GEOCHEMISTRY OF THE BUDE AND BIDEFORD FORMATIONS, DEVON

S. DISKIN

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The depositional relationship of the Bude and Bideford formations is not fully understood, therefore a geochemical study was undertaken to help elucidate it. Twenty one samples were collected from mudstones and siltstones from the Bude and Bideford (including Westward Ho!) formations and were analysed for major and trace (including REEs) elements as determined by ICP-AES and ICP-MS. Major and trace element results, in general do not suggest any differences between the geochemistry of the two formations. However, for REEs, two non-overlapping fields can be drawn showing the distribution of La_N/Sm_N against Gd_N/Yb_N. The Bideford Formation shows a comparative enrichment in LREEs and depletion in HREEs as would be expected for sediments with more Archaean crustal input. The Bude Formation sediments all fall into a field comparable with the Westphalian of South Wales, whereas the Bideford Formation sediments do not, indicating that they may not be depositionally related.

Geology Department, University of Botswana, P/Bag 0022, Gaborone, Botswana.
(E-mail: diskins@mopipi.ub.bw).

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INTRODUCTION

The significance of sedimentary geochemistry in determining the provenance of sedimentary suites, their evolution, and source weathering is well established (Bhatia, 1983; Condie *et al.*, 1995; Cullers, 1994a and b; Cullers *et al.*, 1987, 1988; McLennan *et al.*, 1990, 1993; Roser and Korsch, 1986; Roser and Korsch, 1988; Wronkiewicz and Condie, 1987). The relationship between the tectonic setting and variables such as provenance, relief, physical sorting and weathering, control the composition of sediments. Immobile trace element compositions and rare earth element (REE) abundances of sediments are good indicators of source rock chemistry, since these elements are little-fractionated by sedimentary processes and low grade metamorphism (Taylor and McLennan, 1985; McLennan, 1989). The relationship between the geochemical composition, the provenance of sediments and the tectonic setting can be a useful tool in elucidating information from ancient rocks. The use of major (Bhatia, 1983; Roser and Korsch, 1986, 1988) and trace element (Bhatia and Crook, 1986) compositions in diagnostic diagrams has been used in determining tectonic settings of deposition for sedimentary rocks. Here an attempt is made to examine the relationships of the sediments deposited in the Westphalian Culm Basin of Devon and Cornwall to ascertain the likelihood of their having the same source by considering their geochemical signatures.

GEOLOGICAL SETTING

Within the Culm Basin of Cornwall and Devon, the sedimentary rocks comprise mainly marine deposits (Thomas, 1988) and two distinct sedimentary sequences are recognised, namely the Bude and Bideford formations (Hartley, 1993). The Westphalian Bude Formation comprises some 1300 m of mudstones and laterally extensive sandstones which show many similarities to the Crackington Formation (Freshney *et al.*, 1980). Flute casts and tool marks show palaeoflows from all directions except the south (Higgs, 1984). The Westward Ho! Formation, which crops out on the northern side of the Culm Basin, is partially equivalent in age to the Crackington Formation and consists of coarsening upward cycles indicating progressive shallowing (Higgs *et al.*, 1991). The overlying Bideford Formation comprises nine large-scale (50-100 m) coarsening upwards cycles, with dark grey shales at the base passing gradually upwards into feldspathic sandstones (Eager and Li, 1993). The Bideford Formation may be a lateral equivalent of the upper part of the Crackington Formation and part of the lower Bude Formation (Higgs *et al.*, 1991).

The Culm Basin is separated from the South Wales Basin by the Bristol Channel Fault Zone (Freshney and Taylor, 1980). The original relationship between these depositional areas is unclear with major differences between the Upper Carboniferous of the Culm Basin, and that of the coal bearing basins to the north (Guion *et al.*, 2000). Various issues have thrown doubt on a straightforward relationship with South Wales, and that of the accepted northerly provenance for many of the sandstones (Thomas, 1988). It is difficult to make meaningful palaeogeographic reconstructions, at present, of the Upper Carboniferous of the Culm Basin on account of the post depositional tectonic shortening and unknown relative positions of the Bude-Crackington and Bideford-Westward Ho! sequences. However, most workers consider the Bideford-Westward Ho! succession to have been deposited on the shallow northern margin of the deeper water Culm Basin in which the Bude and Crackington formations were deposited (Guion *et al.*, 2000).

