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Weakly magnetic crust in the Canadian Cordillera

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Abstract

Current models of continental crust favor an increase in magnetization with depth. Here we report a counter example from the Canadian Cordillera where almost a full thickness of non-magnetic continental crust is suggested by joint interpretation of magnetic and seismic data. The magnetic field over the Cordillera is characterized by complex, short-wavelength (<100 km) anomalies associated with intrusive, metamorphic and volcanic rocks that occur at shallow depths (<5 km) within accreted terranes. The long-wavelength (>100 km) portion of the Cordilleran field is subdued and mainly featureless, and suggests a lack of magnetic sources at greater depths. Seismic reflection and refraction data from three major transects in the Yukon and British Columbia, Canada support this interpretation and indicate that sedimentary-like formations make up the majority of the crust. The dominance of shallow, upper crustal magnetization in the Canadian Cordillera contrasts with the generally-held view that the lower continental crust is the primary source for long-wavelength magnetic anomalies. Sources for these anomalies are often assumed to be located in the lower crust when surface magnetizations are insufficient to produce such anomalies or no correlation exists between the magnetic field and the mapped surface geology. The Canadian Cordillera appears to be an example of a non-magnetic lower crust overlain by a more magnetic upper crust that is, however, not magnetized strongly enough to produce significant long-wavelength magnetic anomalies.

Keywords: continental crust; magnetic field; susceptibility

1. Introduction

The magnetic properties of continental crust are dependent on its composition from the surface down to the Curie isotherm, specifically on the distribution of magnetite, the most commonly occurring ferrimagnetic mineral. Generally, crystalline igneous and metamorphic rocks are the main contributors to anomalous magnetic fields, whereas sedimentary rocks can be considered essentially non-magnetic. Within the crust, the division into a felsic upper crust and a more mafic lower crust has led to granulite-facies rocks in the latter to be suggested as the predominant source for long-wavelength magnetic anomalies [1]. Multi-domain magnetite is commonly inferred to be the mineral responsible for this magnetism, although certain forms of the hematite–ilmenite series could also be contributors [2]. The magnitude of crustal magnetization at upper levels within the crust can be determined from surface samples and modelling of short-wavelength magnetic anomalies. For the deeper

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parts, xenolith magnetic properties are useful, as is the interpretation of long-wavelength magnetic anomalies, such as those measured by satellite-altitude surveys [3]. Here, we report an example of almost a full thickness of non-magnetic continental crust suggested by joint interpretation of magnetic and reflection and refraction seismic data, where magnetic sources are restricted to a thin (<5 km) surface layer, and discuss the consequences for the global description of crustal magnetization and the modelling of satellite magnetic data.

2. Magnetic field data

The Canadian Cordillera is characterized by a subdued and mainly featureless long-wavelength (>100 km) magnetic field (Fig. 1). This is in marked contrast to the numerous, extensive, high-amplitude magnetic anomalies that are associated with exposed and buried Precambrian basement to the east and north of the Cordillera. Indeed, the boundary between the two magnetically contrasting regions closely mimics the geologically determined extent of the Cordillera, i.e., the Cordilleran deformation front (CDF, Fig. 1). The only discrepancy between the two occurs north of 65°N where the CDF turns northward to the Arctic coast (e.g., [4]) but the boundary between subdued and higher-amplitude magnetic fields continues approximately westward to the Alaskan border.

The data in Fig. 1 are derived from a series of high-altitude (~5 km) aeromagnetic surveys flown in the 1970s [5]. Flightline spacing averages 37 km over the area shown and the data were gridded at a 10-km interval. A cosine-tapered, low-pass filter with center roll-off wavelength of 100 km was applied to the gridded data to reduce residual navigational error effects. This filtering also suppresses anomalies due to near-surface magnetic sources and emphasizes the effects of deeper bodies occurring in the middle and lower crust. Even in non-filtered data, Haines et al. [5] and Coles et al. [6] noted the clear distinction in magnetic character between the Cordillera and its surroundings. They suggested that the subdued field over the Cordillera was due to the absence of Precambrian crystalline basement material in the region. On the basis of several long aeromagnetic profiles, Caner [7] suggested the smooth Cordilleran field was due to shallowing of the Curie isotherm or the presence of a more felsic crust.

To the east of the CDF, crystalline basement rocks making up the North American craton produce numerous, high-amplitude (hundreds of nanoteslas), laterally-extensive (hundreds of kilometers) anomalies that persist even when covered by thick sedimentary basins (e.g., >5 km in southern Alberta). These kinds of anomalies are not seen within the Cordillera. In the long-wavelength field some higher-amplitude (>200 nT) anomalies do occur, for example, one just to the east of Vancouver Island coincident with the coastline and another centered at 127.5°W, 57.7°N. The low-altitude (~300 m), high-resolution (1-km grid interval) magnetic

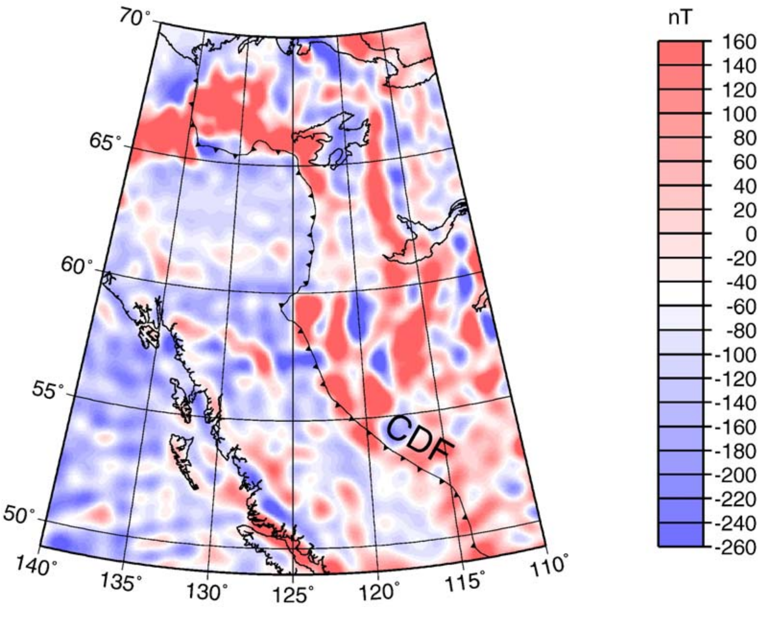

Fig. 1. High-altitude (~5 km) magnetic field of western Canada filtered to remove wavelength components <100 km. CDF, Cordilleran deformation front. Data collection details are given in Haines et al. [5].