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GEOLOGICAL SURVEY OF CANADA — COMMISSION GÉOLOGIQUE DU CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES
MINISTÈRE DE L'ÉNERGIE DES MINES ET DES RESSOURCES

Airborne Geophysical Survey

of the

Chalk River, AECL Research Area

Ontario
1992

NTS 31 K/3d

Contents include gamma ray spectrometric, VLF and magnetic colour maps, flight path map and accompanying stacked profiles

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GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA
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AIRBORNE GEOPHYSICAL SURVEY

In 1992, an airborne geophysical survey was commissioned by the Siting Task Force (STF) Secretariat of the Department of Energy and Mines and flown by the Geological Survey of Canada (GSC) in the Chalk River area of Ontario. The area surveyed is shown on the index map. Gamma-ray spectrometric, VLF electromagnetic and total field magnetic data were recorded to assist in interpreting the geology of the area. The survey will also provide a background radiation baseline for the area prior to long term storage of low-level waste material in a waste management facility.

All data were sampled at one second intervals. The airborne gamma-ray measurements were made using a 256 channel spectrometer, with twelve 102 x 102 x 406 mm NaI(Tl) detectors. The magnetic data were recorded using a Geometrics model G-803 proton precession magnetometer and the VLF electromagnetic data using a Hertz Totem 1A system. The GSC Skyvan aircraft was flown at a mean terrain clearance of 125 m at an average ground speed of 190 km/h. The flight lines were flown in a north-south direction with a line spacing of 150 m.

The airborne data are presented as a set of colour maps and stacked profiles at 1:25,000 scale. Also included is a map of the known bedrock geology of the area taken from Thomas and Hayles (1988) and a quaternary map adapted from Gadd (1962) and Thomas and Dixon (1988).

The colour maps (with the flight path of the aircraft superimposed) consist of the following:

1) A **Total Air-absorbed Dose Rate** map due to man-made and natural sources of radiation,
2) A **Natural Air-absorbed Dose Rate** map due solely to natural sources of radiation,
3) A **Man-Made Air-absorbed Dose Rate** map from man-made sources of radiation. These man-made sources include argon-41, cobalt-60 and cesium-137,
4) A **Ground Level ^{41}Ar Dose Rate** map due to the neutron activation of Argon-40 present in the atmosphere,
5) 3 maps of the ground concentration of **Potassium** (K), **Uranium** (eU) and **Thorium** (eTh),
6) 3 ratio maps - **eU/eTh**, **eU/K** and **eTh/K**,
7) A three component or **Ternary Radio-element** map combining the potassium, uranium and thorium data,
8) Two total field VLF maps, one superimposed on **Total Field VLF** profile data and the other on **Quadrature** VLF profile data,
9) A **Magnetic Total Field** map and **Calculated Magnetic Vertical Gradient** map.

In the booklet, the colour maps are followed by stacked profiles of the geophysical data for each flight line. A five point weighted average filter was applied to each parameter. In order to keep the same scale of 1:25,000 for the profiles and maps, the profiles for each flight line have been subdivided into two sections, north and south of latitude 46 02 30. Each segment shows the aircraft radar altimeter, the three radioelement ratios, the ground concentrations of potassium, uranium and thorium, the dose rate from natural sources of radiation, the total dose rate from man-made and natural radiation, the magnetic total field and the VLF total field and quadature components. The record numbers along the horizontal axis of each profile relates the data to the flight lines shown on the colour maps. The record numbers are structured on flight lines with each line starting with record one.

Gamma-ray Spectrometric Data

Potassium is measured directly from the 1460 keV gamma-ray photons emitted by ^{40}K whereas uranium and thorium are measured indirectly from gamma-ray photons emitted by daughter products in their decay chain Uranium is monitored using gamma-rays at approximately 1760 keV from ^{214}Bi and thorium from 2615 keV photons from ^{208}Tl. Since the gamma-ray emitters in the decay chain may not be in equilibrium with their respective parents, measurements of uranium and thorium are normally referred to as equivalent uranium and equivalent thorium i.e. eU and eTh. The energy windows used to monitor potassium, uranium and thorium are as follows:

Potassium	(^{40}K)	1360 - 1560 keV
Uranium	(^{214}Bi)	1660 - 1860 keV
Thorium	(^{208}Tl)	2410 - 2810 keV

