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Journal of Geochemical Exploration 89 (2006) 96–99
JOURNAL OF GEOCHEMICAL EXPLORATION
www.elsevier.com/locate/jgeoexp

Remagnetization and fluid flow in the Old Red Sandstone along the Great Glen Fault, Scotland

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Received 18 August 2005; accepted 7 November 2005
Available online 22 March 2006

Abstract

The Devonian Old Red Sandstone in the vicinity of the Great Glen Fault (GGF) in Scotland contains two different components residing in hematite: a postfolding Carboniferous CRM1 in the Loch Ness area and a Cretaceous or perhaps Triassic CRM2 near Hilton. The CRM1 could be related to major fluid flow events in the Late Paleozoic which caused hematite authigenesis and remagnetization along other faults in Scotland. The CRM2 near Hilton was also related to a fluid event in the Cretaceous or Triassic which caused hematite authigenesis. The presence of different CRMs residing in hematite along different segments of the GGF is similar to what has been reported for other major faults in Scotland.

Keywords: Remagnetization; Old Red Sandstone

1. Introduction

Recent paleomagnetic, petrographic, and geochemical studies in Scotland document that major faults have been conduits for fluids that caused chemical remanent magnetizations (CRMs). These CRMs can be used to date the fluid migration events along the faults such as the Highland Boundary (HBF) and the Moine Thrust Zone (MTZ) (e.g., Elmore et al., 2002; Blumstein et al., 2005). Little is known, however, about fluid flow along the Great Glen Fault (GGF), another major fault in Scotland. Here we present the results of a preliminary study of the Devonian Old Red Sandstone (ORS) in the vicinity of the GGF to determine if the rocks contain evidence for fluid alteration that can be dated using paleomagnetism. In addition, we will test if there are magnetizations of different ages along different segments of the fault.

2. Geological setting

The GGF extends from near Inverness to the south part of the Isle of Mull. The GGF separates the Moine rocks, composed of metasediments, from the Dalradian metasediments to the south. In the east, the ORS is exposed along both sides of the GGF.

Samples were collected from red fine to medium grained alluvial sandstone in the Lower ORS in the tightly folded syncline in the Mealfaurvonie Outlier (Mykura and Owens, 1983) on the northwest side of Loch Ness. The fold, as well as thrust and normal faults, are of Late Devonian age (Mykura and Owens, 1983). A

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doi:10.1016/j.gexplo.2005.11.034

few sites were also collected from sandstones in the Middle ORS on the southeast side of Loch Ness north of Foyers, which were deformed in the Devonian (Mykura, 1983).

To the north of Loch Ness samples were collected from the Middle ORS on the east limb of the Inver-Black Isle syncline northwest of the GGF along the shore adjacent to the Inner Moray Firth near the town of Hilton. The lithologies sampled here include fluvial red and green sandstone, as well as bituminous shales/limestones deposited in lakes (Johnstone and Mykura, 1989). Geologic evidence suggests that displacement occurred along the GGF in the Permian in the Inner Moray Firth region (Roberts et al., 1990).

Most previous paleomagnetic studies of the ORS have been from the Orcadian Basin north of the GGF in Caithness and the Orkney Islands. In a summary of previous paleomagnetic studies, Tarling (1985) proposed that there were two main components of magnetization in the ORS in Scotland. Component B has southerly declinations and horizontal inclinations that were interpreted as Carboniferous in age. Component A has south–southeasterly declinations and moderate negative inclinations that were interpreted as Permian in age. Most of these magnetizations were interpreted as CRMs. Plaster-Kirk et al. (1995) reported a reversed Carboniferous CRM residing primarily in magnetite in the organic-rich lacustrine carbonate laminates from the Orcadian Basin. Several previous studies focused on the possibility of considerable sinistral offset along the GGF (e.g., Van der Voo and Scotese, 1981; Torsvik et al., 1983; and numerous others) which was shown to be untrue.

3. Paleomagnetic and other methods

Samples were collected from sites (commonly 6 to 8 samples per site) using a hand-held drill and oriented with an inclinometer and Brunton compass. Samples were collected for a fold test on the northwest side of Loch Ness. We also attempted to collect samples away from the GGF for a contact (fault) test, but the outcrops did not allow for progressive sampling away from the fault.

Paleomagnetic measurements were acquired using a 2G Enterprises cryogenic magnetometer. Specimens were subjected to stepwise thermal demagnetization in 15–20 steps and representative specimens were subjected to alternating field (AF) demagnetization. Directions were determined using principal component analysis with mean angular deviations (MAD) of less than 15°. Fisher's (1953) statistics were used to compute the mean directions. Preliminary petrographic studies were conducted by examining thin sections in transmitted and reflected light to identify the magnetic mineralogy.

4. Results and interpretations

The AF demagnetization does not remove a stable magnetization in red specimens from the different locations. Thermal demagnetization of the ORS specimens from the Loch Ness area removes a characteristic remanent magnetization (ChRM1) with southerly declinations and shallow inclinations (Table 1). In sites which have low N/N_o values (e.g., D1 and LN2; Table 1), most specimens which were not used in the statistical analysis contained the ChRM1 but their MAD angles were greater than 15°. In some specimens the ChRM1 is removed from 300 to 650–680 °C whereas in other specimens the ChRM1 is removed over a lower temperature range. Removal of a significant fraction of the ChRM1 between 580 and 680 °C and the lack of AF decay suggests that the ChRM1 resides in hematite. Preliminary petrographic studies indicate that coarse detrital hematite and several forms of authigenic hematite (e.g., as pigment with clay around grains and

Table 1
Paleomagnetic data

Site # N/N_o	In situ		k	α_{95}	Tilted	
	Dec (°)	Inc (°)			Dec (°)	Inc (°)
Middle ORS — Mealfaurvonie Outlier						
D1 4/7	147.8	6.6	55.0	12.5	146.4	−42.2
D3 6/6	153.0	11.6	17.7	16.4	154.5	−32.8
D4 5/9	167.1	10.7	15.5	17.5	170.6	−30.5
D6 6/6	183.4	−6.7	52.2	9.4	197.9	−38.7
LN2 4/8	175.9	−2.7	14.5	20.8	199.1	45.5
LN4 9/9	209.7	19.6	13.2	14.7	237.3	61.8
LN5 7/10	200.3	10.2	12.9	17.5	211.3	8.0
Lower ORS — east side of Loch Ness						
LNE1 5/6	185.5	−29.6	15.3	20.2	202.5	40.9
LNE2 5/5	182.6	7.7	7.6	29.8	186.5	17.0
Middle ORS — Hilton						
H2 6/6	202.9	3.0	18.2	16.1	203.4	9.2
H3 6/6	173.1	−43.8	230.1	5.1	171.1	−37.0
H6 6/9	180.7	−50.6	49.6	9.6	178.4	−50.6
H7 8/8	181.9	−42.6	73.9	6.5	180.0	−34.9

N/N_o — number of specimens with direction versus number of specimens demagnetized; in situ — geographic coordinate direction; tilted — stratigraphic coordinates; Dec — declination; Inc — inclination; k — precision parameter; α_{95} — cone of 95% confidence. Site H2 is from the laminate beds and H3, H6 and H7 are from red sandstones.