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Magnetic and Gravity Maps with Interpreted Precambrian Basement, Saskatchewan.

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INTRODUCTION

This open file report includes three types of magnetic map and two types of gravity map of the province of Saskatchewan at a scale of 1:1,500,000. Superposed on each map are boundaries between regional geological units observed on the Canadian Shield, and a preliminary interpretation of Precambrian geology buried beneath the Athabasca Basin and Phanerozoic sedimentary cover south of the Shield. The boundaries on the Shield have been digitized mainly from the Geological Map of Saskatchewan (1:1,000,000) published by the Saskatchewan Geological Survey (Macdonald and Broughton, 1980). The interpretation of buried Precambrian geology relies entirely on gravity and magnetic patterns and characteristics, and utilises comparisons of such features with similar features observed over the Canadian Shield. Direct extrapolations of Shield geology under Phanerozoic cover based on the geophysical patterns were attempted wherever possible. Drill core information was not consulted and accordingly the interpretations are ambiguous. Every care has been taken to reproduce accurately the positions of all boundaries on the Shield, estimated to be accurate to within a couple of kilometres. However, given that the geological source map dates to 1980, more recent geological mapping may indicate the need for revisions to positions in some areas. Slight errors in absolute position of some boundaries may also arise because they were digitized from figures in various reports, whose geographic projections may not be consistent with the Lambert Conformal Conic projection (central meridian at 106° west) used to produce the geophysical maps.

TYPES OF MAPS

The five types of potential field map are: (1) residual total magnetic field, (2) colour shaded relief of residual total magnetic field, (3) vertical derivative (= gradient) of residual total magnetic field, (4) Bouguer gravity anomaly, (5) vertical derivative of Bouguer gravity anomaly. Each makes a unique contribution to the overall geological interpretation. The residual total magnetic field map defines the relative strength of the magnetic field, outlining positive and negative magnetic signatures. Its shaded relief counterpart offers a three-dimensional perspective of the residual total magnetic field, useful for structural mapping, while maintaining information on variations in magnetization. The maps of the vertical derivative of the residual total magnetic field and of the Bouguer gravity anomaly eliminate long wavelength components, resultant features tending to reflect shallower crustal units. A useful characteristic of vertical derivative maps is that the zero value contour coincides closely with steeply dipping contacts between units having significantly different magnetizations or densities. The residual total magnetic field map exhibits much more detail than that portrayed by the Bouguer gravity map, partly because of much closer data spacing, and partly because the overall range of magnetic susceptibilities of rocks is orders of magnitude larger than the range of rock densities. Because of their greater detail, magnetic maps are excellent for mapping structure. The Bouguer gravity map and its vertical derivative counterpart outline light and heavy masses within the crust, and in the context of Precambrian basement are particularly useful for locating granitic and mafic/ultramafic rocks, which represent end members in terms of the density spectrum.

UTILITY OF POTENTIAL FIELD MAPS

Potential field images are effective tools for geological mapping, particularly where geology is obscured by water, glacial till, desert sands or younger sedimentary cover. Trends of gravity and magnetic features mimic those of geology. Consequently, structural trends are reflected accurately in potential field maps. Identification of lithology is more ambiguous, since the magnetic and density properties of different rock types can be very similar. Nonetheless, "calibration" of gravity and magnetic anomalies with exposed geology provides a measure of control for interpretation, and helps reduce ambiguity. The utility of potential field maps is demonstrated in this set of five maps for Saskatchewan, used to examine Precambrian basement geology under Phanerozoic sedimentary cover south of the Canadian Shield and under the Athabasca Basin.

CALIBRATION OF POTENTIAL FIELD ANOMALIES

Comparison of potential fields with geology on the exposed Shield provides a geological "calibration" of the fields. Since the geological and geophysical trends run more or less perpendicular to the Shield margin and to much of the boundary of the Athabasca Basin, once calibrated, the geology can be extended with confidence for some distance. One problem that needs to be noted is that as the Phanerozoic sedimentary rocks increase in thickness to the south, attaining about 3400 m at the U.S. border (Kim Kreis, personal communication, 1997), the depth to the Precambrian sources increases and potential field anomalies become attenuated, especially magnetic anomalies. Hence, the "texture" of a magnetic pattern on the Shield, which may be characteristic of a particular geological unit, may not have the same appearance further south, possibly leading an interpreter to seek an alternative source. Suppression of potential field signatures also occurs over the Athabasca Basin, where the Proterozoic sediments attain a maximum thickness of 1500 m (Pilkington, 1989). On the Precambrian Shield, the following correlations between anomalies and geology are noted:

