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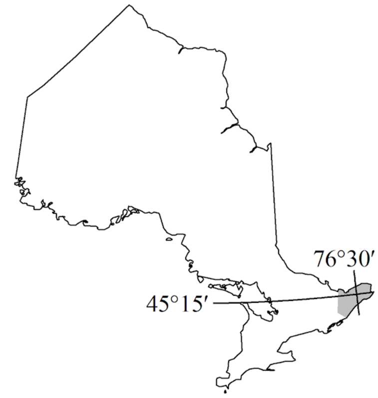
15. Project Unit 13-032. Precambrian Geology of Eastern Ontario Based on Data from a New Aeromagnetic Survey



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INTRODUCTION

The geology of the Precambrian basement beneath the Paleozoic strata of eastern Ontario was poorly known because of low-resolution aeromagnetic coverage (800 m line spacing) and limited diamond drilling that penetrated through to basement. To improve our knowledge of this area, in late 2013, 34 724 line-kilometres of aeromagnetic data were collected at 400 m line spacing over a 12 515 km^2 area of eastern Ontario east of longitude 76°30′30″W to the Quebec border (Figure 15.1). These data were recently released as Geophysical Data Set 1075 (Ontario Geological Survey 2014a) as well as a series of hard-copy maps (Ontario Geological Survey 2014b-u), as indicated in Figure 15.1. This article summarizes both the results of the survey and the preliminary interpretation of the underlying basement geology, based on tracing known surface geology beneath the Paleozoic strata, which are assumed to be magnetically transparent. Once interpretation is complete, a 1:100 000 scale compilation map showing the Precambrian geology of both the surface and subsurface of eastern Ontario will be published.

Geological Setting of Eastern Ontario

Eastern Ontario is underlain by Mesoproterozoic metasedimentary and metaplutonic rocks of the Central Metasedimentary Belt of the Grenville Province. Two main lithotectonic subdivisions of the Central Metasedimentary Belt are present in eastern Ontario, with Highway 7 approximately coincident with roughly paralleling the boundary between the 2 subdivisions. To the south and southeast are medium-pressure granulite-facies rocks of the Frontenac terrane, whereas to the north and northeast are upper greenschist to lower amphibolite-facies rocks of the Sharbot Lake domain. They are separated by the Maberly shear zone that formed at *circa* 1160 Ma.

Detailed descriptions of the Frontenac terrane and Sharbot Lake domain can be found in Easton (1992) and Carr et al. (2000). The following brief summary is based on those sources. The Frontenac terrane consists of marble, quartzite and paragneiss, which were metamorphosed to granulite facies at *circa* 1168 Ma coincident with emplacement of monzonite, syenite and diorite plutons of the Frontenac intrusive suite (Easton 1992; Corfu and Easton 1997). Frontenac intrusive suite plutons younger than *circa* 1164 Ma occur in both Frontenac terrane and Sharbot Lake terrane, indicating that the 2 terranes were amalgamated to one another by that time. Argon-argon cooling ages on hornblende suggest that the Frontenac terrane was little affected by subsequent Grenville metamorphic events after *circa* 1120 Ma (Cosca, Sutter and Essene 1991). In contrast, Sharbot Lake domain is a marble-dominated terrane, although amphibolite, derived from mafic metavolcanic rocks, is abundant along the Maberly shear zone and in the northwestern part of the domain. The supracrustal rocks of Sharbot Lake domain were intruded at *circa* 1225 Ma by large gabbroic intrusions of the Lavant intrusive suite and, subsequently, at least in

Summary of Field Work and Other Activities 2014,
Ontario Geological Survey, Open File Report 6300, p.15-1 to 15-7.

the southeast, by plutons of the Frontenac intrusive suite. Between 1090 and 1065 Ma, both the Frontenac terrane and the Sharbot Lake domain were intruded by monzonite, syenite and granite plutons of the Kensington–Skootamatta intrusive suite.

Several mafic dike swarms are present within the survey area, mostly within Frontenac terrane, and include the Frontenac (or Kingston) dike swarm (emplaced at 1160 Ma, U/Pb: Davidson et al. 2009), the Rideau dike swarm (594 Ma, U/Pb: Buchan et al. 2011), the Grenville dike swarm (590 Ma, U/Pb: Kamo, Krogh and Kumarapeli 1995) and the Brockville dike swarm (*circa* 420 Ma, K/Ar: Park and Irving 1972).

GEOPHYSICAL DATA

Figure 15.2 illustrates some of the key features identified during the preliminary phases of geological interpretation of the aeromagnetic survey of eastern Ontario. These features are described in the following sections. Note that the highly urbanized areas around the cities of Ottawa and Cornwall were excluded from the survey because of the concentration of man-made magnetic features and for safety reasons.