The count rates in the potassium, uranium and thorium windows have been corrected for dead-time, ambient temperature and pressure changes and background radiation due to cosmic radiation, the radioactivity of the aircraft and radon decay products in the air. Additional corrections were made for gamma-ray spectral scattering in the ground, the air and the detectors as well as for deviations of terrain clearance from the planned survey altitude. Factor for converting the corrected airborne count rates to ground concentrations of potassium, uranium and thorium were determined from flights over a calibration range in the Ottawa area (Grasty et al, 1984). These factors are:

1 pct K	=	91.0 counts per second
1 ppm eU	=	9.1 counts per second
1 ppm eTh	=	7.0 counts per second

The natural air absorbed dose rate in nano-Grays per hour (nGy/h) was computed from the measured ground concentrations of potassium, uranium and thorium using the following relationship taken from Grasty et al (1984):

1 pct K	=	13.08 nGy/h
1 ppm eU	=	5.43 nGy/h
1 ppm eTh	=	2.69 nGy/h

The airborne data represent an average surface concentration which is influenced by varying amounts of outcrop, overburden, vegetation, soil moisture and surface water. A comparison of the quaternary map and the natural dose rate map shows the boggy and swampy area to be low in radioactivity. Areas of increased radioactivity generally correspond to the area with greater bedrock exposure. In built-up areas, such as the towns of Chalk River and Deep River, the airborne measurements will be affected by materials used for roads and house construction. This could explain the somewhat higher levels found in these communities. Similarly the slightly increased radiation levels found along the road from the community of Chalk river to the Chalk river site are probably related to the increased natural radioactivity of the road material and lack of trees which suppress the airborne count rates. The total radiation levels for the towns of Chalk River and Deep River were found to be at or below typical levels observed for adjacent surveys.

Examination of the airborne spectra in the eastern part of the survey block showed sources of man-made radiation as well as those due to natural radiation. These sources, associated with waste management facilities, were identified as ^{137}Cs and ^{60}Co and are identified on the radioactivity maps. An additional source of man-made radiation was due to ^{41}Ar emanating from the plant facilities. The total count rate, which records all gamma-rays above an energy of 400 keV was used to estimate the ground level dose rate due to all sources of man-made and natural radiation This was done by comparing the total count rate to the **Natural Dose Rate** calculated from potassium, uranium and thorium in the western part of the survey block where there are no sources of man-made radiation. From this comparison, a calibration constant was derived to convert the total count rate to nanoGrays per hour. This calibration constant was then applied to the total count rate for the entire survey area to produce a **Total Dose Rate** map from man-made and natural radiation

A comparison of the natural dose rate map with the dose rate map made from the total count data shows excellent agreement in the western part of the survey area where there is no man-made radiation. Because the gamma-ray spectral shapes of ^{41}Ar, ^{60}Co and ^{137}Cs are different from those of potassium, uranium and thorium, the total dose rate map could have considerable errors in areas where the man-made contribution is significant. For example, when flying through the ^{41}Ar plume the dose rate at ground level from ^{41}Ar would be much lower than at survey altitude where the plume is both above and below the aircraft. However, the total dose rate map provides some estimate of the overall radiation levels in the area. The total dose rate was used to produce a **Man-made Dose Rate** map by subtracting the natural dose rate due solely to natural sources of radiation from the total dose rate due to both man-made and natural radiation. This map also has similar limitations to the total dose rate map but clearly identifies the man-made sources of radiation.

An analysis of the airborne gamma-ray spectrum showed that the gamma-ray count rate due to ^{41}Ar could be separated from the measured spectrum. The energy windows used to monitor ^{41}Ar was 150 keV wide and centered on the 1290 keV peak of ^{41}Ar. ^{41}Ar has a small contribution into the nearby potassium window. This contribution was measured using a pure ^{41}Ar spectrum obtained previously over the Ottawa river. The contribution of potassium, uranium and thorium into the ^{41}Ar window was calculated from measurements over large concrete calibration pads with known concentrations of the three radioactive elements. The measured count rates in the ^{41}Ar window were then corrected for the contribution due to potassium, uranium and thorium using a simple stripping procedure. The corrected ^{41}Ar window data were used to calculate the **Ground Level ^{41}Ar Dose Rate** map assuming the gas was uniformly distributed in the air both above and below the aircraft.