Some faults, or sections of faults coincide with narrow, linear magnetic lows. Faults often provide preferential pathways for circulating groundwaters that may oxidize and destroy magnetite, thereby decreasing magnetization and giving rise to magnetic lows. Not all faults are marked by such lows. The map of the vertical derivative of the residual total magnetic field, in particular, shows that the Needle Falls Shear Zone (NFSZ) tends to lie near the flanks of discrete linear highs, as do some faults of the Tabbernor fault system.

A broad zone of relatively high magnetic field covers most of the Wollaston Domain (comprises mainly passive margin sediments metamorphosed to upper amphibolite-lower granulite facies grade) and the adjacent granitic Wathaman Batholith. In detail, the map of the vertical derivative of residual total magnetic field reveals that the zone comprises a series of narrow linear magnetic features, most of which are aligned parallel to the overall trend of the domain and batholith.

Near the Shield margin, there is a stark contrast in the magnetic expressions of the Wollaston Domain and the southeastern margin of the reworked granulitic and migmatitic Archean basement of the Mudjatik Domain. The latter margin coincides with a roughly 15 km wide zone of low magnetic intensity, which traced northeastward through the Athabasca Basin emerges in a position along the northwestern margin of the Wollaston Domain. Northwestward into the Mudjatik Domain, the zone is flanked by a higher intensity pattern of intermixed highs and lows. These anomalies are generally linear and have fairly low aspect ratios. In a general sense they are roughly parallel to the trend of the domain itself. Yet as resolved in the high frequency image of the vertical derivative of the residual total magnetic field, many trends are observed to be oblique to the margins of the domain. Much of the southern part of the exposed Wollaston Domain coincides with a strong positive gravity anomaly. Traced southwestward to the Shield margin, this is replaced with a narrower positive anomaly along the northwest boundary of the domain, and a weak negative anomaly along the southeast boundary.

Much of the Rottenstone Domain, represented mainly by a tonalitic-migmatitic complex, is characterized by narrow, linear magnetic highs and lows, that run along its length. In contrast, the magnetic field associated with the Birch Rapids Straight Belt (BRSB), a high strain zone of intense strike shear along the eastern margin of the domain, is relatively featureless. The domain exhibits a close correlation with a broad gravity high that continues far to the south of the Shield margin.

The La Ronge Domain and Flin Flon Belt both consist largely of low metamorphic grade, mafic volcanics and granitoids. The Glennie Lake Domain comprises mainly quartz dioritic to granodioritic orthogneisses and plutons. The magnetic patterns of the La Ronge Domain (anomalies trend predominantly northeast-southwest), Flin Flon Belt (north-south) and Glennie Lake Domain (north-south) are somewhat similar. And they are all comparable to the intermixed high-low pattern of the Mudjatik Domain, although linear anomalies within the La Ronge Domain tend to have a more uniform orientation. Because of this similarity, unambiguous identification of buried counterparts on the basis of magnetic pattern alone may not be feasible.

The eastern margin of the La Ronge Domain, known as the Meraste Zone (MZ), is marked by strong positive gravity and magnetic signatures, attributed to ubiquitous mafic and richly hornblendic quartz dioritic and granodioritic rocks, amphibolite and amphibolitic migmatites. Much of the Glennie Lake Domain coincides with a moderately strong positive gravity signature, although conspicuous negative gravity anomalies lie along the western and eastern margins. That in the west coincides with two Archean windows, which seismic modelling indicates may represent the tip of an Archean core underlying the Trans-Hudson Orogen (Hajnal et al., 1996). The presence of a gravity low suggests that the Archean is relatively light in this area.

