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Comment on "Geophysical evidence for a large impact structure on the Falkland (Malvinas) Plateau"

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Rocca et al. (2017) discuss geophysical data from west of the Falkland Islands and suggest the presence there of a large impact structure of a supposed Late Permian age. We argue that there is insufficient evidence for their dramatic conclusion, and that the seismic data presented is inconsistent with their crater hypothesis. Geophysical studies are useful for detailed investigations of confirmed impact craters, but, in the absence of shock-metamorphic features, they cannot provide unique interpretations or independent evidence (Pilkington and Grieve, 1992; Grieve and Pilkington, 1996; French and Koeberl, 2010). Rocca et al. (2017) provide no geological context and completely ignore the absence of any predictable regional geological effects from such a large impact event; for example, the absence of any thick ejecta layer or shock metamorphism.

The gravity low to the west of the Falkland Islands was first assessed by Platt and Philip (1995) who, utilising gravity datasets from the nineties, suggested the presence of a sedimentary basin or igneous intrusion; neither interpretation is supported by any seismic reflection data. Additionally, they noted that the commercial magnetic data did not feature an anomaly in the area, but that there were some high-amplitude magnetic features south-west of the islands. Richards et al. (1996), based on the geological and geophysical data available at that time, described the area to the west of the islands as a Palaeozoic platform transected by WNW–ESE-striking structures. They also described a series of low-gravity anomalies and suggested that these represent a sedimentary basin, but also concluded that a basin is only discernible in seismic data on the southern margin of the gravity low. Without well correlation, a tentative Permian–Triassic age was assigned to this basin (Richards et al., 1996). Additionally, Richards et al. (1996) identified a series of folds within the strata and highlighted that the folds are truncated by an unconformity marked by an ?Upper Jurassic volcanic event.

While Rocca et al. (2017) describe a 250 km diameter circular gravity anomaly, we present a Bouguer gravity anomaly map with wavelengths <100km (Figure 1), based on Sandwell et al. (2014). A circular negative gravity anomaly is not observed on this map, but an elongate anomaly is clearly observed. We disagree that this anomaly was formed by a cratering process, as it does not cross-cut any regional trends and has a similar strike (NW–SE) to the Palaeozoic structures observed onshore in the north-west of the Falklands (Aldiss and Edwards, 1999) and in the southern North Falkland Basin (Lohr and Underhill, 2015).

Rocca et al. (2017) used a single profile of the sparse local seismic reflection data to support the crater hypothesis. Whilst seismic reflection data can identify large impact structures (Scott and Hajnal, 1988; Wu et al., 1994; Poag, 1996; Poag, 1997; Morgan et al., 1997; Poag et al., 1999; Osinski and Spray, 2005; Stewart and Allen, 2005), we argue that the seismic data they presented does not corroborate the crater hypothesis. Typically, impact craters identified on seismic data have the following features (French, 1998; French and Koeberl, 2010), none of which are convincingly seen in the seismic data:

1. modest downward and inward displacements of the rocks at the crater margin;
2. a complex ring fault system;
3. structural disruption in a central zone, with incoherent seismic reflectors and evidence of preserved and continuous reflectors at depth.

The seismic profile shown (SGFI93-117) by Rocca et al. (profile A on Figure 1) was displayed with an inverted orientation: in reality, the Mesozoic and Cenozoic strata seen in this profile thicken towards the south-east (away from the area of their postulated basin), not the north-west. Also, the vertical scale is incorrect; it should be TWT and not TVDSS, since the data were acquired in the time domain and were not depth-converted due to the lack of any wells and/or velocity models in proximity. As the seismic profile was displayed with a vertical exaggeration of at least 5.5, it gives a false impression of the real structures at depth. Furthermore, the seismic profile location is poorly selected if the aim was to provide meaningful information regarding the gravity anomaly. Our interpretation of SGFI93-117 is shown in Figure 2; additionally we have shown profile SGFI93-100 (Profile B on Figure 1), which is more appropriately placed to provide insights into the gravity anomaly.