Magnetic Character of Major Rock Units

Marbles in both Frontenac terrane and Sharbot Lake domain are characterized by low magnetic susceptibility, as are the more extensive areas of metasandstone (quartzite) present within Frontenac terrane (*see* Figure 15.2). Most of the granulite-facies metasedimentary gneisses of Frontenac terrane have moderate to high magnetic susceptibility. The metasedimentary gneisses can be distinguished from

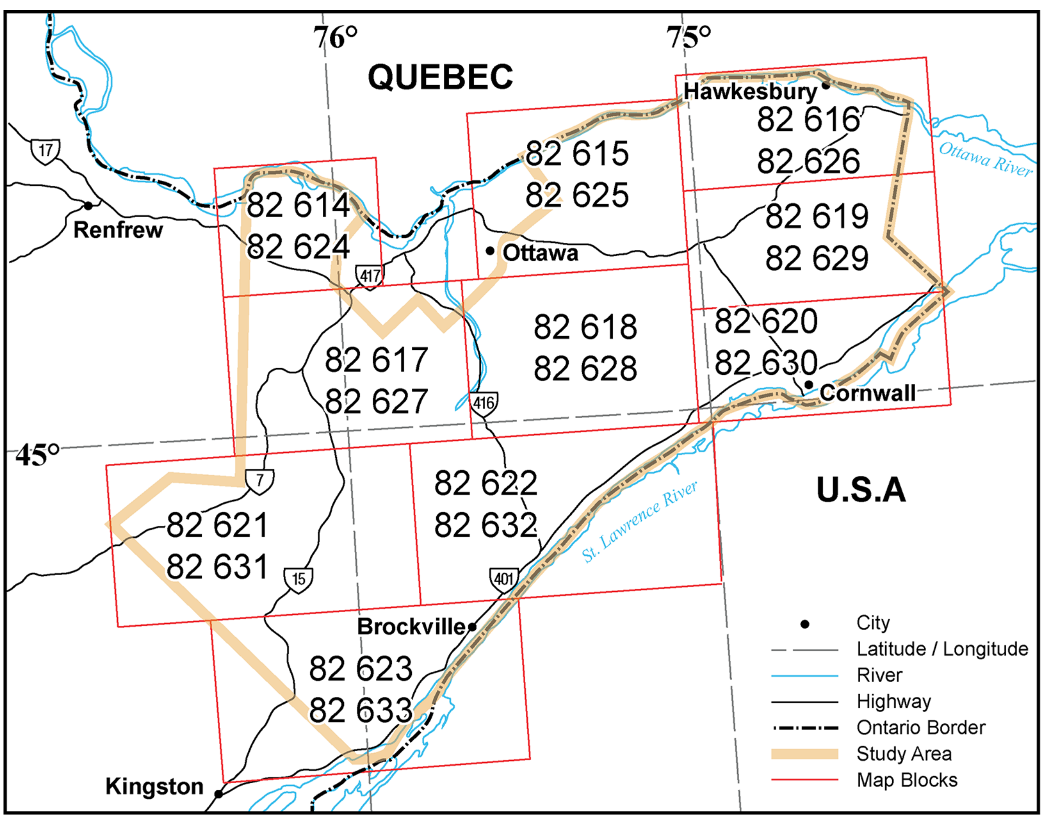

Figure 15.1. Map of eastern Ontario showing the area covered by the aeromagnetic survey (Ontario Geological Survey 2014a) and the hard-copy geophysical maps released in June 2014 (Ontario Geological Survey 2014b-u).

other units with high magnetic susceptibility by their relatively narrow width and their curvilinear trends, which locally give the appearance of being bent or folded (*see* Figure 15.2). Plutons of both the Frontenac and Kensington–Skootamatta suite are characterized by moderate to high magnetic susceptibility, regardless of bulk rock composition, and cannot be distinguished easily from one another on the basis of magnetic data. These plutons can exhibit ovoid to semicircular shapes of generally uniform magnetic character, such as the 3 closely spaced Kensington–Skootamatta suite plutons located north of Westport (*see* Figure 15.2), or they can have more elongate shapes with alternating bands of magnetic highs and lows, with the Christie Lake pluton (Frontenac suite) being a typical example (*see* Figure 15.2).

Mafic dikes appear as thin linear aeromagnetic highs, and are assigned to a particular dike swarm based on their orientation. Dikes of the Frontenac (Kingston) dike swarm trend north to northwest, and are found mainly in the western part of the survey area near Kingston. Dikes of the Grenville dike swarm trend west-northwest, and are commonly subparallel to coincident with faults of the Ottawa–Bonnechere graben. Dikes of the Rideau and Brockville dike swarms both trend northeast, subparallel to faults along the St. Lawrence River and, consequently, in the absence of surface exposure, cannot be separated from one another magnetically.