Description of samples and analysis

Samples were taken from stratigraphically well-known sections in the Westphalian Bude and Bideford (including Westward Ho!) formations of the Culm Basin (Table 1, Figure 1), and provide examples of typical sediments and as such were expected to give the best picture of variations in the regional sediment geochemistry / provenance. Samples were taken from quarries, coastal cliffs and road cuttings, where material obtained was as fresh as could be expected from surface sampling (Table 1). While only a few grammes of powdered sample are required for analysis, samples obtained were as large as possible to obscure local peculiarities; similarly very coarse grained material was avoided to prevent bias caused by a single large pebble. The rocks sampled mainly comprised mudstones with some siltstones and fine grained sandstones.

Sample no.	Grid ref	Location	Rock type	Comments
00-08/9	SS451273	Bideford	Siltstone	Bideford Fm.
98-03/2	SS224247	Hartland	V.f.g.s	Bideford Fm.
99-08/9	SS224246	Hartland Quay	V.f.g.s	Bideford Fm.
99-04/3	SS323246	Clovelly	Siltstone	Bideford Fm.
00-08/7	SS453274	Bideford	Siltstone	Bideford Fm.
98-05/4	SS412282	Westward Ho!	Mudstone	Westward Ho! Fm
98-05/8	SS412280	Westward Ho!	Siltstone	Westward Ho! Fm
98-05/9	SS411278	Westward Ho!	Siltstone	Westward Ho! Fm
98-05/18	SS411280	Westward Ho!	Siltstone	Westward Ho! Fm
98-05/15	SS410277	Westward Ho!	Mudstone	Westward Ho! Fm
98-05/10	SS411281	Westward Ho!	Siltstone	Westward Ho! Fm
98-05/5	SS411279	Westward Ho!	Siltstone	Westward Ho! Fm
99-06/3	SS247275	Shipload Bay	Mud/silt	Bude Fm.
98-03/1	SS197027	Widmouth Bay	V.f.g.s	Bude Fm.
99-08/6	SS202101	Sandy mouth, Devon.	Siltstone	Bude Fm.
99-08/7	SS202087	Northcott Mth., Dev	Sand/mud	Bude Fm.
98-03/4	SS197028	Widmouth Bay, Bude	V.f.g.s	Bude Fm.
00-08/12	SS393255	Abbotsham	Siltstone	Bude Fm.
99-06/2	SS397260	nr. Abottsham	Siltstone	Bude Fm.
98-03/5	SS197026	Widmouth Bay, Bude	V.f.g.s	Bude Fm.
99-08/8	SS202102	Sandy mouth, Devon.	Siltstone	Bude Fm.

Table 1. *Sample locations for sedimentary rocks of the Bude and Bideford formations. (V.f.g.s is very fine grained sandstone).*

Twenty-one samples of mudstone to fine-grained sandstone were analysed for major and trace elements (including REEs). Although some authors have suggested only fine grained rocks should be considered (Clauer and Chaudhuri, 1992), others such as Leng *et al*. (1999) demonstrated that in the Pennine Basin the grain-size of the sediments used makes no difference to the elemental results obtained on the basis of genetically related sandstone-siltstone-mudstone triplets.

