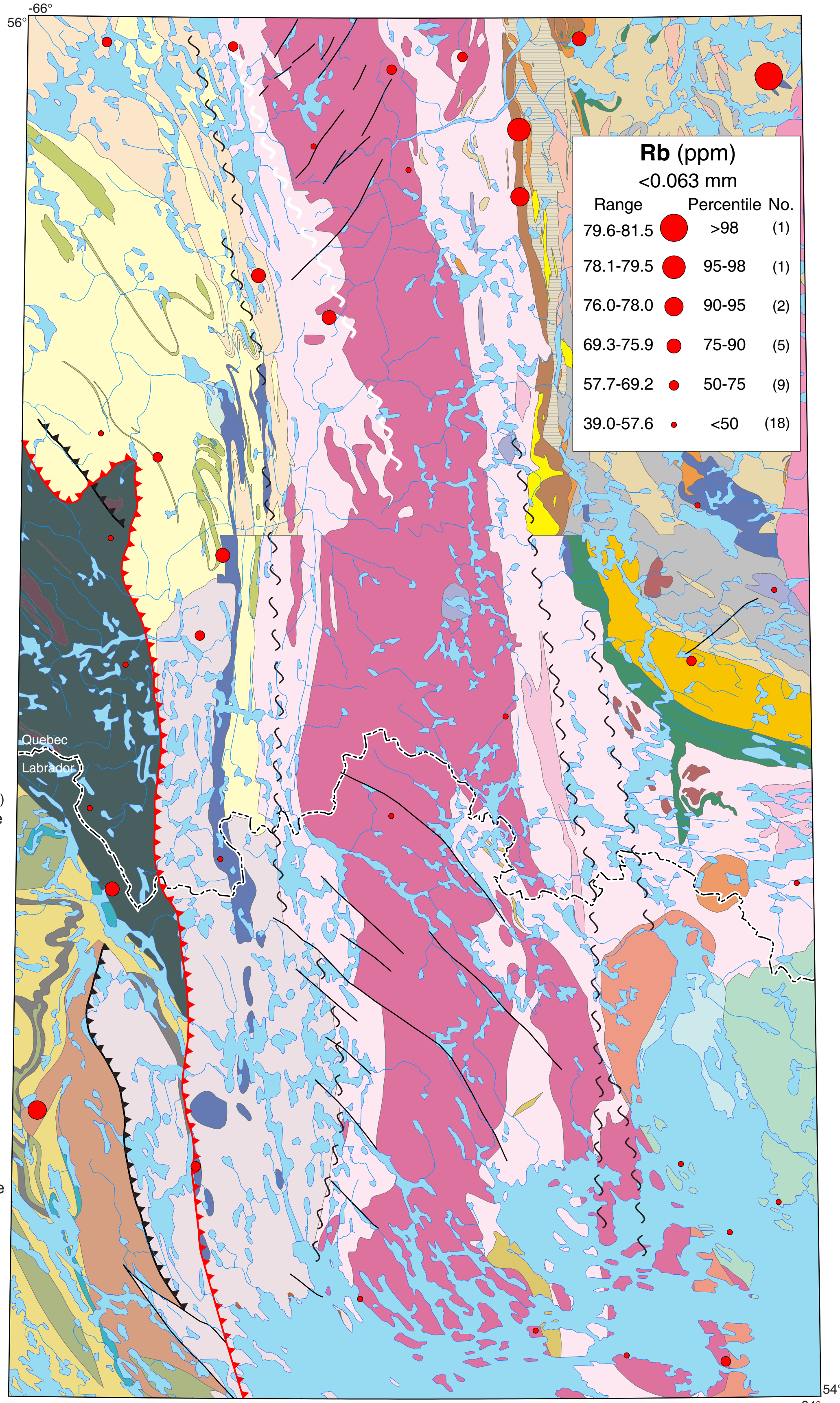
Map 10. Proportional dot map of La (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



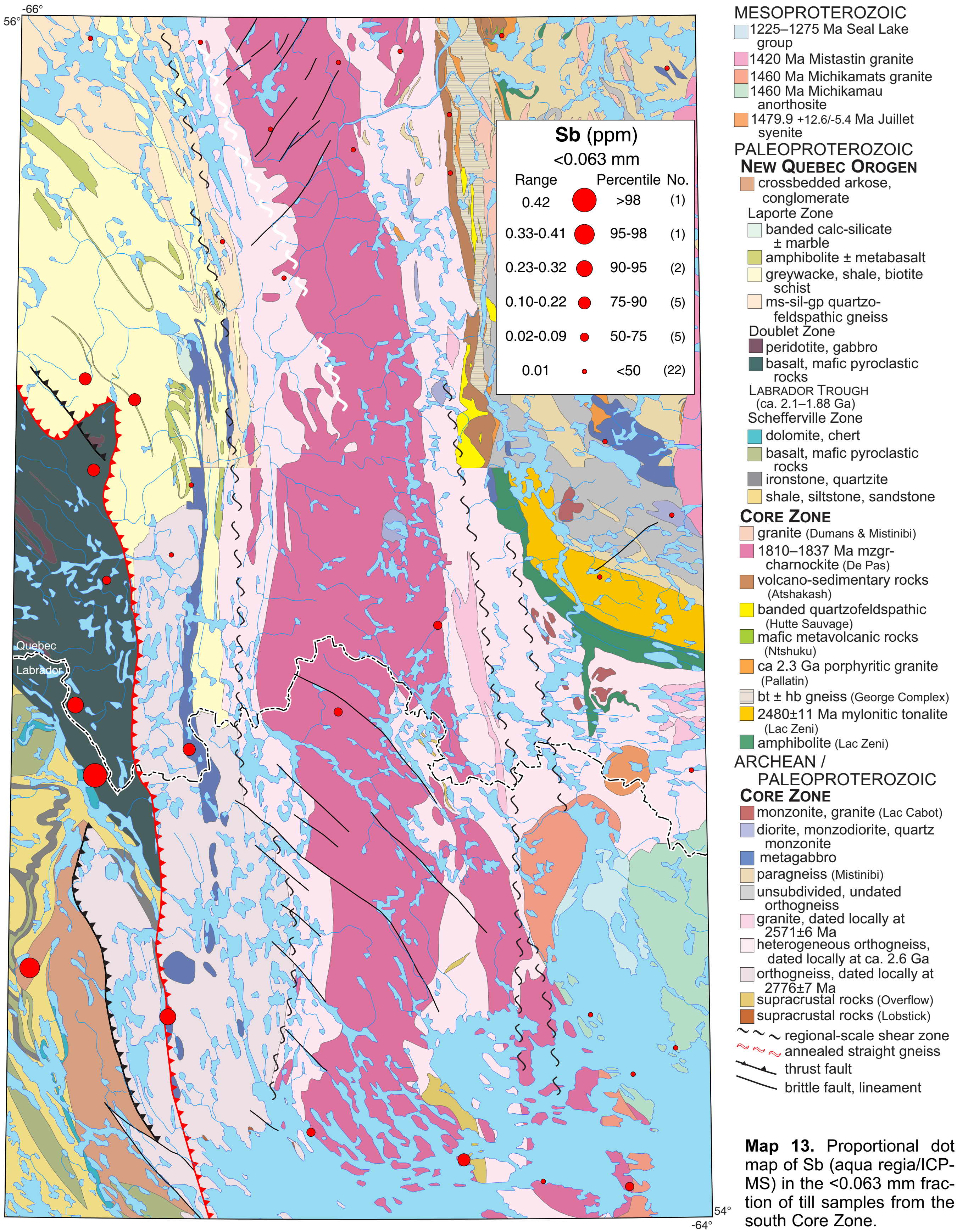
Map 11. Proportional dot map of Lu (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



Map 12. Proportional dot map of Rb (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



Map 13. Proportional dot map of Sb (aqua regia/ICP-MS) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.

