3 or 1? - 3D cone-sheet architecture provides insight into the centre(s) of Ardnamurchan

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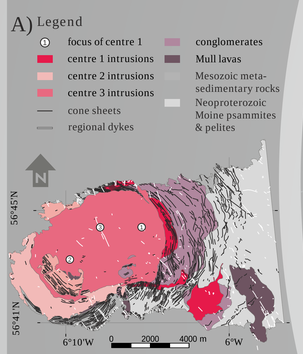
1. Introduction

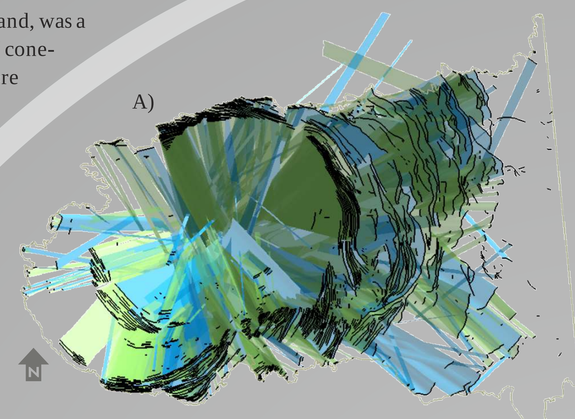
The Palaeogene Ardnamurchan igneous centre, NW Scotland, was a defining place for the development of classic concepts of cone-sheet, ring-dyke, and dyke emplacement. It holds therefore an iconic status among geologists and has influenced our understanding of subvolcanic structures fundamentally.

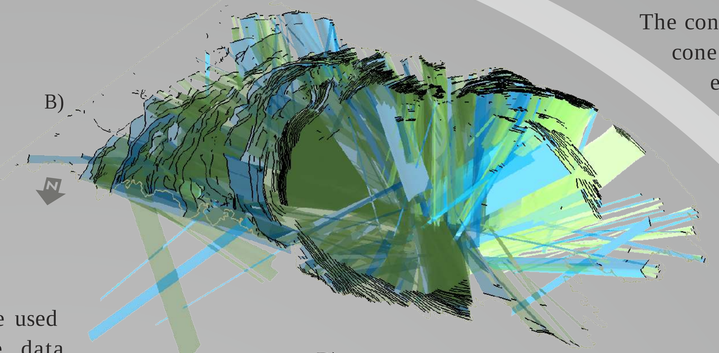
Mapping the Ardnamurchan rocks and structures, led Richey and Thomas (1930) to define three successive centres of activity (centres 1, 2, and 3) from the focal points of the exposed cone-sheet swarm(s) and their relative age relationships with major intrusions (Fig. 1).

Figure 1. A) Simplified geological map of the Ardnamurchan complex. B) Cone sheet at the southern coast. View NNE.

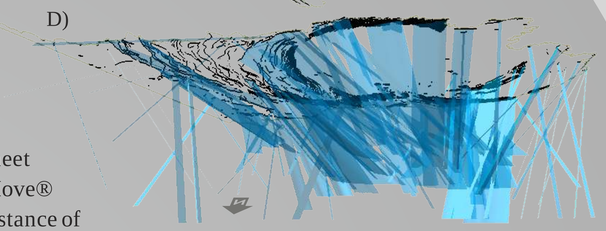


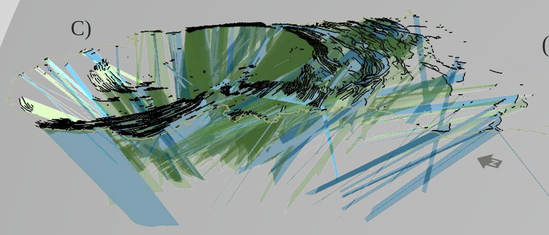
2. 3D cone-sheet architecture

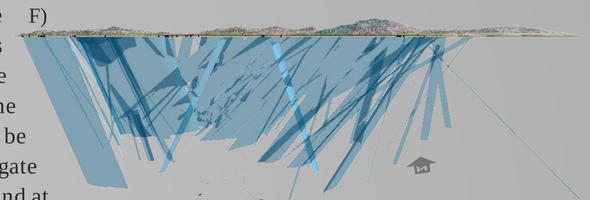


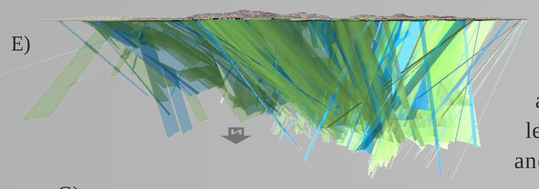


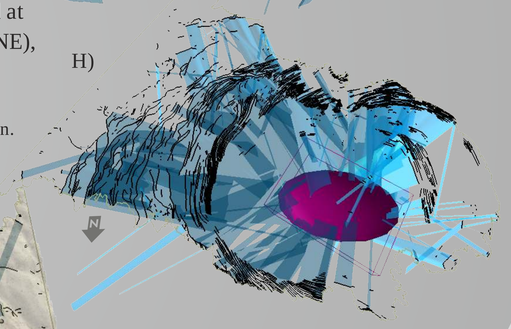
We used the data on cone-sheet strike, dip direction and dip by Richey and Thomas (1930) and Emeleus (2009) and projected the traces of 797 cone sheets down-dip to produce a 3D image of Ardnamurchan's cone-sheet architecture (Fig. 2) with the software package Move® (Midland Valley Ltd.). We chose a projection distance of 5000 m and a straight projection geometry. The 3D image shows that the majority of the projected cone sheets converges in the subsurface beneath the central part of the Ardnamurchan peninsula (Fig. 2). Individual focal points of cone sheets, such as the three centres of Richey and Thomas (1930) cannot be distinguished. Instead, cone-sheet projections concentrate in an elongate area that can be illustrated as an ellipsoid, about 5000 m × 3000 m wide and at least 2000 m thick. The long axis of the ellipsoid strikes approximately 070° (NE), and its top is located at about 1500 m below the present land surface.