All samples were cleaned of weathered surfaces and then crushed to <2 cm before being ground to a <200 µm powder in a tungsten-carbide Tema mill. Chemical analyses of the bulk sediments were performed at Chemex Laboratories in Canada or at Oxford Brookes University, using a combination of ICP AES and ICP MS, with samples repeated to ensure analytical consistency. The samples were prepared for major element analysis by fusion dissolution. A similar process was followed by preconcentration by cation exchange for rare earth elements, and an HF-$HClO_4$ acid dissolution was used for other trace elements. All solutions were determined against calibrations defined with international standard rocks materials (SRMs). Accuracy and precision are estimated to be better than 5% rsd on the basis of SRM results and replicate analyses

Results

Major element abundances in the sedimentary rocks of the Culm Basin (Table 2) show considerable variation. SiO_2 contents range from 52.4 wt% in Sample 98-05/15 (mudstone) to 70.5 wt% (Sample 99-08/6 - siltstone), though most samples lie in the narrower range of 60–68 wt%. The Al_2O_3 contents vary inversely with SiO_2 (14.2–23.8 wt%), with most samples containing 14–24 wt%. A Harker variation diagram shows a negative correlation between SiO_2 and Al_2O_3 (Figure 2a). The group of samples from both the Bude and Bideford formations form a linear array.

