Geophysical Research Abstracts
Vol. 14, EGU2012-3543-1, 2012
EGU General Assembly 2012

Cenozoic right-lateral slip on the Great Glen Fault, Scotland: Additional Evidence and Possible Causes

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The Great Glen Fault (GGF) trends NNE-SSW across all of Northern Scotland, separating two Neoproterozoic supergroups (Moine and Dalradian). The GGF developed as a left-lateral fault during the Caledonian Orogeny (Ordovician to Early Devonian). However, according to previous studies (involving seismic data from the Moray Firth and analyses of Tertiary dyke swarms in NW Scotland), the GGF reactivated right-laterally in the Tertiary. Here we present additional evidence for this later phase, from a study of Jurassic outcrops along the GGF and the nearby Helmsdale Fault.

At Eathie and Shandwick, on the NE coast of Scotland, Jurassic strata of marine origin (mostly shale) crop out along the GGF, in contact with Neoproterozoic basement or Devonian Old Red Sandstone. Minor folds and faults in these outcrops indicate post-depositional right-lateral slip, under transpression. In the shale, we have also found bedding-parallel calcite veins ('beef' and 'cone-in-cone'). If these veins provide evidence for overpressure development and maturation of organic matter at significant depth (as they do in other basins), the host sediment must have accumulated deeper offshore in the Moray Firth. Therefore, the Jurassic strata at Eathie and Shandwick must have been subject to Cenozoic exhumation during right-lateral displacement along the GGF.

At Helmsdale, according to previous studies, the Jurassic 'Boulder Beds' accumulated during a period of normal faulting on the Helmsdale Fault. There the sedimentary facies are more proximal than those at Eathie and Shandwick and abundant conglomerate contains Devonian clasts but no 'beef'. However we have found steep calcite veins, which cut the entire Jurassic sequence. Their sigmoidal shapes indicate left-lateral slip along the Helmsdale fault zone. Such a motion is compatible with right-lateral displacement on the GGF. Indeed, according to previous studies, folds between the Helmsdale Fault and the GGF may have developed as a result of opposing senses of slip on these two faults.

Again according to previous work, some possible causes of Cenozoic reactivation of the GGF are: (1) intra-plate compression from the Alpine Orogeny, (2) ridge push from the NE Atlantic and (3) compression due to the Iceland Mantle Plume. Here we consider a fourth possibility, which is differential sea-floor spreading in the NE Atlantic. We have shown elsewhere, by palinspastic restoration, that variations in the direction and rate of sea-floor spreading, between the Reykjanes, Aegir and Mohns ridges, generated left-lateral transpressional displacements along oceanic fracture zones, especially the Faeroe Fracture Zone (FFZ). These displacements along fracture zones may have been responsible for post-rift compressional deformation on the continental margin of NW Europe. Indeed, left-lateral slip along the FFZ is compatible with right-lateral reactivation of the GGF.