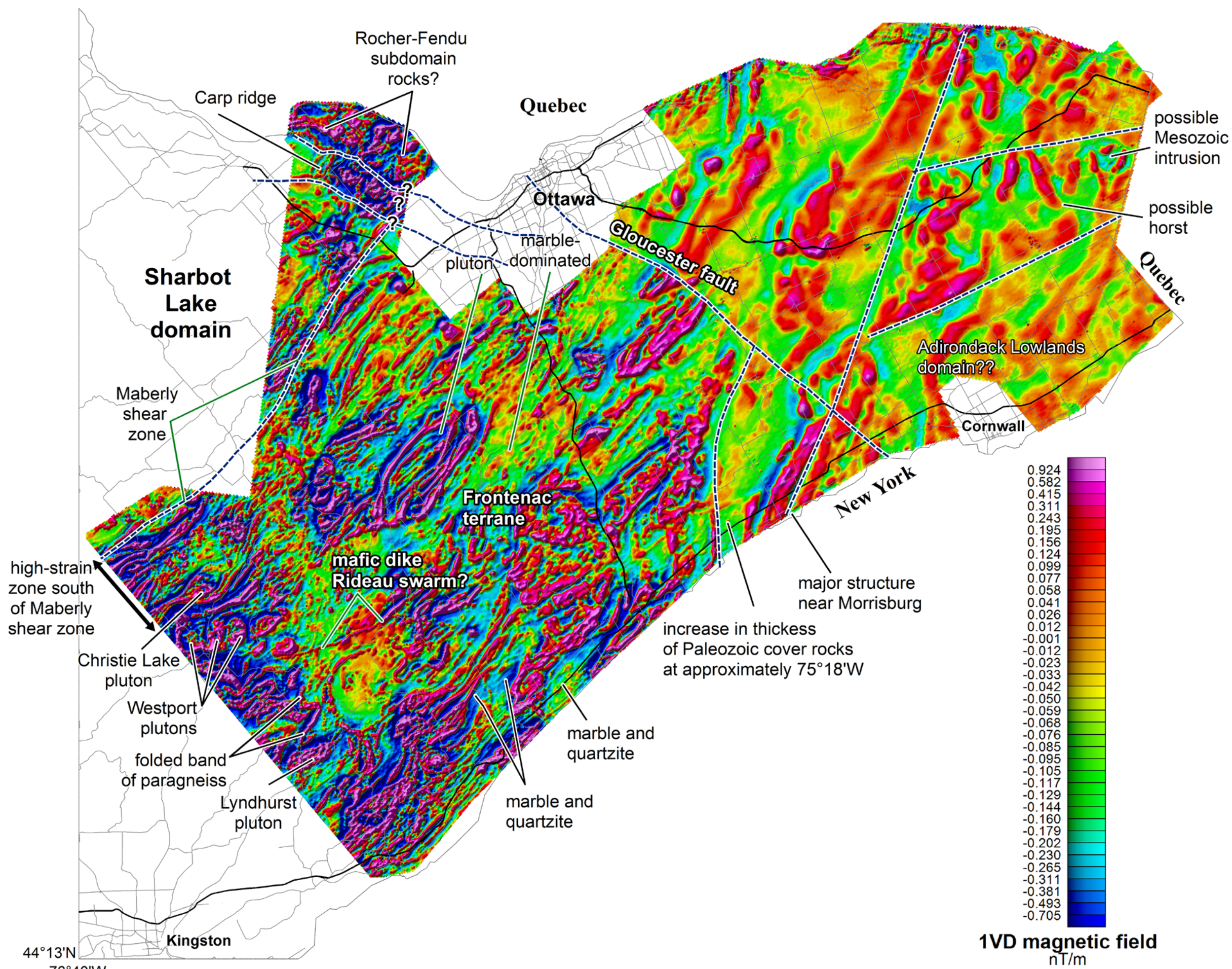

Figure 15.2. Map showing the first vertical derivative (1-VD) of the magnetic field for eastern Ontario, with key features indicated. See text for details. Magnetic data *from* Ontario Geological Survey (2014a).

First-Order Observations

The Paleozoic cover in the western two-thirds of the survey area, roughly all of the area from approximately 75°18′W to the western limit of the survey (~76°30′30″W) is relatively thin, that is, less than 400 m thick given the strength of the observed magnetic signal from the basement rocks (*see* Figure 15.2). Generally only the lowermost part of the Paleozoic section in eastern Ontario is exposed in the western two-thirds of the survey area, representing deposition during the Cambrian to the lowermost Upper Ordovician.