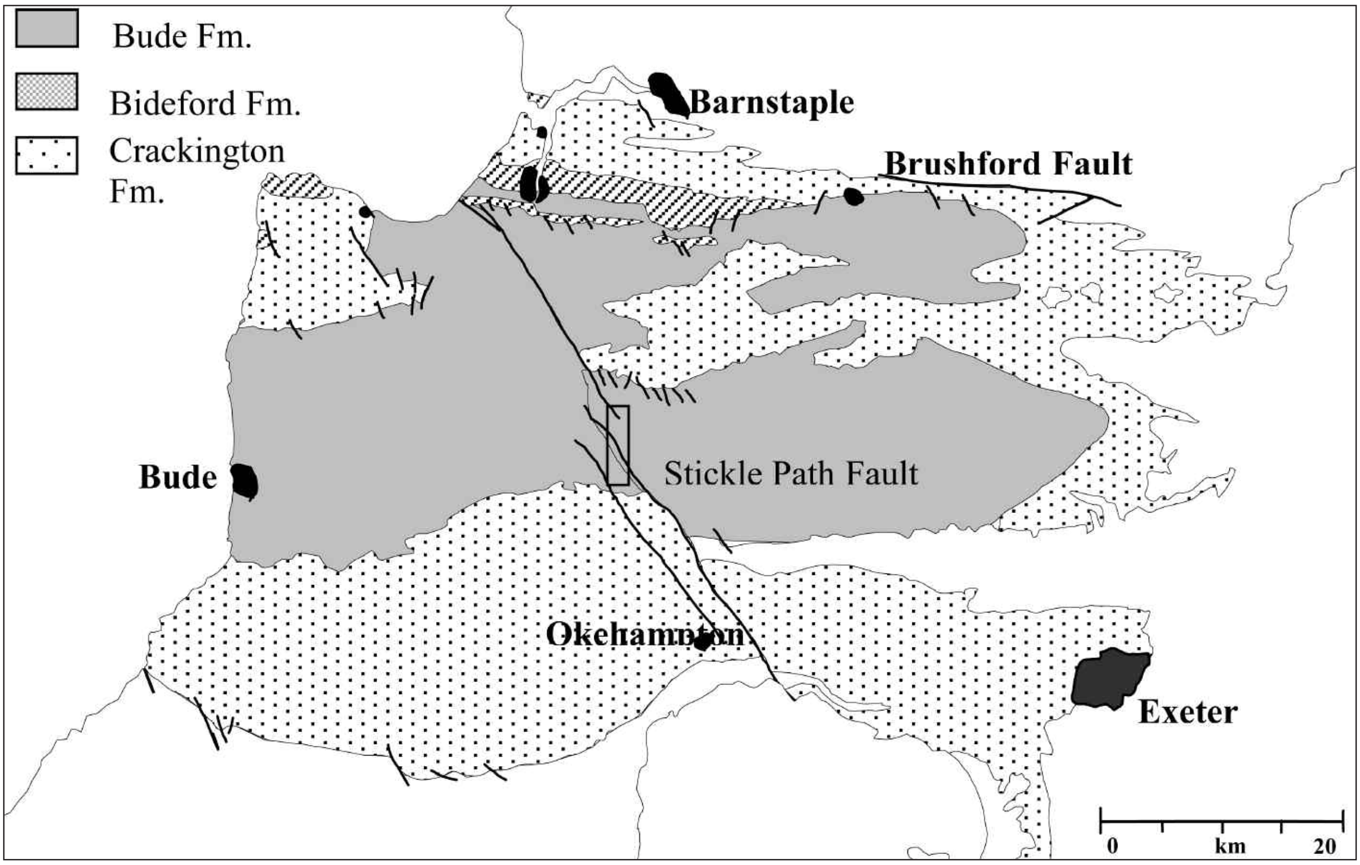

Figure 1. *Generalised geology of the Culm Basin after Thomas (1988).*

Sample	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Subtotal	LOI	Total
00-08/9	61.18	1.08	16.93	7.88	0.18	1.76	0.08	1.32	2.68	0.68	95.77	4.68	100.50
98-03/2	65.55	1.12	16.58	5.15	0.06	1.41	0.17	1.28	2.68	0.34	94.38	5.46	99.80
99-08/9	61.71	1.20	18.99	5.29	0.04	1.61	0.16	1.52	3.60	0.31	94.42	4.95	99.40
99-04/3	65.42	1.08	14.93	7.69	0.17	1.82	0.09	1.30	2.99	0.84	96.34	3.58	99.90
00-08/7	63.46	1.09	17.23	6.58	0.17	1.65	0.13	1.40	2.99	0.54	95.23	4.65	99.90
98-05/4	54.88	1.89	19.64	6.31	0.10	1.93	0.32	0.33	3.61	0.64	89.67	9.39	99.10
98-05/8	65.42	1.08	14.93	7.69	0.17	1.82	0.09	1.30	2.99	0.84	96.34	4.28	100.60
98-05/9	62.39	1.08	16.40	7.78	0.16	1.71	0.08	1.29	2.75	0.71	94.35	4.98	99.30
98-05/18	62.89	1.09	16.90	7.88	0.16	1.71	0.08	1.29	2.75	0.71	95.46	4.11	99.60
98-05/15	52.42	0.88	23.77	5.76	0.09	1.98	0.32	0.26	3.61	0.44	89.55	10.28	99.80
98-05/10	67.18	1.04	16.25	7.27	0.11	1.66	0.06	1.35	2.29	0.57	97.78	2.48	100.30
98-05/5	58.42	0.88	23.77	5.76	0.09	1.98	0.32	0.26	3.61	0.44	95.55	4.26	99.80
99-06/3	69.13	1.14	17.36	2.91	0.08	1.27	0.15	1.95	1.92	0.25	96.15	5.16	101.30
98-03/1	66.34	1.47	15.41	5.61	0.09	1.32	0.18	0.68	2.68	0.51	94.28	5.68	100.00