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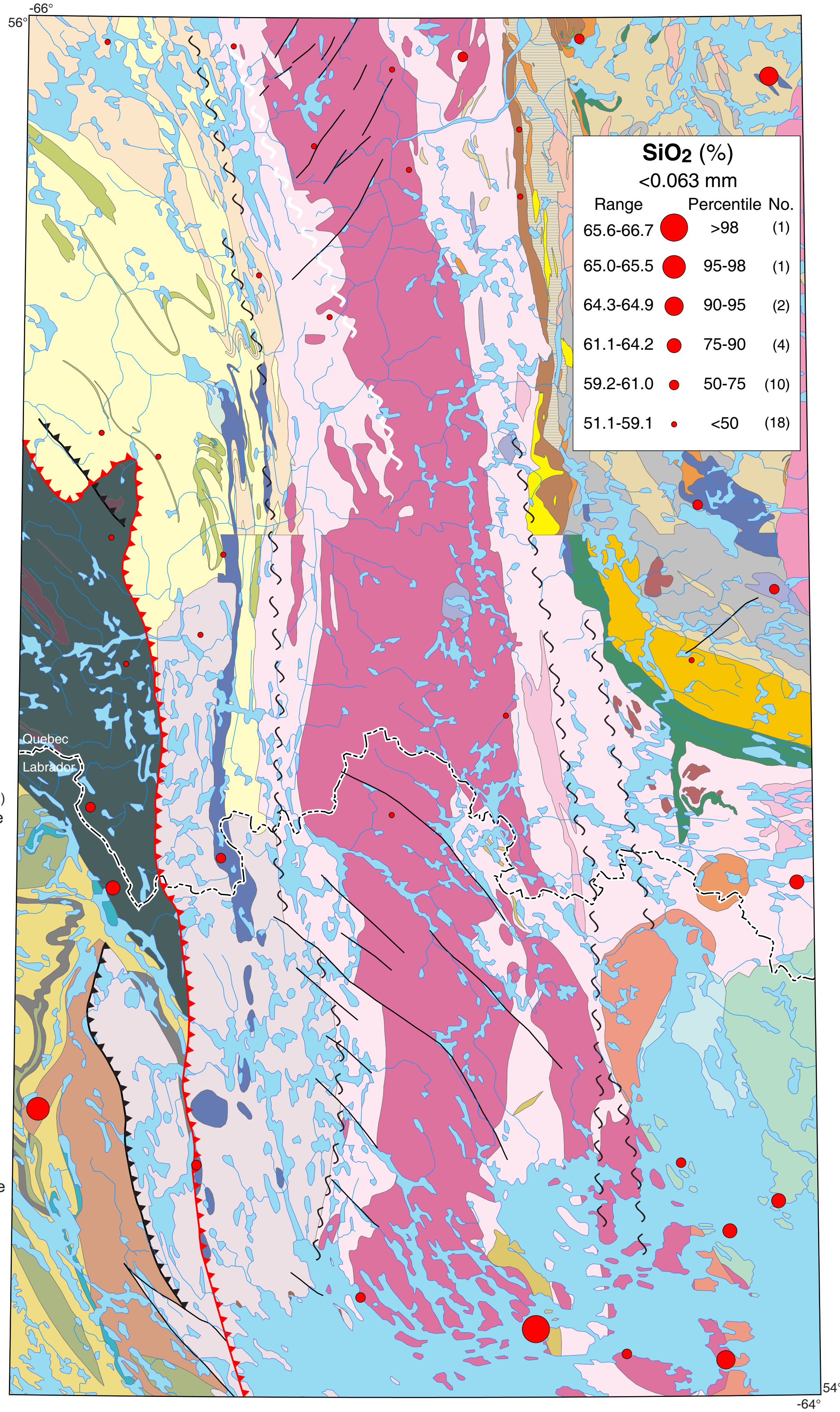
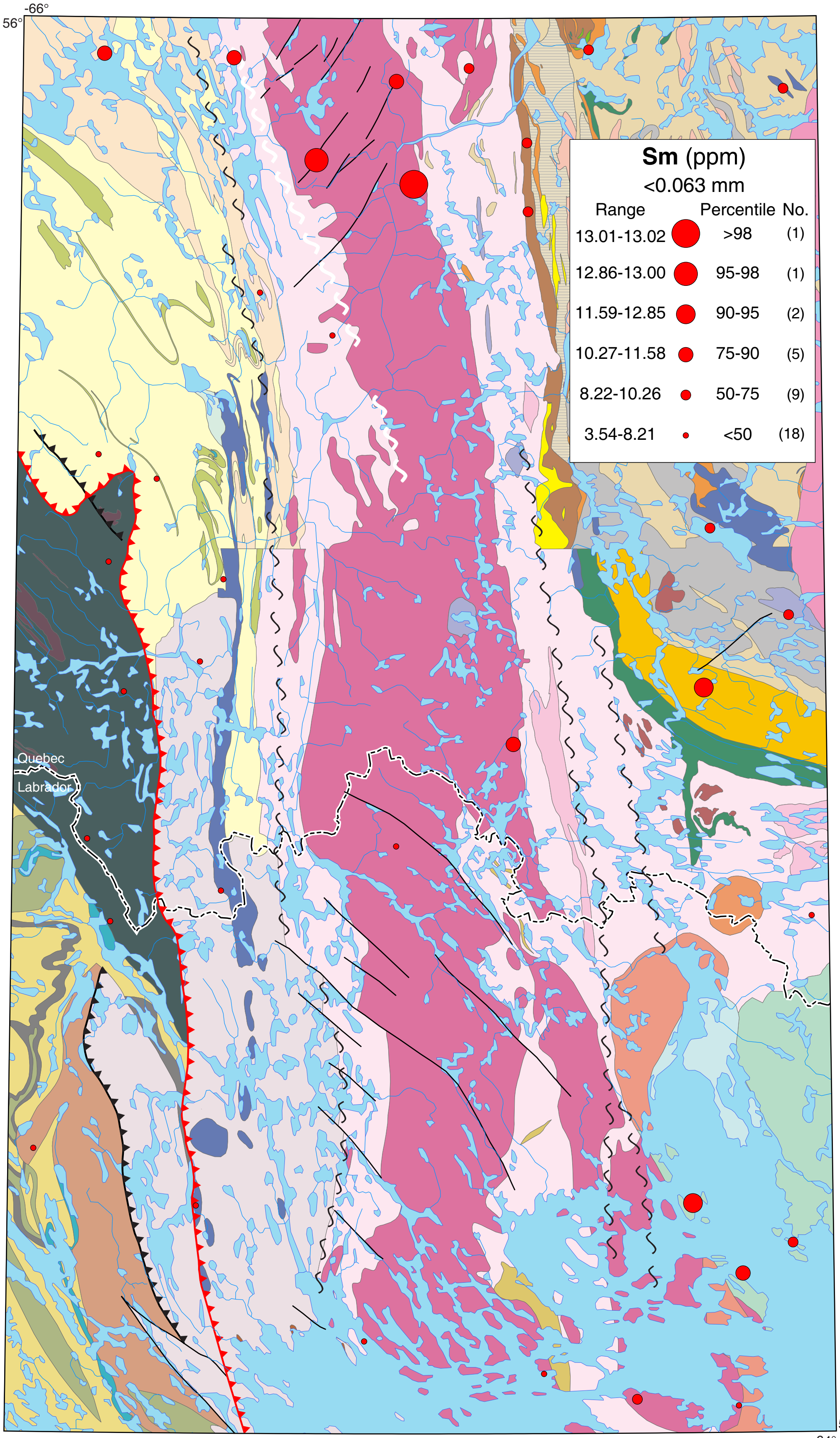


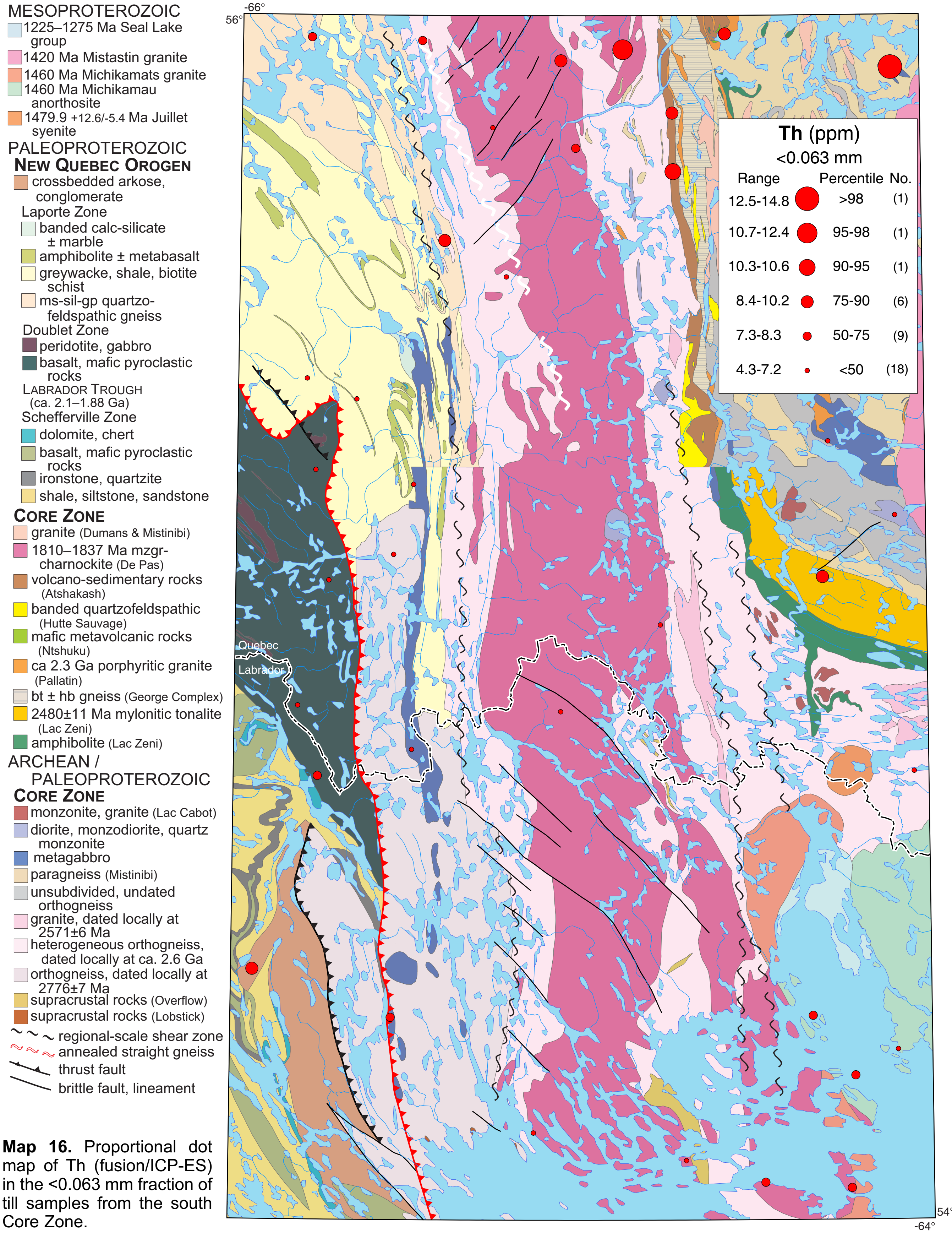
