GEOPHYSICAL STUDIES OF THE MONTAGNAIS IMPACT CRATER

M. Pilkington, L.F. Jansa* and R.A.F. Grieve, Geophysics Division, Geological Survey of Canada, Ottawa, Canada, *Atlantic Geoscience Centre, Geological Survey of Canada, Dartmouth, Canada.

The Montagnais impact structure is located on the outer continental shelf ~200 km SSW of Halifax, Nova Scotia and is the only crater to have been discovered beneath the ocean [1]. The structure consists of a near-circular disturbed area with a central fault-bounded uplifted basement block with a diameter of ~11-13 km surrounded by an annular trough of down-dropped basement and sediments extending out to a diameter of 45 km, interpreted to be the crater rim [2]. Seismic reflection data suggests that impact breccia up to 800m thick extends outwards from the central uplift to distances of ~8.5 km and overlies the uplifted basement rocks. Although interpreted to be of volcanic origin [3] or due to a combination of tectonic and volcanic processes [4,5], the presence of petrographic indicators such as planar features in quartz and feldspars and geochemical evidence [2] strongly favours an impact origin. $^{40}Ar/^{39}Ar$ dating of the melt rock gives an age of 51 Ma. Extensive multichannel reflection seismic data and drill hole samples from the Montagnais I-94 well located within the central uplift indicate that the Montagnais structure has all the morphological elements expected of a complex terrestrial impact crater.

Two sets of detailed gravity and magnetic data have been collected in the Montagnais area. The first consists of data measured in conjunction with seismic lines carried out by the CSS Hudson [6]. The second consists of additional observations taken in conjunction with a detailed hydrographic survey of the Scotian Shelf. Regional potential fields over the Scotian Shelf are related to the Cambro-Ordovician Meguma Group (metasediments and associated granite plutons) which outcrops in Nova Scotia and underlies the Mesozoic sedimentary basin on the shelf.

The local gravity field in the Montagnais area is dominated by the steep shelf-edge gravity gradient related to the transition from continental to oceanic crust. This regional crustal effect has been removed from the observed data by high-pass filtering which passes all wavelengths less than 56 km and rejects all those greater than 85 km. Hence, any crater related signature of 40-50 km size should be retained. Figure 1 shows that the structure is marked by a gravity anomaly high of ~8 mGal with width ~11 km centered on 42° 52'N, 64° 15'W. The contoured data suggest that no negative anomaly delineates the crater extent (determined from seismic interpretation) as found in the majority of terrestrial impact craters. Radial gravity profiles centered on the gravity anomaly high confirm the absence of a definitive negative anomaly associated with the crater. A small inflection in the radially-averaged gravity anomaly at ~23 km radius could reflect density changes related to the impact and as such, define a negative anomaly of ~1 mGal. However, the magnitude of such an anomaly is within the estimated error in the data and is therefore not justified.

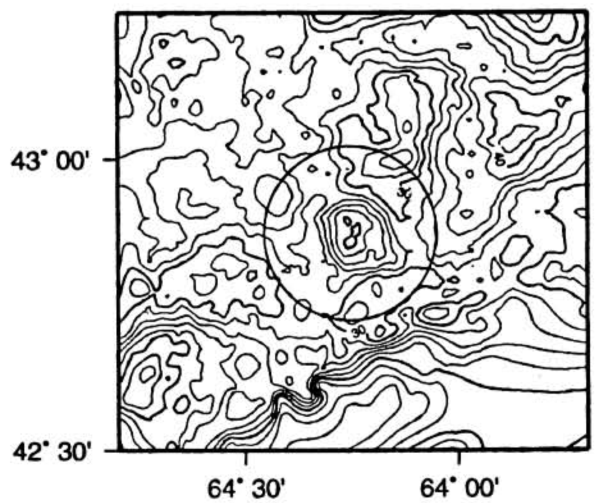

Figure 1. Residual Bouguer gravity anomaly map of Montagnais area after removing regional crustal component associated with the continental shelf edge. Contour interval is 2 mGal. Circle is 45 km in diameter and centered on 42° 52'N, 64° 15'W.

For a structure of the size of Montagnais, we expect a maximum negative anomaly of -5 to -10 mGal and a central gravity high of less than this magnitude [7]. The gravity signature of

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Montagnais (only a gravity high associated with the central uplift), however, most resembles those found over heavily eroded structures formed in sedimentary rocks, e.g., Upheaval Dome, Utah; Kentland, Indiana. In these cases, erosion has removed the low density crater lithologies such as impact breccia and fractured/brecciated target rocks that contribute most to the negative gravity anomaly. All that remains is the effect of the uplifted denser root of the central uplift. Montagnais, on the other hand, appears well preserved. We may expect some reduction in the expected gravity anomaly due to the sedimentary component in the Montagnais target stratigraphy [7]. More important is the non-brittle behaviour of saturated unconsolidated material in the target and its more efficient absorption of impact energy compared to more compact targets. This will limit the formation of fractures and hence the size of the low density zone.

The total magnetic field intensity over the Montagnais region is given in Figure 2. The impact is located at the southern end of a NNE-trending magnetic high. The close association of this high with a gravity low suggests that the causative body may be a Devonian granite pluton such as that interpreted for other shelf anomalies. The field within the interpreted crater rim shows no expected features related to the impact process such as truncation of regional trends nor reduced field intensities [7]. However, a small magnetic high occurs ~3 km east of the central gravity anomaly. Depth estimates from the magnetic data give values of <2 km for the eastern part of this small central anomaly and 3-5 km for the western part. The latter depths are similar to those estimated for the larger (granite?) magnetic high to the NNE, while the shallower depths correspond to the average basement depth in the surrounding region. Although zones of melt rock have been found in the I-94 drill core, these units are unlikely to be responsible for the central magnetic anomaly. Melt sheets at impact craters generally produce a zone of several high-amplitude short-wavelength magnetic features with a greater areal extent than the Montagnais anomaly. The simple form of the central anomaly and the estimated source depth suggests a cause related to uplift of more magnetic basement material at depth.

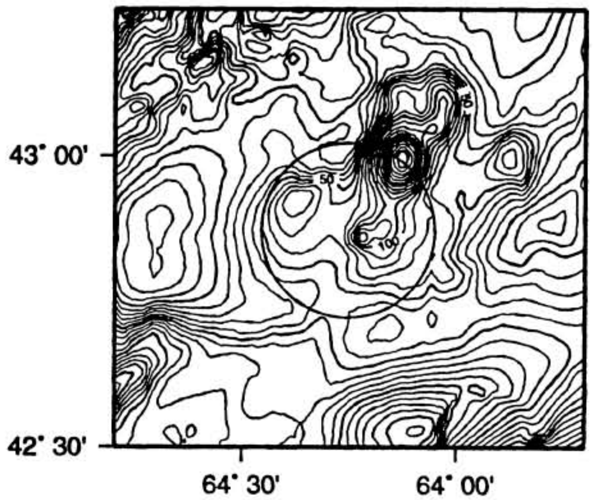

Figure 2. Total magnetic field intensity map of Montagnais area. Contour interval is 20 nT.

The unusual gravity signature of the Montagnais crater has important consequences for the location/detection of impact structures formed in offshore regions, particularly on continental shelves. The usual case of a gravity anomaly low which outlines the crater extent and is modified by a central anomaly high related to the central uplift is replaced by simply a positive anomaly whose size reflects the dimensions of the central uplift. Similarly, the existence of any associated magnetic anomaly will depend on whether crystalline basement is shallow enough to be involved in the impact process.

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