99-08/6	70.50	0.98	14.66	3.21	0.06	0.87	0.14	1.15	2.32	0.17	94.05	5.07	99.10
99-08/7	69.40	1.05	14.17	5.01	0.09	1.20	0.18	1.03	1.75	0.38	94.25	5.98	100.23
98-03/4	63.88	1.89	16.64	5.81	0.10	1.43	0.17	0.33	3.61	0.64	94.51	5.38	99.90
00-08/12	59.52	1.08	22.87	5.16	0.18	1.91	0.10	1.06	2.91	0.68	95.49	4.61	100.10
99-06/2	63.28	0.94	17.99	8.66	0.11	1.71	0.07	1.22	2.31	0.87	97.16	2.78	99.90
98-03/5	66.13	1.22	16.97	5.09	0.92	1.27	0.15	1.06	1.90	0.41	94.70	5.47	100.17
99-08/8	68.46	1.15	15.31	4.97	0.10	1.30	0.17	0.72	2.65	0.48	94.82	5.35	100.17

Table 2. *Major element data (Wt. %).*

Among the other major elements, only MgO shows any clear correlation with Al_2O_3 (Figure 2b) but has a low abundance MgO (<2%), this may be related to the presence of clinochlore $(Mg_5Al)(Si_3Al)O_{10}(OH)_8$. Using LOI as a proxy for Corg there appears to be no correlation of elemental trend with carbon. Abundances of CaO (<1%), and Na_2O (<1.5%), are generally low and show no correlation with Al_2O_3 or Corg (Figure 2c–d), whereas K_2O contents are moderate (<4.9%) and weakly correlated with Al_2O_3 (Figure 2e). P_2O_5 contents are generally low (<0.2 wt%) in samples with low or moderate Corg, but some higher values (0.6 wt%) occur in Corg-rich samples (Figure 2f).