The maps of natural radioactivity show some blanked out areas. These areas are places where the gamma-radiation from natural sources could not be separated from those due to man-made radiation. In some cases this was due to spectral distortion arising from the high count rate of ^{41}Ar. In other cases gamma-radiation from ^{60}Co which emits gamma-ray photons at 1390 keV was detected in the potassium window, resulting in errors in estimating the potassium concentration of the ground.

VLF Data

The primary electromagnetic field is generated by VLF communication stations. For this survey, the receiving coils were tuned to station NAA in Cutler Maine which transmits at a frequency of 24 0 kHz.

Anomalies reflect distortions in the primary field cause by a secondary electromagnetic field generated by eddy currents flowing in geological and man-made conductors. Anomalies produce positive peaks on the total field trace and are of the cross-over type (negative to positive) on the quadrature trace. Both parameters are plotted with positive deflections toward west. The profiles presented are the total field value (vector sum of the horizontal and vertical components) and the quadrature value (out-of-phase component). For the stacked profiles, the mean value or line average of the total field and quadrature component were removed along each flight line. The quadrature, which depends on the flight line direction, was inverted for lines flown from north to south.

The VLF-EM colour maps are gridded total field VLF data superimposed with the profile total field data for the first map and profile quadrature data for the second map. All the VLF data are plotted with a two second lag. The gridded data was produced by applying a twenty one point triangular filter to the profile data. This filtered data was then subtracted from the original data and the resultant total field data was then gridded. This effectively removed the long wave length response created by changing field stength and altitude.

Magnetic Data

The aeromagnetic data were acquired using an instrument with one (1) nT sensitivity. The magnetic data were corrected both manually and digitally for spikes, heading effects and diurnal variations. The magnetic and vertical gradient maps show changes in the magnetic characteristics of the underlying rock-types. In this area, the paragneiss, except for the diabase dykes, is the most magnetic unit and the gabbro-anorthosite the least magnetic.

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Thomas, M.D. and Hayles,J.G.
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Information regarding Open File 2638 may be obtained from:
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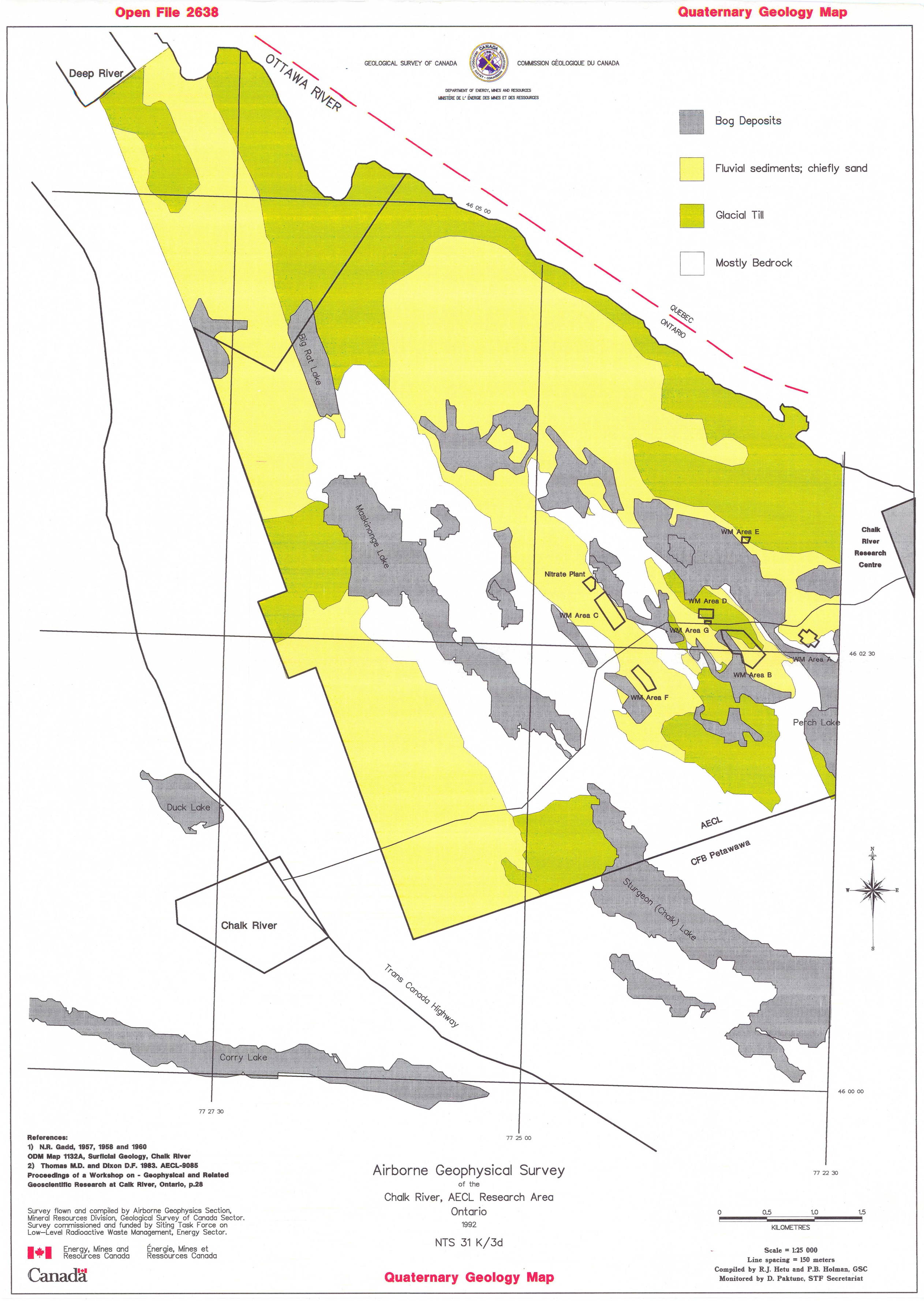
78 0	77 30	77 0	76 30
31 K/05	31 K/06	31 K/07	46 30
31 K/04	31 K/03	31 K/02	46 15
31 F/13	31 F/14	31 F/15	46 0
			45 45

