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Geological evolution of sub-unconformity basement highs in rifted margins

1. Background

Basement 'highs' or 'buried hills' are often uplifted footwall blocks formed by syn-rift normal faults. The initial spacing and segmentation of the syn-rift faults controls the across- and along-strike size of basement highs as well as the amount of tilting and uplift that occurs. These footwall highs may be eroded when above base levels, and while at surface, fissure formation, mineralisation and sediment filling can occur and preserved beneath regional unconformities (see Holdsworth et al 2019, 2020 and Fig. 1).

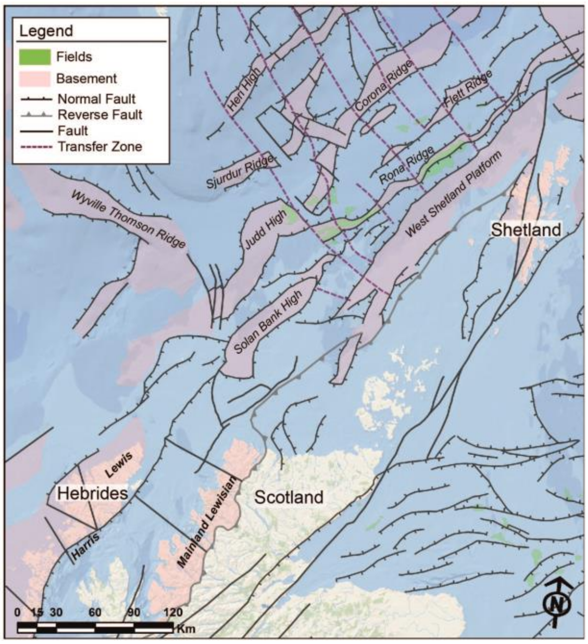

Figure 1 Basement highs in the Faroe-Sheltand basin (modified from McCaffrey et al in review)

The development of tensile fissures and faults in strong crystalline rocks, carbonates or other low porosity rocks close to the surface during tectonic extension enables the development of naturally propped networks of deeply penetrating structures with high porosities and permeabilities. Following burial beneath a regional (or local) unconformity, these partially-filled fissure systems are then potential sites for the accumulation and storage of large volumes of aqueous fluids and/or hydrocarbons leading to the development of major aquifers, geothermal or petroleum reservoirs. The potential economic significance of basement highs remains largely unexplored.

In this project, you will investigate how and why sub-unconformity basement highs develop within rifted continental crust and how they become modified while exposed at surface and subsequently buried.

2. Methods and Timeline

The project is a combination of seismic interpretation, fieldwork and geodynamic modelling. The various parts of this project are designed to assess 1) how basement highs develop and their 3D morphologies, 2) what happens to the highs over time while they are at surface and subsequently when they become buried highs.

Year 1 will involve literature review and mapping examples of well-constrained basement highs using Petrel on 2D and 3D publically released data seismic sets in areas of NW Australia, SW New Zealand and the UK continental shelf. This mapping along with borehole-constrained basin histories will enable an assessment of the degree of erosion of the basement highs and their longevity as a high.

Years 2-3. Given the highs are likely to be footwall blocks on normal faults, you will also create a series of basin-scale models using the ASPECT geodynamic modelling software to replicate fault blocks topography in 3D (based on templates that replicate mapped rift morphologies). Constraints on basement types will also be incorporated into models where they might influence the uplift patterns, e.g. density contrasts.

You will also collect/augment analogue data on the brittle structures within a number of different basement terrains this will include a Hebrides example, where we have much existing data but we also need to update our present models based on newly discovered fissure systems associated with normal faults.

In Year 3-4, you will incorporate these data into models of basement highs developed from their own mapping with 3D morphology defining the overall container shape and size (e.g. Fig 2). They will then vary the internal structure to reflect different geohistories (from analogue fracture fills, geometrical and size atributes) and make a (numerical) comparison of volumetrics and connectivity for different scenarios building on McCaffrey et al In review).

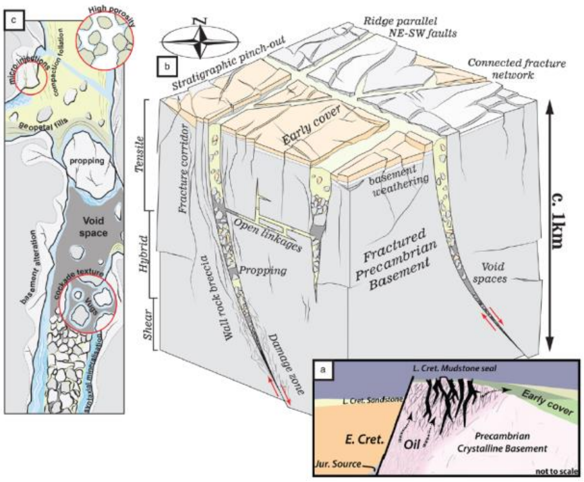

Figure 2 Fissure formation in buried basement highs (Holdsworth et al 2020)

Year 4 will involve manuscript/thesis writing and submission. Anticipated research outputs - 1) case studies of basement highs and their evolution including a classification scheme, 2) models of fault segmentation and slip distributions, the resulting footwall uplifts and their evolution and 3) fluid flow schemes for different basement high types – with comparisons and where possible calibrations from known examples.

3. Training

You will become part of a vibrant research culture in the department of Earth Sciences, in which ~80 postgraduate students work on a wide range of Earth Science research projects. In particular, you will closely collaborate with the academic staff, postdoctoral researchers and fellows, and postgraduate students in the geodynamics, tectonics, and geophysics research groups.

Training will be provided in seismic interpretation, structural analysis methods and geodynamical modelling. The project is an opportunity you to become proficient in sub-surface geological mapping, outcrop-scale structural geology and computer programming and modelling. ASPECT is open source with an importance placed on member participation in development (see here).

The CDT studentship incorporates a 20 week bespoke residential classroom and field-based training programme spread out over the first 3 years of the studentships. The aim of this training is to broaden your understanding of the applications of geoscience and provide you with additional skills valued by future employers.

References & reading

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