It is clear from both of these profiles that the Palaeozoic basement unit is consistently folded with a style and sense of vergence that closely resemble the structural features of the folded Silurian to Devonian strata described onshore (Curtis and Hyam, 1998; Aldiss and Edwards, 1999). The strong asymmetry of the folds seen in profile A resembles the style of D2 deformation as described in Aldiss and Edwards (1999), while the upright folding in the northern part of profile B is typical of the D1 foldbelt in the islands. These folds have been linked to the Gondwanide, Cape Fold Belt deformation

(Curtis and Hyam, 1998) and to local, fault-related displacements during rotation of the Falklands microplate (Aldiss and Edwards, 1999, p.73) and are not the result of an impact. The basement is truncated by a clear unconformity, as noted by Rocca et al. (2017). A widespread ?Upper Jurassic volcanic interval is typically associated with this unconformity (Gust et al., 1985) and is characterised by the high amplitude reflector observed on both profiles in Figure 2. Overlying this volcanic interval are a Lower to Upper Cretaceous interval and a Cenozoic interval. Neither the Cretaceous nor the Cenozoic intervals display any evidence of impact deformation, nor are there any traces of a faulted ring complex.

Rocca et al. (2017) describe a "rose"-like circular positive magnetic anomaly; contrary to their assertions, magnetic anomalies rarely have a consistent or simple correlation to impact structures. This is largely due to the fragmentation and mixing of rock during cratering (Pilkington and Grieve, 1992; Scott et al., 1997; French, 1998). While we do not dispute that some large impact structures (>40 km) display a high-amplitude anomaly of ~1000 nT limited to the central dome, it should be noted that most craters have a dominantly low magnetic response (Henkel and Guzman, 1977; Cisowski and Fuller, 1978; Robertson and Roy, 1979; Kukkonen et al., 1992; Pilkington and Grieve, 1992; Plado et al., 1996; Plado et al., 2000) [For a more complete review of the magnetic responses of impact craters see Scott et al. (1997)]. It is therefore considered unlikely that such a widespread positive magnetic high as observed to the west of the Falkland Islands would be related to a cratering process. It is also worth noting that the magnetic data in the region are sparse and any resulting grids are created from data interpolation, which should be used with caution. It would be very informative if Rocca et al. could provide maps of the magnetic data distribution.

Large magnetic anomalies can be plausibly explained by widespread volcanic rocks/igneous intrusions or basement lithologies with high remanent magnetism at shallow depths (Frese et al., 1982). Aldiss has made an unpublished suggestion (cited by Rocca et al.) that the large area of geophysical anomalies west of the Falklands could mark a volcanic centre. This would be a much larger structure than the volcanic centre proposed by Aldiss and Edwards (1999) to lie south-west of West Falkland, possible geophysical evidence for which is noted by Rocca et al. (2017). However, Rocca et al. (2017) refute the existence of a very large volcanic centre in the area by noting the absence of a large positive gravity anomaly, the lack of evidence for a volcanic centre on seismic data, and the lack of a topographic expression at the seabed. These points can easily be explained:

- gravity anomalies are caused by lateral density contrasts, which may or may not be due to lithology changes;
- while a volcanic centre is not clearly imaged in the seismic data, high-amplitude reflectors, interpreted as marking volcanic rocks, are widespread;
- the Jurassic interval does not reach the seafloor in the area covered by the gravity anomaly, so there is little seafloor expression.

Rocca et al. (2017) conclude that a negative gravity anomaly coincident with a positive magnetic anomaly is explained by a large, buried impact structure, yet this is not a unique solution. Frese et al. (1982) relate combined negative gravity and positive magnetic anomalies to areas of relatively thick crust and high magnetization.

The supposed crater outlined by Rocca et al. (2017) extends to overlap the westernmost islands of the Falklands archipelago (New Island and the Jason Islands), but there are no structural features exposed at these localities suggestive of impact-related deformation. On the contrary, the structure of the Jason Islands is concordant with that of north-western West Falkland and adjacent islands (Aldiss and Edwards, 1999). Given the proximity of the archipelago to the proposed impact site and the Permian age for the impact preferred by Rocca et al. (2017), some indication of the cataclysmic event might also be expected to have been preserved in the Permian succession at outcrop across the southern part of East Falkland. This succession has been well-studied (Lafonia Group: Aldiss & Edwards, 1999; Trewin et al. 2002) and there are no such indications. In their earlier discussion, Rocca and Báez Presser (2015) speculated that the earliest Permian-aged Fitzroy Tillite Formation, low in the Lafonia Group, could comprise an impact breccia despite the overwhelming evidence for its entirely glacigenic origin (Stone and Horan, 2016). We note that this speculation has not been repeated. Furthermore, if the impact is conveniently timed to be younger than the top of the Falklands Permian succession (possibly coinciding with the end-Permian mass-extinction) then, given the likely palaeogeography of the time (Torsvik and Cocks, 2017), some effect would be expected in the more continuous Permian succession of southern Africa's Karoo Basin.