The trace elements analysed (Table 3) can be divided into groups according to their correlation with Al_2O_3. Most incompatible elements, including Nb, Th, Ga, Y and REEs, are moderately strongly correlated with Al_2O_3 abundances, whereas Sc and Co show no correlation with Al_2O_3, and Zr has a strong negative correlation. More mobile elements including Ba and Sr also show a moderate to strong positive correlation with Al_2O_3. The final group of trace elements (Cr, Ni, and V) generally have low abundances (<200, <40, and <130 ppm, respectively) and show moderate correlation with Al_2O_3.

Figure 3 shows Chondrite normalised plots for a selection of typical samples from the Culm Basin (Taylor and McLennan, 1985). On first glance all the samples from both the Bude and Bideford formations show very similar patterns and display a pattern typical of post Archaean sediments with LREE enrichment and fairly flat HREE patterns. Total REE abundances are variable, although this is primarily controlled by variable dilution from quartz, and range from 92 to 243 ppm, averaging 174 ppm, slightly less than that of average post-Archean Australian shale (PAAS) and greater than average upper continental crust (UCC) (183 and 146 ppm, respectively; Taylor and McLennan, 1985)(Table 4).

Chondrite-normalised REE parameters show similar variability, with La_N/Yb_N ratios of 7.96–12.23 (average 9.7); La_N/Sm_N 3.57–5.92 (average 4.58), and Gd_N/Yb_N 1.14–1.52 (average 1.32). The averages of these ratios are comparable with those in both PAAS (La_N/Yb_N 9.17; La_N/Sm_N 4.27; Gd_N/Yb_N 1.36) and UCC (9.21, 4.20, 1.40, respectively) (Taylor and McLennan, 1985). All samples have Gd_N/Yb_N ratios between 1.0–2.0, which indicates relatively flat HREE patterns. All shales have distinct negative europium anomalies (Eu/Eu* 0.72–0.96), which average 0.77, higher than Post Archaean Average Shale and Upper Continental Crust (Taylor and McLennan, 1985). However, except for Sample 98-05/15 (Eu/Eu* = 0.96) all the samples have Eu/Eu* ratios less than 0.85, which is a value characteristic of sediments recycled from old upper continental crust (McLennan and Taylor, 1991). Despite the variability observed within the Bude and Bideford formations, the overall REE distributions are typical of sediments of cratonic derivation (Taylor and McLennan, 1985; McLennan and Taylor, 1991).

Discussion

Results from the major element data from both the Bude and Bideford formations were plotted for tectonic setting discrimination on Roser and Korschs' (1986 and 1988) diagrams. The plotting coordinates were extracted from Roser and Korsch, (1986 and 1988). The data do not vary systematically with respect to stratigraphic age or geographic position. Figure 4 shows the data to be spread mainly into the Passive Margin and Active Continental Margin zones according to Roser and Korschs' (1986) diagram and mainly into the Quartzose Sedimentary according to Roser and Korschs' (1988) diagram. This tends to confirm that the main source rocks came from recycled sedimentary and metamorphic rocks of cratonic platforms or recycled orogens, and granite-gneisses and siliceous volcanics from uplifted basement as opposed to calc-alkaline or tholeiitic arc material and felsic volcanic rocks (Bhatia, 1983). For the purposes of separating the Bude and Bideford formations, major elements are not found to be particularly useful.