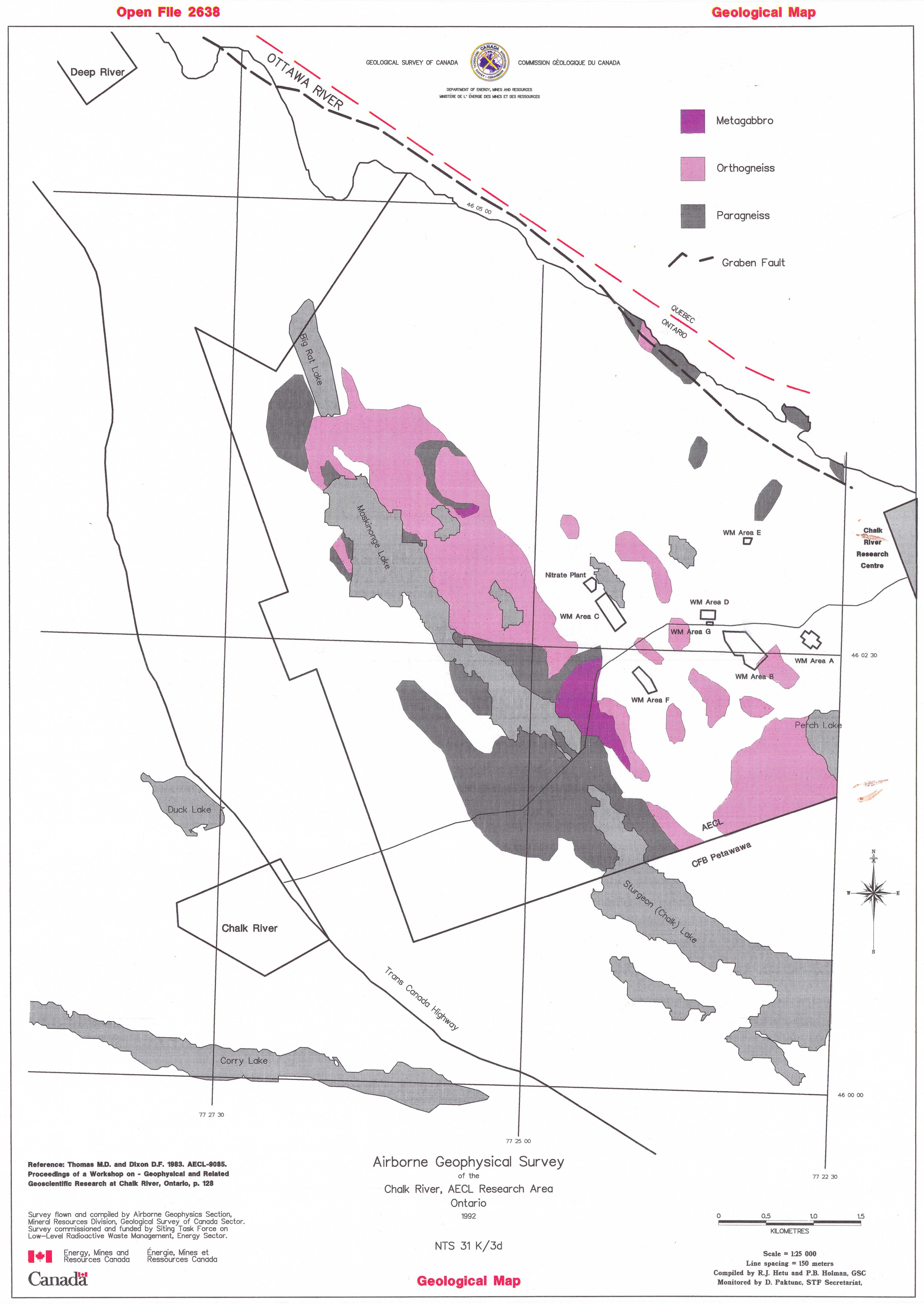
Index Map

Open File 2638 — Quaternary Geology Map