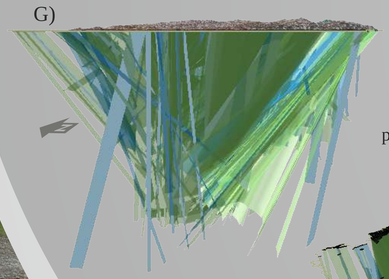
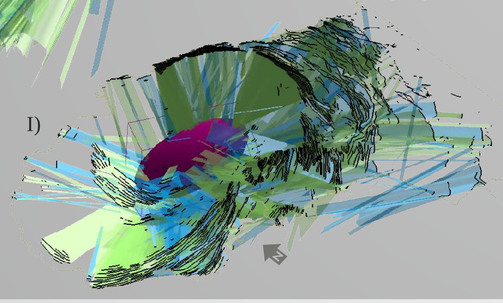
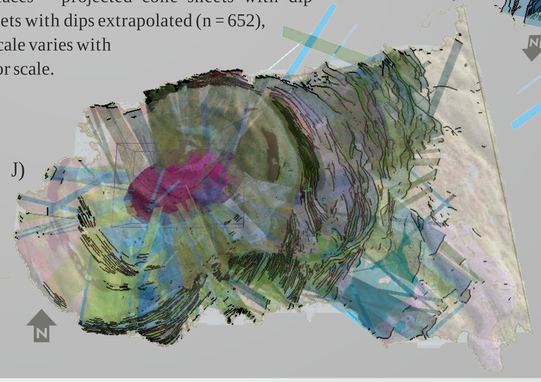


Figure 2. Different perspective views of the 3D model of the cone-sheet architecture of Ardnamurchan. Projections are based on maps by Richey and Thomas (1930) and Emeleus (2009). Brown = coast line, black = map traces of cone sheets, blue surfaces = projected cone sheets with dip measurements (n = 145), green = projected cone sheets with dips extrapolated (n = 652), purple = area of cone sheet convergence (focal area). Scale varies with perspective. See Fig. 1 for scale.





3. Discussion

The concept of a single, elongate magma reservoir feeding the cone sheets of Ardnamurchan is consistent with (i) the ellipticity of major intrusions, (ii) the shape of the underlying Bouger gravity anomaly, (iii) the sedimentary depositional record and the deformation pattern in the country rocks, and (iv) the shape of the peninsula (Fig. 3). A dynamically evolving magma reservoir would also imply a rather small age range of cone sheets and would exempt the Ardnamurchan volcano from extreme longevity, which is in line with the age of other centres in the area.

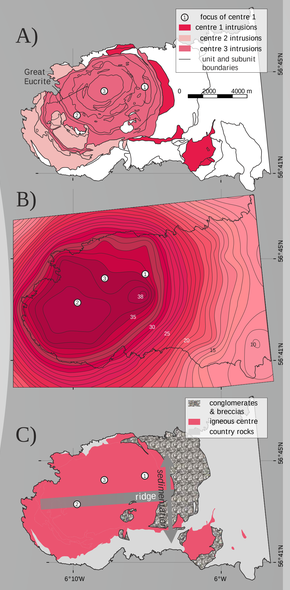
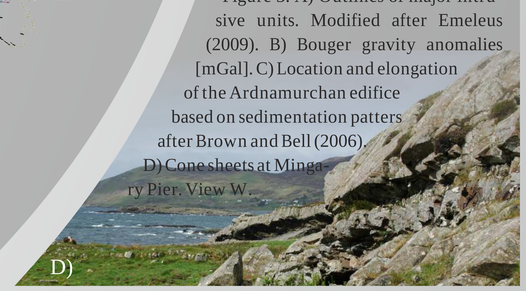


Figure 3. A) Outlines of major intrusive units. Modified after Emeleus (2009). B) Bouger gravity anomalies [mGal]. C) Location and elongation of the Ardnamurchan edifice based on sedimentation patters after Brown and Bell (2006). D) Cone sheets at Mingary Pier. View W.



References: Brown, D. J. & Bell, B. R. Intrusion-induced uplift and mass wasting of the Palaeogene volcanic landscape of Ardnamurchan, NW Scotland. Journal of the Geological Society, London 163, 29-36 (2006). - Emeleus, C. H. for British Geological Survey. Ardnamurchan Central Complex. Bedrock and Superficial Deposits. 1:25 000 Geology Series. Keyworth, Nottingsham (2009). - Richey, J. E. & Thomas H. H. The geology of Ardnamurchan, northwest Mull and Coll. Geological Survey of. Scotland Memoirs HMSO, 393 p. (1930).