The REE, Th and Sc are considered to be the most useful for inferring source rock composition because their distribution is not seriously affected by secondary processes such as diagenesis and metamorphism and are less affected by heavy mineral fractionation than are elements such as Zr and Hf (Bhatia and Crook, 1986; Floyd *et al.*, 1991; McLennan and Taylor, 1991; Cullers, 1995). Although care must be taken in

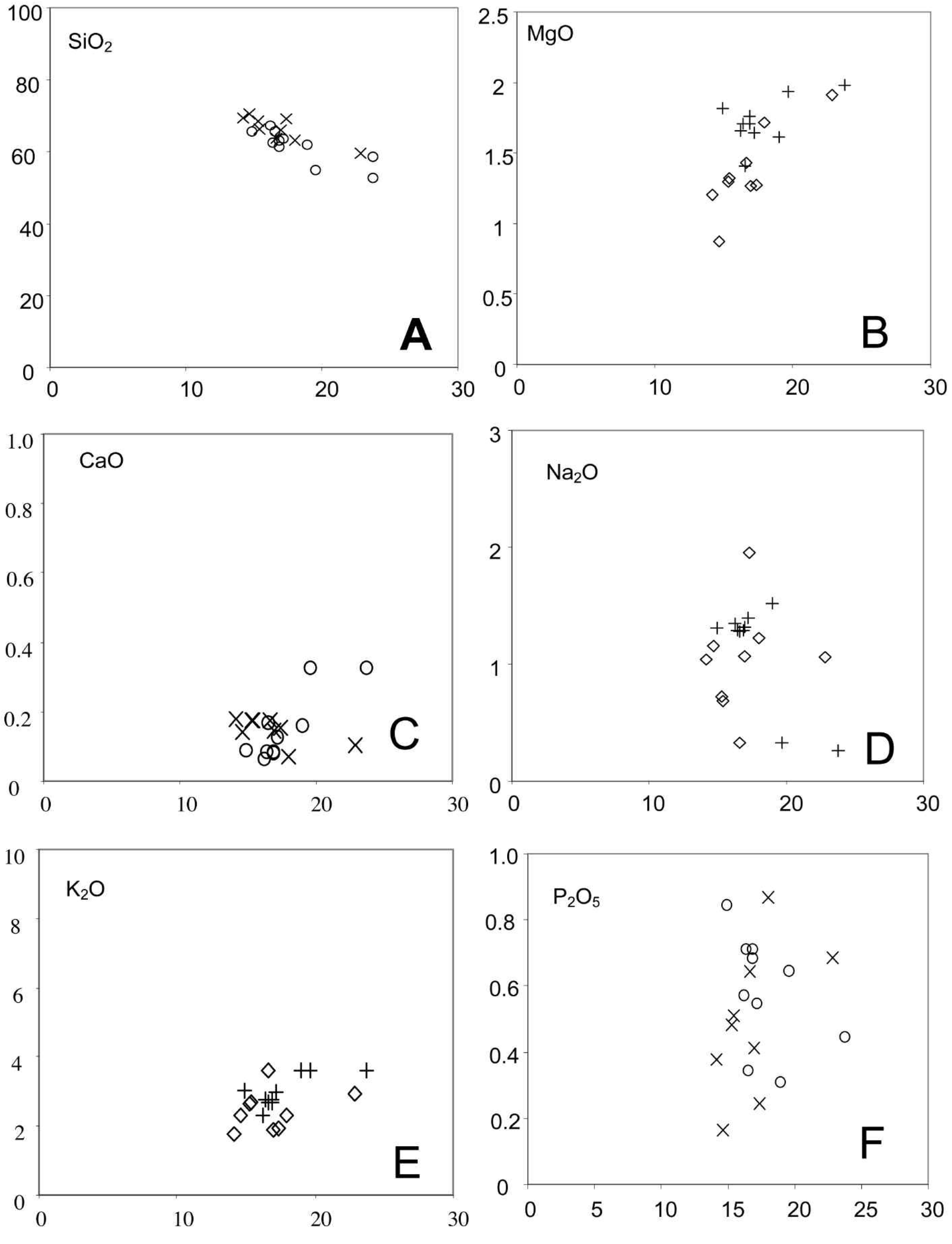

Figure 2. *Harker diagrams for major elements. Horizontal axis is Al_2O_3.*

Sample	Sr	Ba	Y	Zr	Cr	Zn	Co	Ni	Th	V	Ga	Nb	Cu	Sc
00-08/9	104	601	51	351	129	91	30	37	31	87	18	5.2	18	6.7
98-03/2	121	622	53	372	128	93	31	36	31	89	18		20	7.6
99-08/9	116	720	46	326	114	58	35	35	33	123	25	10.0	21	9.3
99-04/3	121	638	76	411	170									
00-08/7	119	643	52	356	132	88	33	35	31	98	21	8.8	19	8.2
98-05/4	165	639	73	267	199									
98-05/8	121	638	76	411	170									
98-05/9	114	631	75	402	167	102	34	44	43	94	19	1.0	28	13
98-05/18	114	631	75	402	167									
98-05/15	169	641	73	271	203	82	31	42	39	99	21	9.0	27	12
98-05/10	104	601	51	351	129	106	29	41	39	93	22	14.0	25	12
98-05/5	169	641	73	271	203									
99-06/3	124	563	49	391	137	61	30	27	28	78	19	6.5	22	11
98-03/1	146	582	66	342	171									
99-08/6	133	540	48	295	126	62	30	26	26	90	17	6.4	23	12
99-08/7	126	524	60	418	143	60	32	29	28	106	21	8.2	22	10
98-03/4	165	639	73	267	199	34	50	27	27	43	9	1.0	3.4	6.7
00-08/12	169	641	73	271	203	62	29	32	35	104	26	17.0	27	12
99-06/2	123	611	55	361	189									
98-03/5	141	543	61	335	167	54	33	29	29	89	18	8.2	19	10
99-08/8	130	516	58	371	149	61	31	26	27	91	19	7.0	23	11