In conclusion, we are highly sceptical of the interpretation of a geophysical feature to the west of the Falkland Islands in terms of a giant impact structure.

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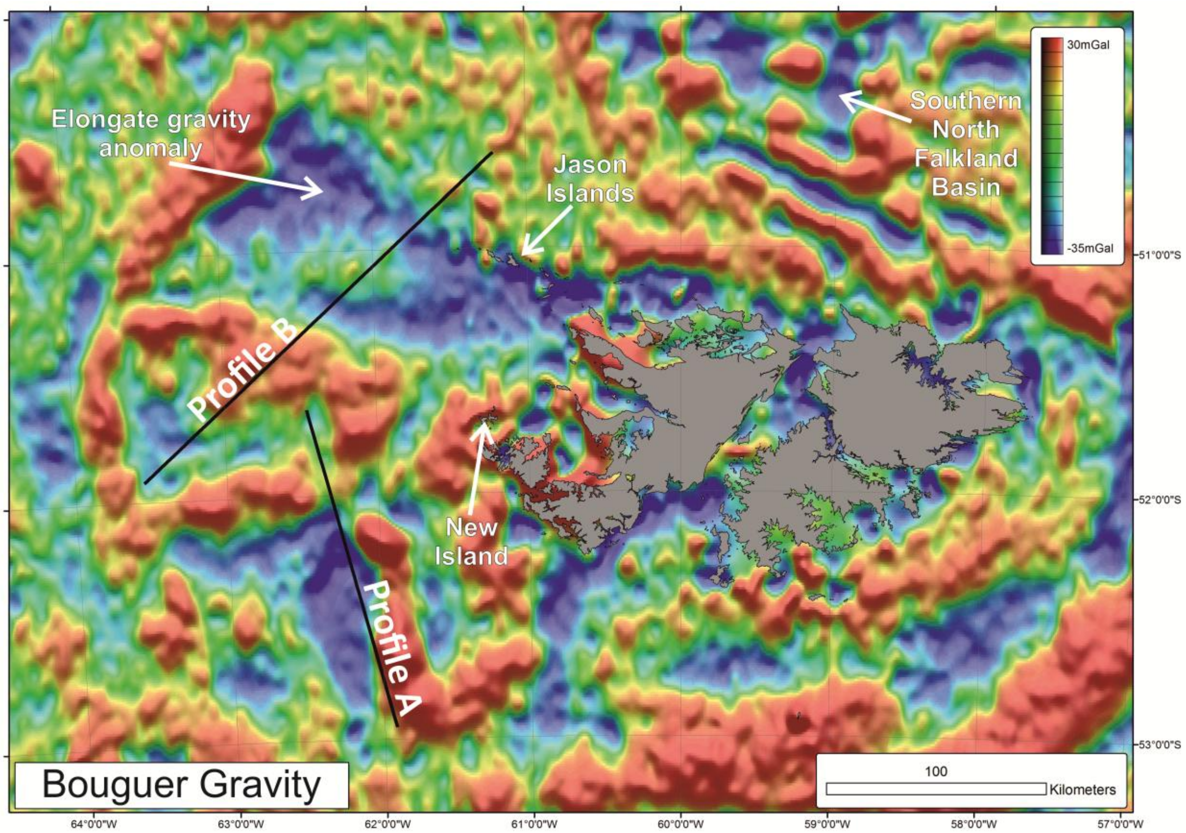
Figure 1