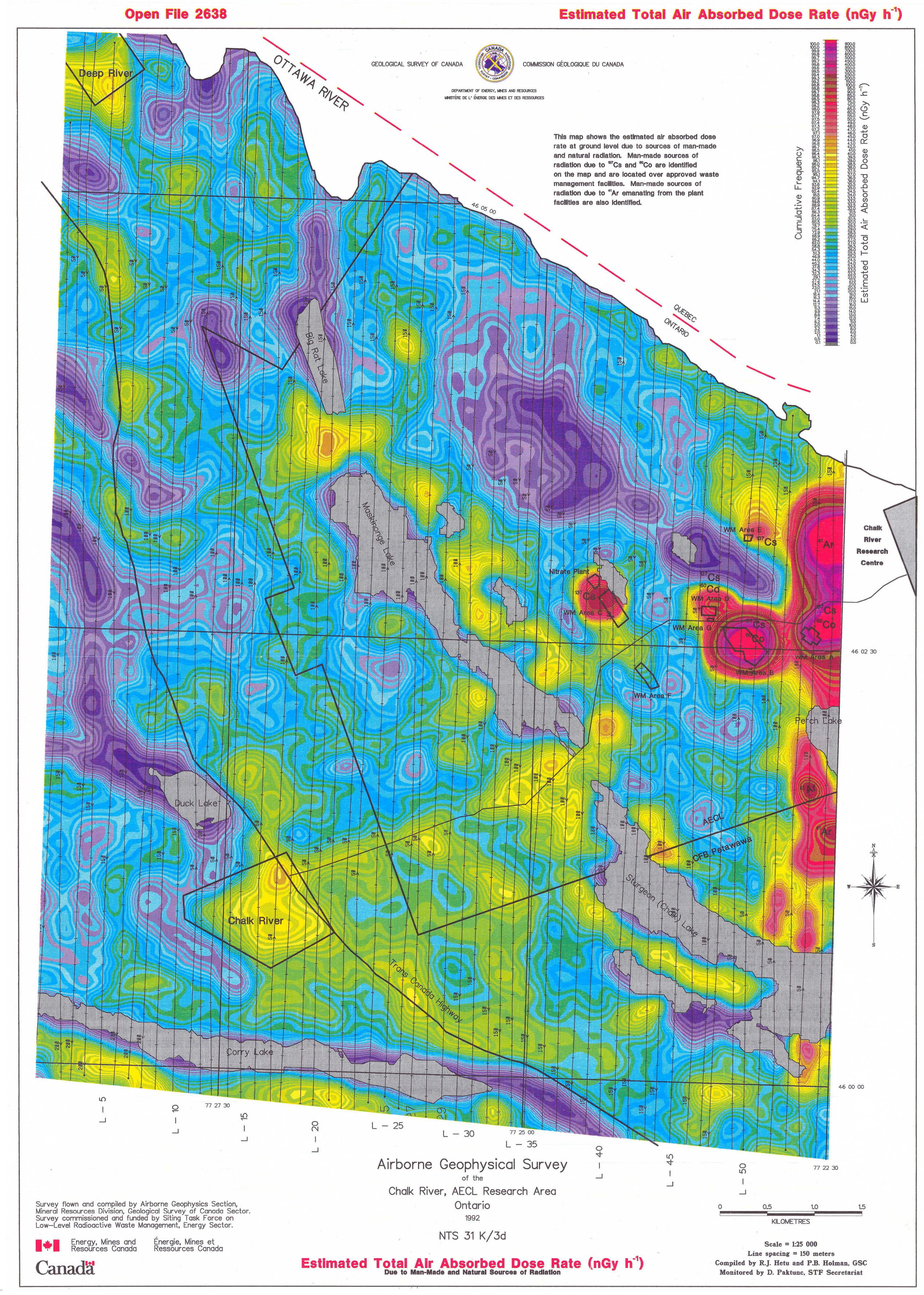
Quaternary Geology Map

Open File 2638 — Geological Map



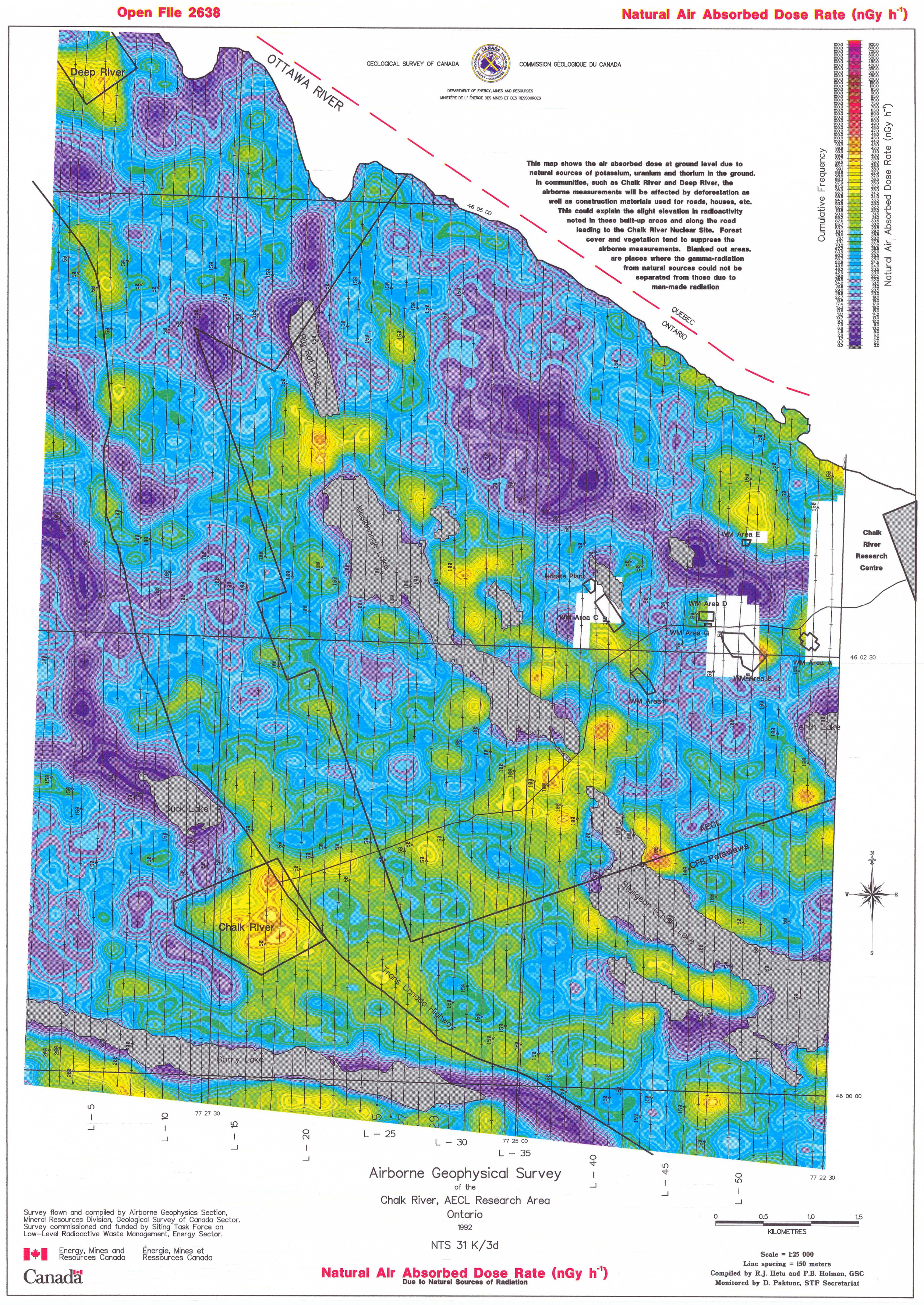
Geological Map

Open File 2638 — Estimated Total Air Absorbed Dose Rate (nGy h^{-1})