EXTRAPOLATIONS OF GEOLOGY

Precambrian geology is interpreted under the Athabasca Basin and the Phanerozoic sediments south of the Shield margin. Beneath the Athabasca Basin, the boundary between the Western Craton (WC) and Mudjatik Domain and several linear features are interpreted on the basis of magnetic patterns, and several granitic bodies (G) are proposed on the evidence of distinct gravity lows. For more information on geophysical interpretation of sub-Athabasca Basin geology, the reader is referred to Pilkington (1989). The Mudjatik-Wollaston boundary can be traced with confidence on the basis of magnetics to a point, labelled P, 60 km southwest of the Shield margin. Possibly it extends another 60 km southwest to point Q, although the weight of magnetic evidence favours a path that swings southward from P through points X and Y and beyond. East of this path, the strong positive magnetic expression that typifies the Wollaston Domain apparently continues to about latitude 50° 30'. The southern extension does not have such a high frequency, lineated pattern as does the section on the Shield and the near-shield extension. This is expected, considering the southward deepening of Precambrian basement under the Phanerozoic.

Whether all of the Precambrian crust west of the proposed Mudjatik-Wollaston boundary can be ascribed to the Mudjatik Domain is conjectural. A consistent pattern of magnetic anomalies (seen in both the residual total magnetic field map and its vertical derivative) over the exposed Mudjatik Domain and its probable near-Shield extension is apparently interrupted along a southwest-northeast line running from point T through R, Q and P to the Shield margin. Within a roughly triangular area south of T-R, and west of R-S, the magnetic field is noticeably relatively negative. This may reflect a variation in the composition of Mudjatik crust or could signify the presence of a crustal element that is distinct from both the Mudjatik and Wollaston Domains. East of this negative triangle, between R-S and X-Y, lies a 60 km wide belt containing positive magnetic anomalies. The western margin of the belt is marked by, and includes, a north-south line of prominent linear positive anomalies. The belt is tentatively assigned as part of the Mudjatik Domain. Alternatively, the presence of a strong positive gravity anomaly in its northern part, that extends northeastward into the exposed Wollaston Domain, suggests a possible connection to the latter domain.

The eastern limit of the zone of high magnetic intensity interpreted to outline the Wollaston Domain south of the Shield is marked by a grossly linear, north-south belt of steep gradients, that probably maps the path of the Needle Falls Shear Zone (NFSZ). Immediately south of the Shield margin, magnetic lineations trending south-southwest within the presumed continuation of the Rottenstone Domain, which includes the Birch Rapids Straight Belt (BRSB), appear to die out along another north-south belt of steep magnetic gradients a few kilometres east of the Needle Falls Shear Zone (NFSZ). Southwest-trending magnetic lineations in the buried La Ronge Domain, which includes the Meraste Zone (MZ), also tend to terminate at, or swing into this belt. The belt, and that assumed to track the path of the Needle Falls Shear Zone (NFSZ), continues far south of the Shield margin. Between them lies a prominent, 10 to 15 km wide, north-south zone of low magnetic field, which may signify a broad zone of shearing.

Magnetic patterns suggest that the Glennie Lake Domain widens southward from the Shield margin, occupying a tract between the belt of low magnetic field on the east side of the Needle Falls Shear Zone (NFSZ) and a similar belt lying along the projected southward extension of the Tabbernor fault system. Much of the interpreted sub-Phanerozoic extension of the domain is characterized by strong positive magnetic anomalies, large parts of which coincide with prominent positive gravity anomalies. By analogy with similar gravity and magnetic anomalies observed over the granulitic Pikwitonei Gneiss of the Superior Province, it is speculated that much of the extension comprises intermediate-mafic granulites. Magnetic patterns also indicate that the Rottenstone Domain pinches out just south of the Shield margin, although an associated strong positive gravity anomaly suggests otherwise. Even though the latter narrows appreciably near the presumed magnetic termination of the Rottenstone Domain, hinting at a coincidental termination, an overall positive signature continues southward into the western part of the area designated as Glennie Lake Domain. This may signify the presence of rocks of the Rottenstone Domain. A negative gravity anomaly coinciding with Archean (A) windows in the exposed Glennie Lake Domain connects with a conspicuous negative gravity anomaly immediately south of the Meraste Zone (MZ), in the domain's buried extension. It may trace the axis of an Archean culmination defined by Lithoprobe seismic modelling (Hajnal et al., 1996). Farther south, and slightly to the east, the axis may be expressed in a narrow negative anomaly trending south-southwest through the central part of the extension.