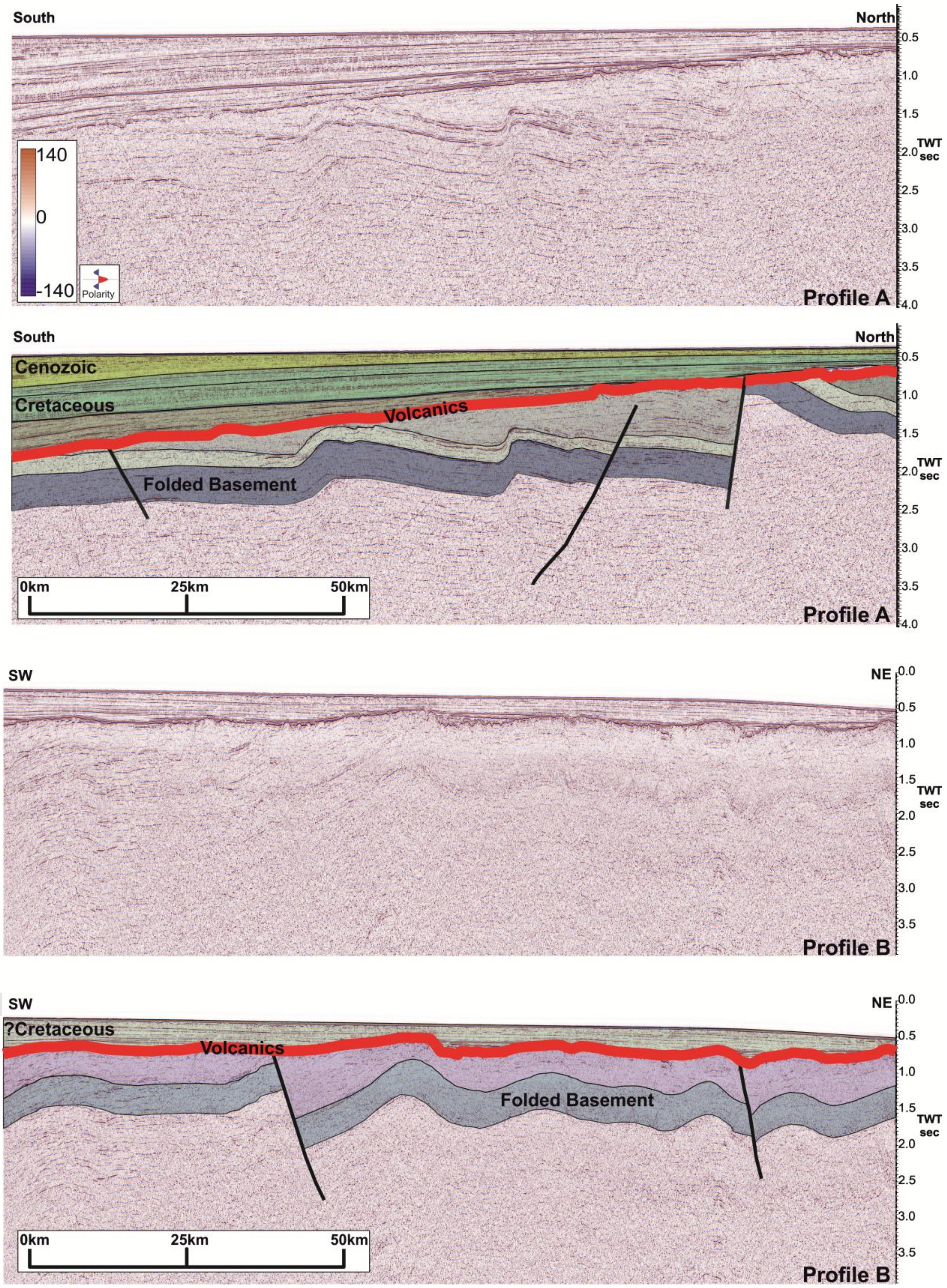
Bouguer gravity map of the western Falklands Plateau. No circular anomaly is observed.

Locations of seismic profiles A and B are illustrated.

Figure 2

Seismic data from the western Falkland Plateau. Reproduced by courtesy of WesternGECO. (A) Correct display of SGFI93-117, with an alternative interpretation below. (B) Display of SGFI93-100. This profile is better placed to provide insights into the gravity anomaly.

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