Map 14. Proportional dot map of SiO_2 (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



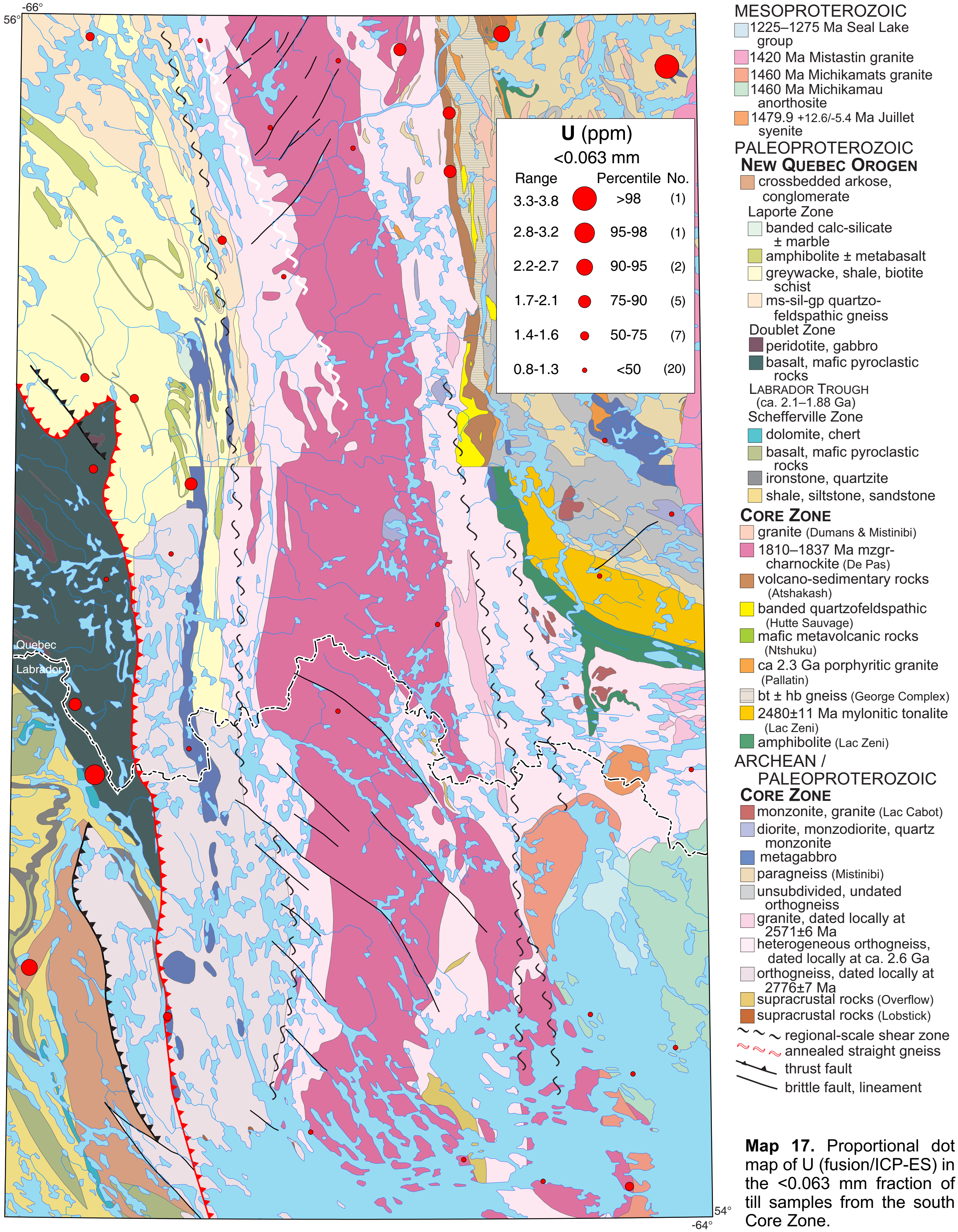
Map 15. Proportional dot map of Sm (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



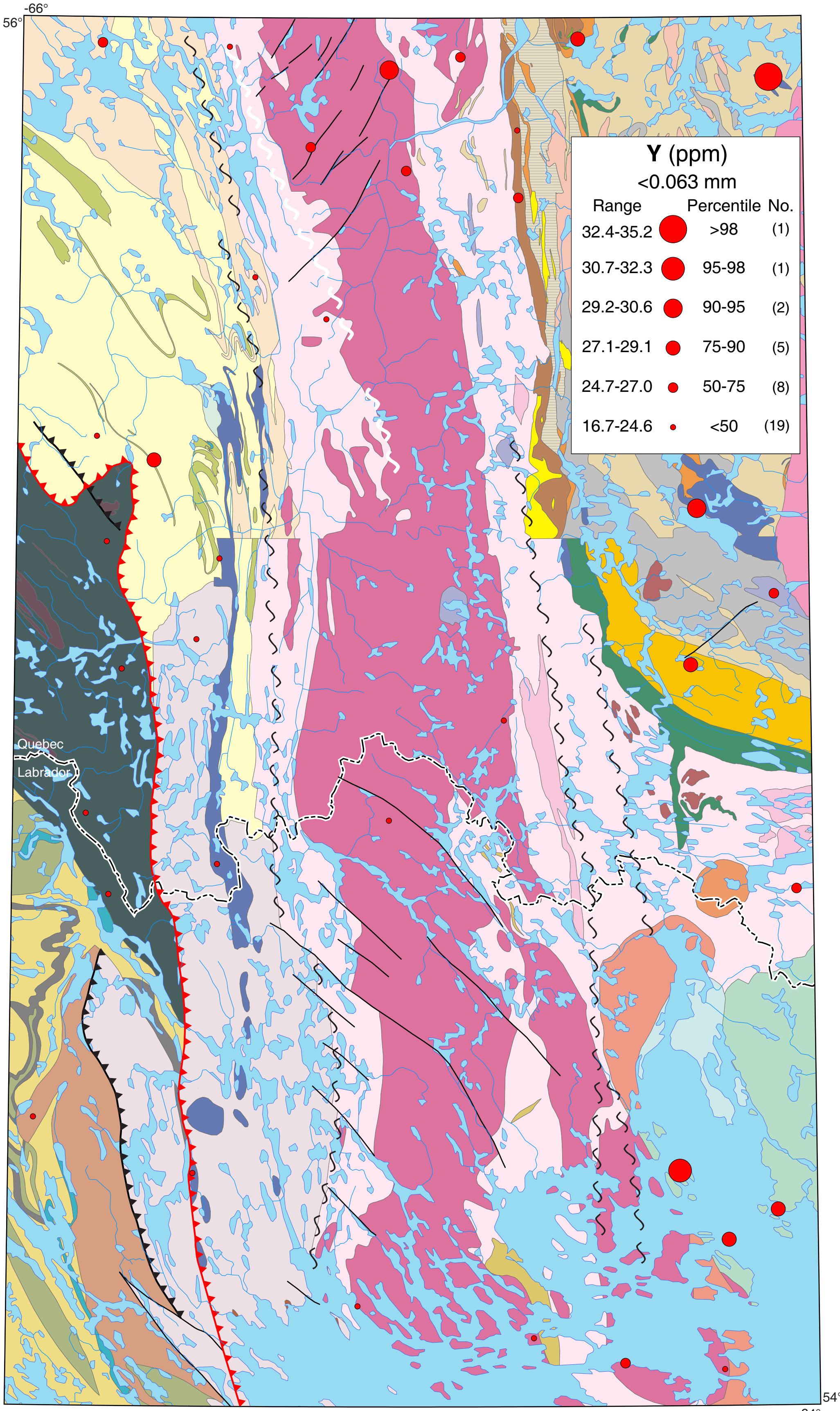
Map 16. Proportional dot map of Th (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