On the Shield, the Tabbernor fault system is well expressed in narrow, linear north-south trends on magnetic maps. South of the Shield margin it seems to continue as a linear zone of relatively low magnetic level that widens from about 15 km at the margin to around 50 km approximately 400 km further south. The suppressed magnetic field may reflect, in part, the destruction of magnetite by groundwater circulation controlled by faults of the Tabbernor system. Internally this negative zone is not entirely featureless or flat, but contains small anomalies that impart a texture to it, particularly between about 70 and 210 km south of the margin. The zone does not have a particularly unique or singular gravity signature, although some gravity contours run parallel to the zone. Two prominent gravity highs migrate eastward into the magnetic low as extensions of highs underlying the proposed buried extension of the Glennie Lake Domain.

East of the buried segment of the Tabbernor fault system, much of the gravity field is represented by a pattern of pronounced lows and intervening highs. This is similar to patterns observed over the Flin Flon Belt, where they are attributed to arc-type granitic intrusions (G) and mafic volcanics that characterize the belt. The magnetic pattern in the same area also displays similarity with that over the Flin Flon Belt. Accordingly, this part of the sub-Phanerozoic basement is considered to represent an extension of that belt. A linear, north-trending gravity high along the southern part of the eastern boundary of Saskatchewan is attributed to granulitic Pikwitonei Gneiss. This interpretation is based principally on the fact that the high continues northeastward through Manitoba to occupy a position over Pikwitonei Gneiss on the Shield. Furthermore, the gravity high coincides with a belt of positive magnetic anomalies, and Pikwitonei Gneiss characteristically has a strong magnetic expression.

In the southeast corner of the map, west of the Pikwitonei gravity high, two other prominent belts of gravity high occur. They trend essentially northwest to north-northwest, but tend to swing northward and merge with north-trending gravity highs within the buried extension of the Glennie Lake Domain. Much of the area covered by these highs coincides with a magnetically quiet zone, leading to speculation that they are associated with Kisseynew-type gneisses. The Kisseynew Gneiss Belt, comprising granulite grade metagreywackes deposited in an interarc basin, is marked by a prominent gravity high, and yet has one of the most featureless and low magnetic expressions in the Canadian Shield.

Prediction of basement geology is probably most difficult for the southwest corner of Saskatchewan, partly because some magnetic data remain proprietary and will not be released to the public until the Fall of 1998. The presence of prominent gravity lows suggests the presence of granitic intrusions (G), and a strong magnetic signature in the same general area may indicate that the granites are part of an extensive granitoid-orthogneiss complex. There is a hint of a southwest-oriented truncating trend in the magnetic images near the south end of the Needle Falls Shear Zone (NFSZ). Magnetic trends are grossly north-northeast and southeast, respectively, to the northwest and southeast of the line of truncation. Support for this discontinuity is provided by a coincident belt of steep gravity gradients.