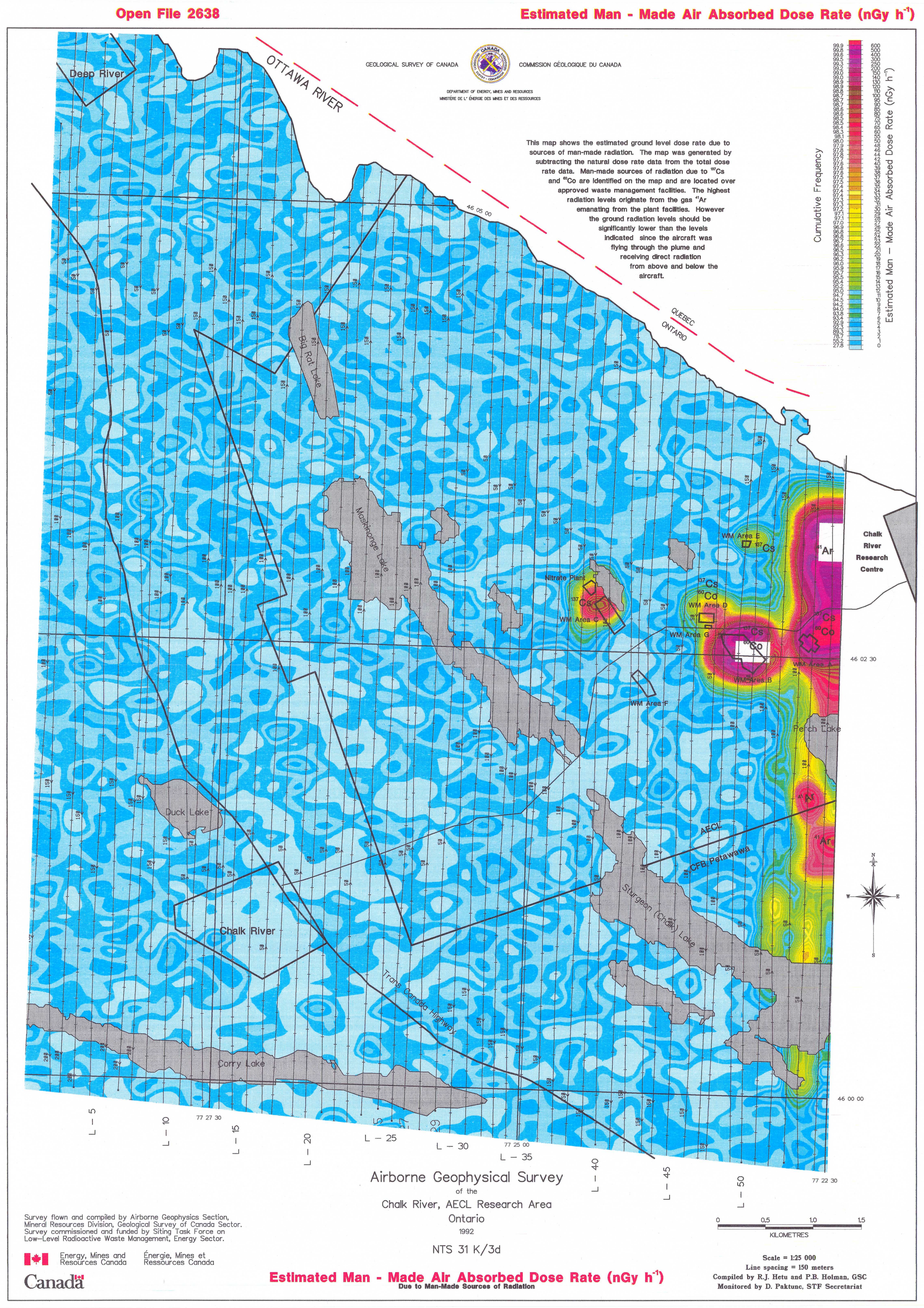
Estimated Total Air Absorbed Dose Rate (nGy h^{-1})

Open File 2638 — Natural Air Absorbed Dose Rate (nGy h^{-1})