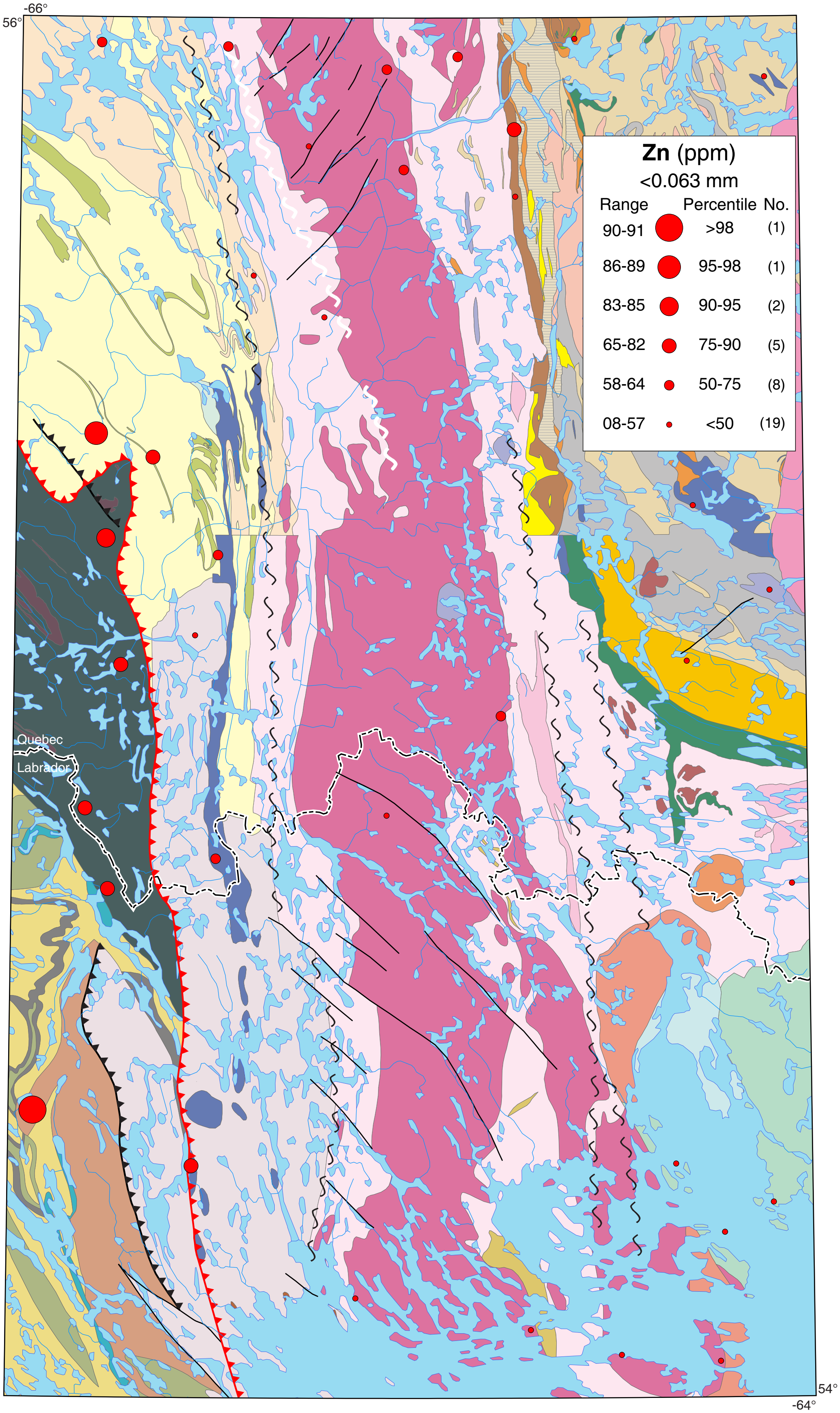
Map 17. Proportional dot map of U (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



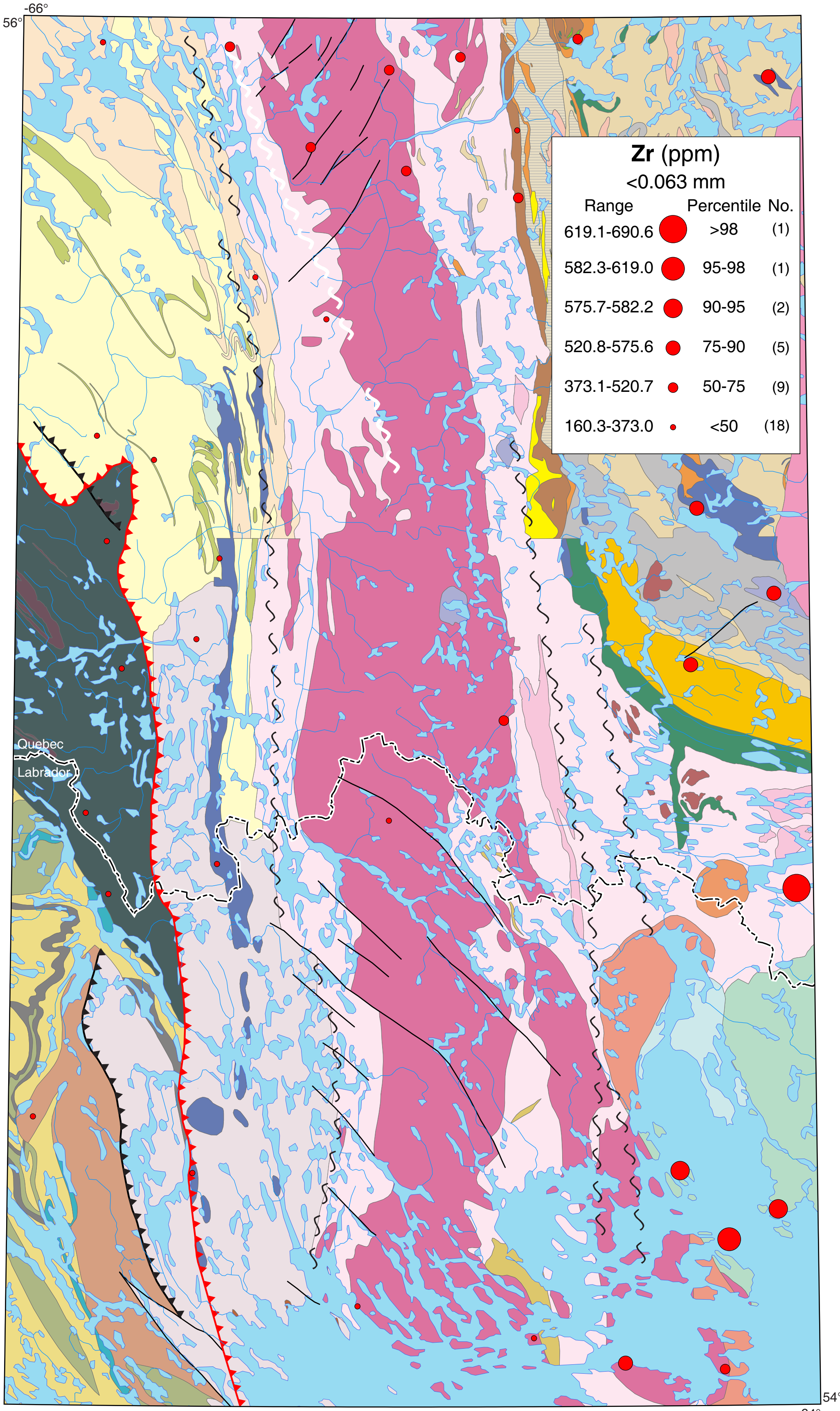
Map 18. Proportional dot map of Y (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



Map 19. Proportional dot map of Zn (aqua regia/ICP-MS) in the <0.063 mm fraction of till samples from the south Core Zone.

Appendix D continued.



Map 20. Proportional dot map of Zr (fusion/ICP-ES) in the <0.063 mm fraction of till samples from the south Core Zone.