In contrast, the Paleozoic cover in the eastern one-third of the survey area, east of approximately 75°18′W and north of east-trending Gloucester fault (*see* Figure 15.2), is considerably thicker, that is, more than 800 m thick. This greater thickness has the effect of smoothing the magnetic signal from the basement rocks, making the resulting anomalies more diffuse and/or less intense (*see* Figure 15.2). This change in thickness is corroborated by a few diamond-drill holes that indicate depth to basement of between 800 to 900 m in the area near the town of Russell (Williams, Rae and Wolf 1985a; Williams 1991). As well, the upper part of the Paleozoic section, consisting of the uppermost units of the Upper Ordovician, is exposed north of the Gloucester fault (Williams, Rae and Wolf 1985a; Williams 1991). The estimated maximum thickness of the complete Paleozoic section in eastern Ontario is less than 1260 m, based on data from Williams (1991). As a consequence of this increased thickness, interpretation of the basement geology is less reliable in the eastern one-third of the survey area, although a possible Monteregian (Mesozoic) intrusion (*see* Figure 15.2) and a basement horst (*see* Figure 15.2) occur near the Quebec border north of Cornwall.

A north-northeast trending structure extending from Morrisburg to the Quebec border (*see* Figure 15.2) may represent a major change in the basement geology, perhaps marking the change from Frontenac terrane granulite-facies rocks to the west, to middle to upper amphibolite-facies marbles and plutonic rocks of the Adirondack Lowlands to the east.

The Maberly shear zone itself is not readily apparent in the magnetic data; however, a 10 to 20 km zone in Frontenac terrane immediately south of the known trace of the Maberly shear zone is characterized by strong linear magnetic trends (*see* Figure 15.2). This linear zone is interpreted as an area of high strain present in the hanging wall of the Maberly shear zone.

Basement rocks are exposed in the Carp Ridge, which is an approximately 8 km wide horst developed between the Hazeldean fault on the south and an unnamed fault to the north (*see* Figure 15.2). Existing maps suggest that the boundary between the Frontenac terrane and the Sharbot Lake domain crops out near the centre of the Carp Ridge (e.g., Ontario Geological Survey 1991); however, if present there, the boundary is not well defined magnetically (*see* Figure 15.2). In fact, field observations made during the 2014 field season by one of the authors (RME) suggest that the boundary may lie up to 12 km farther east than previously indicated (cf. Ontario Geological Survey 1991). Additional work will be needed to better locate the northernmost trace of this major lithotectonic boundary in Ontario.

The magnetic character of the Precambrian basement on the north side of the Carp Ridge is totally different than any other part of the survey area, and consists of a pattern of closely spaced, alternating, linear magnetic highs and lows (*see* Figure 15.2). A similar pattern was observed in magnetic data from both Ontario and Quebec in the Cobden area immediately to the west-northwest (Easton, this volume, Article 13). Easton (this volume, Article 13) assigned the rocks exhibiting this magnetic pattern to a new subdomain, the Rocher–Fendu subdomain, which consists of high-grade mafic to intermediate gneiss present as thrust sheets sitting atop lower grade marbles.

Surprisingly, few faults and lineaments identified in the basement (e.g., Williams, Rae and Wolf 1985a, 1985b; Williams, Wolf and Carson 1985a, 1985b) propagate into the overlying Paleozoic strata.

Furthermore, many mapped faults in the Paleozoic, for example those shown on the 1:1 000 000 scale geology map of southern Ontario (Ontario Geological Survey 1991), are not obviously present in the basement magnetic pattern. This does not mean that these faults do not exist; it only indicates that they apparently have limited or no effect on the Precambrian rocks. Also, west- to northwest-trending faults near Ottawa strike at a high angle to ductile shear zones present in the basement suggesting that, in this area, the development of the faults in the Paleozoic did not reactivate older structures in the basement.

Second-Order Observations

Several large dikes, possibly related to either the Grenville or Rideau dike swarm, are present beneath the Paleozoic north of Gananoque (*see* Figure 15.2).

Implications for Mineral Exploration

The thinness of the Paleozoic cover over the western two-thirds of the survey area means that mineral types exposed on surface should be present, and relatively accessible, throughout much of the survey area. Conditions are especially favourable for finding contact-related mineralization given the sharp magnetic contrast between the plutons and their host rocks.

Metallic mineral exploration over the eastern one-third of the survey area is impractical given the much greater thickness of the Paleozoic cover. This area does, however, have potential for hydrocarbon exploration.

The possible Monteregian (Mesozoic) intrusion near St. Anne de Prescott is potentially accessible, as it occurs in the centre of a horst, and there are a few exposures of Precambrian rock on the north side of the intrusion. In addition, a diamond-drill hole through the Paleozoic on the east flank of the intrusion intersected the Precambrian basement at a depth of 9.1 m (Williams, Rae and Wolf 1985b).

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