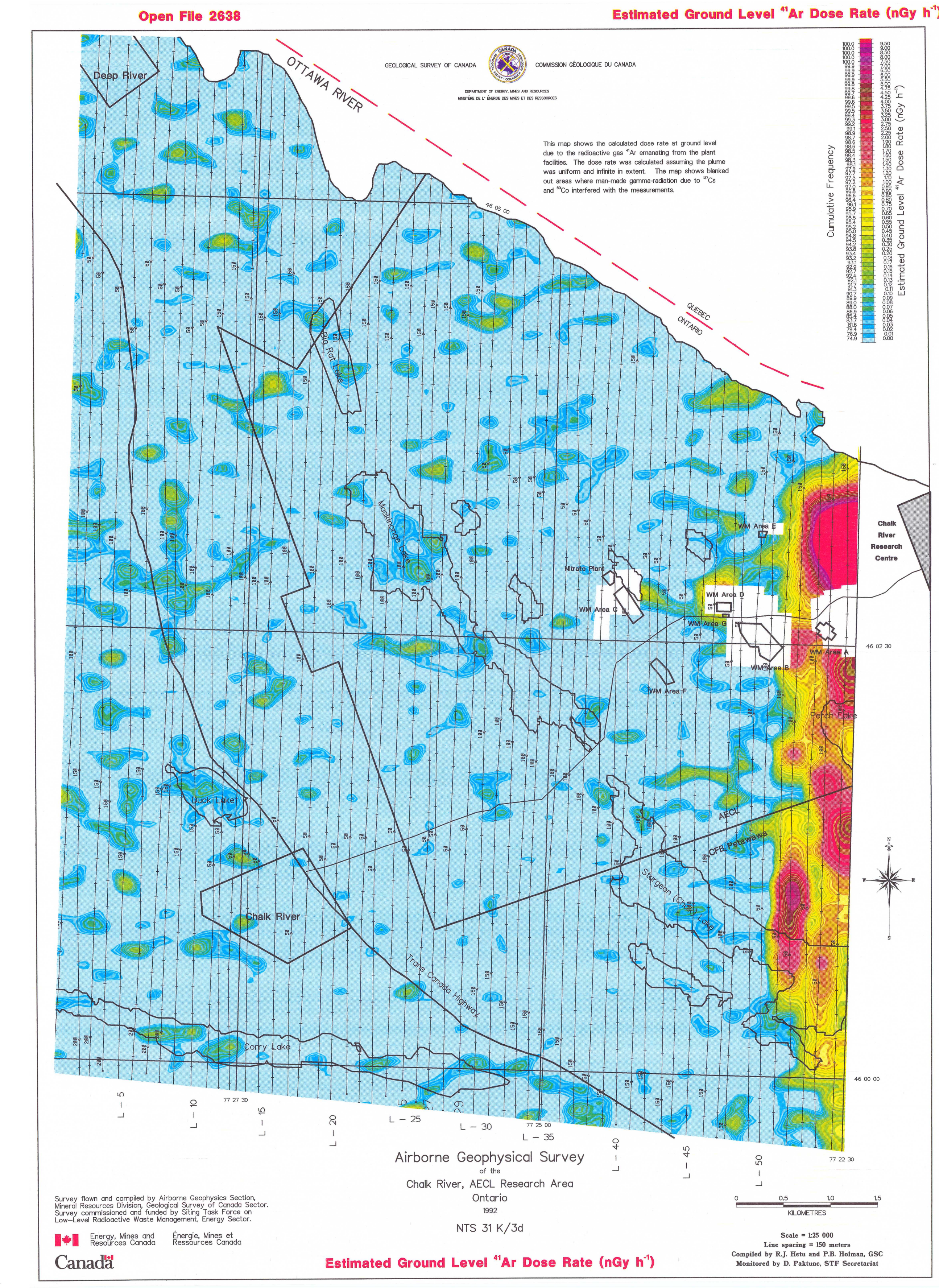
Natural Air Absorbed Dose Rate (nGy h^{-1})

Open File 2638 — Estimated Man - Made Air Absorbed Dose Rate (nGy h^{-1})



Estimated Man - Made Air Absorbed Dose Rate (nGy h^{-1})

Open File 2638 — Estimated Ground Level ^{41}Ar Dose Rate (nGy h^{-1})



Estimated Ground Level ^{41}Ar Dose Rate (nGy h^{-1})