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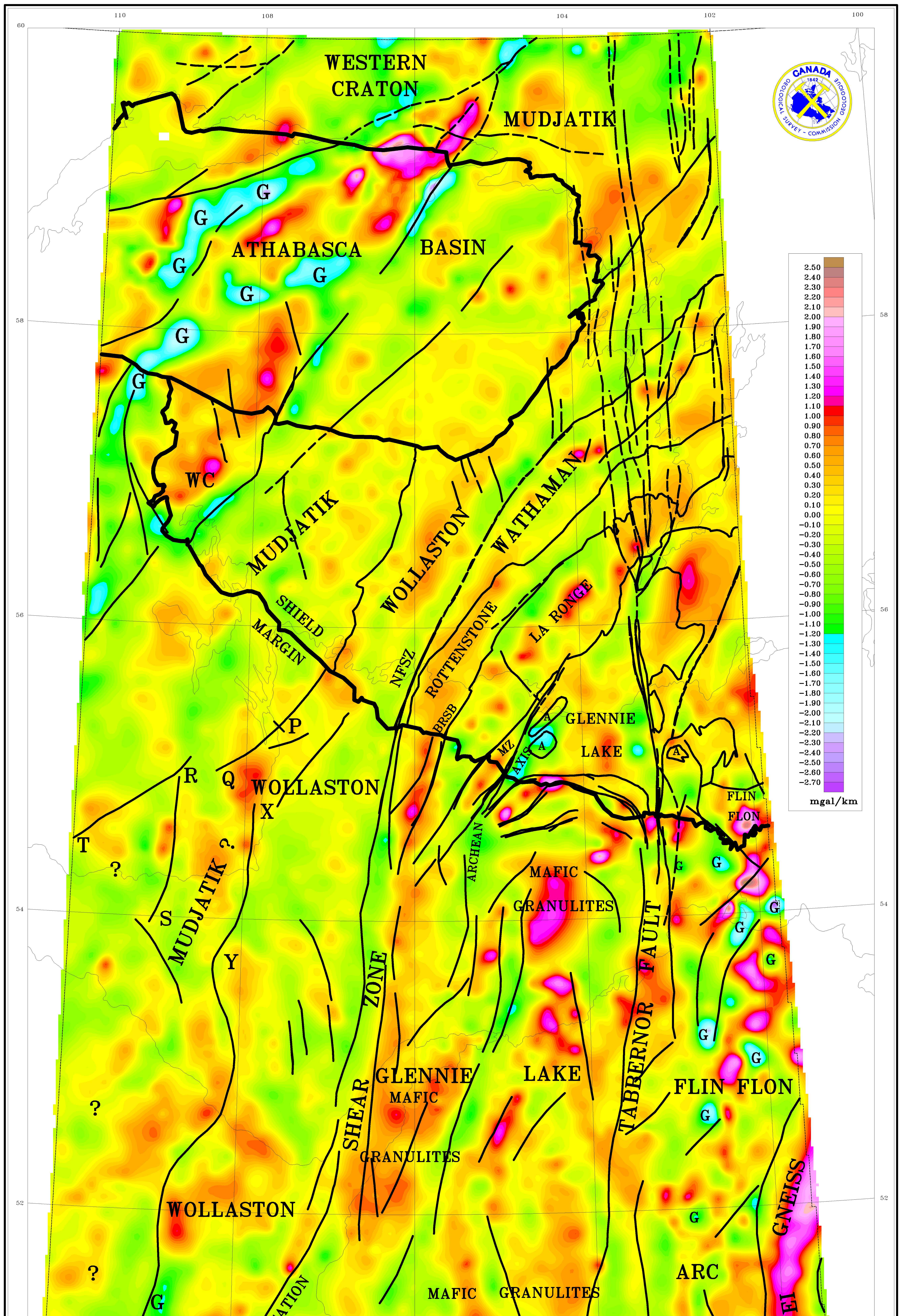

This map was compiled from holdings in the National Gravity Data Base maintained by the Geological Survey of Canada, Ottawa. All measurements used in the compilation of this map were reduced to the International Gravity Standardization Net 1971 (IGSN71) datum. Theoretical gravity values were calculated from the Geodetic Reference System 1967 (GRS67) gravity formula. Bouguer anomalies were calculated using a vertical gravity gradient of 0.3086 mGal/m and a crustal density of 2670 kg/m^3. Terrain corrections were applied in areas of high relief where sufficient topographic information was available. The data were interpolated to a 2 km grid, upward continued by 2.5 km, and the first vertical derivative was calculated. Digital gridded or point data and copies of this map are available from the Geophysical Data Centre, Geological Survey of Canada, 1 Observatory Crescent, Ottawa, K1A 0Y3.

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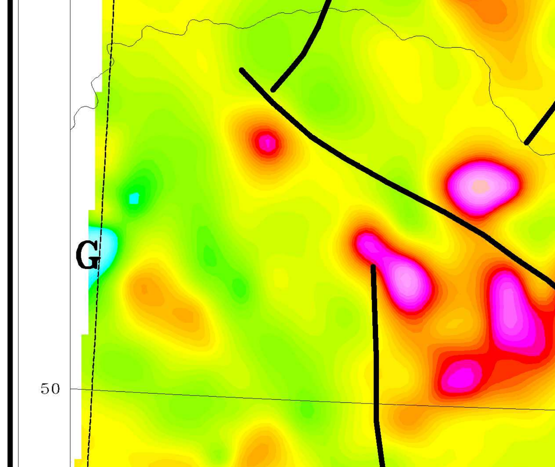

VERTICAL DERIVATIVE OF THE BOUGUER GRAVITY ANOMALY MAP, SASKATCHEWAN
CARTE DE LA DERIVEE VERTICALE DE L'ANOMALIE GRAVIMETRIQUE DE BOUGUER, SASKATCHEWAN

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