Table 3. *Trace element data. All values in ppm.*

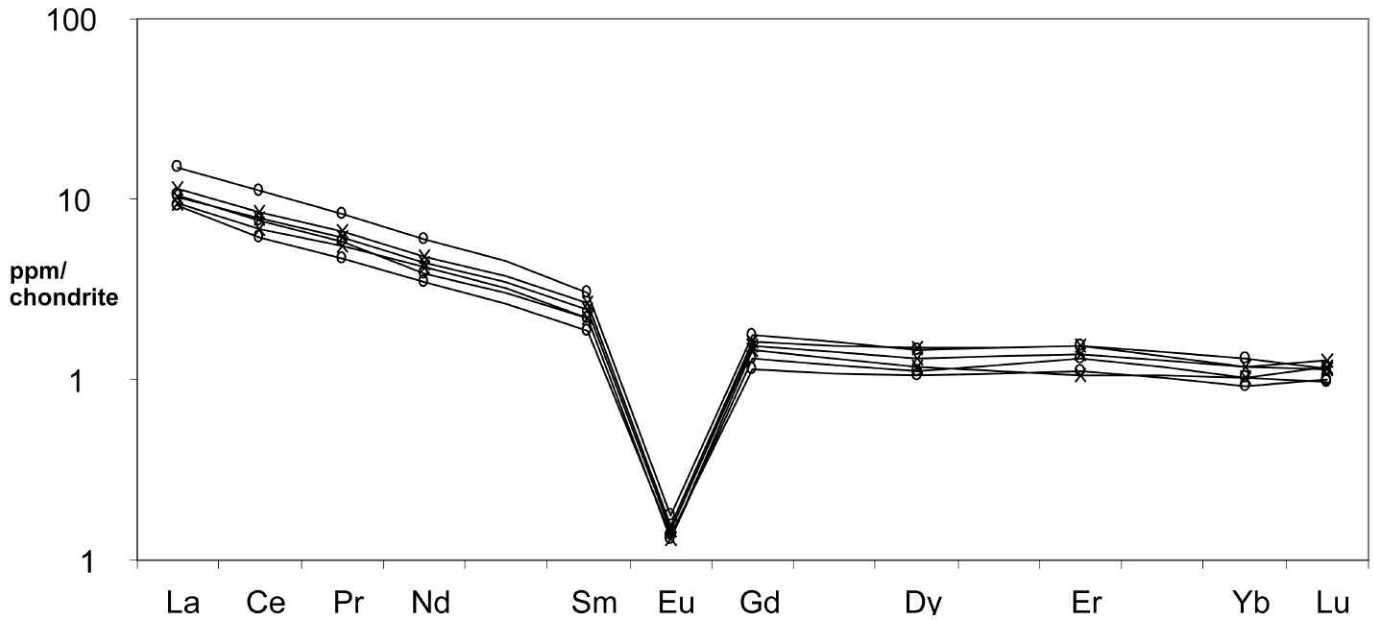

Figure 3. *Chondrite normalised plot of REEs for selected representative samples from the Bude and Bideford formations.*

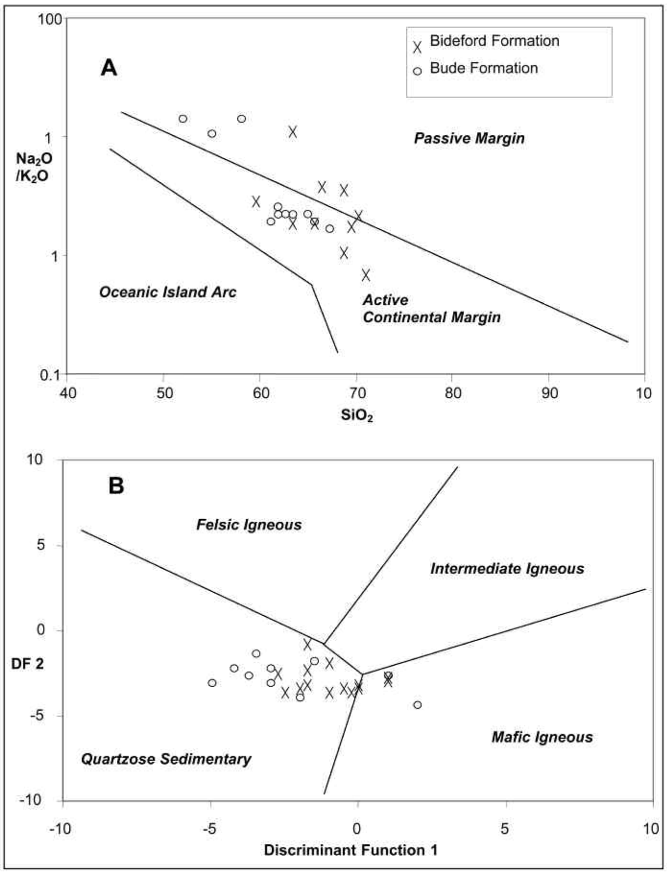

Figure 4. *Provenance discriminator diagrams according to (A) Roser and Korsch (1986) and (B) Roser and Korsch (1988).*

interpreting absolute abundances, Taylor and McLennan (1985) indicate that there is an enrichment in incompatible elements (e.g. Th, Sc, La) at the Archaean-Proterozoic boundary. They considered that this is best seen in an examination of Th data where a sharp increase in Th abundances in fine grained sedimentary rocks has been noted, by a factor of about 1.5-3.0, with abundances remaining essentially constant since then. There is also a dramatic shift in Eu/Eu* at the Archaean Proterozoic boundary, from Eu/Eu* $\approx$ 1.0 to Eu/Eu* $\approx$ 0.65 (Taylor and McLennan, 1985).

So, here Th (ppm) is plotted against Eu/Eu* to investigate the potential influence of Archaean material on the elemental distribution seen. On this diagram (Figure 5) the Bude and Bideford formations plot separately, with the Bideford Formation having consistently more abundant Th and a slightly higher Eu/Eu*, which is indicative of a stronger Archaean influence. All of the Bude Formation data fall into the South Wales field as defined by Diskin (2003) suggesting a possible relationship.

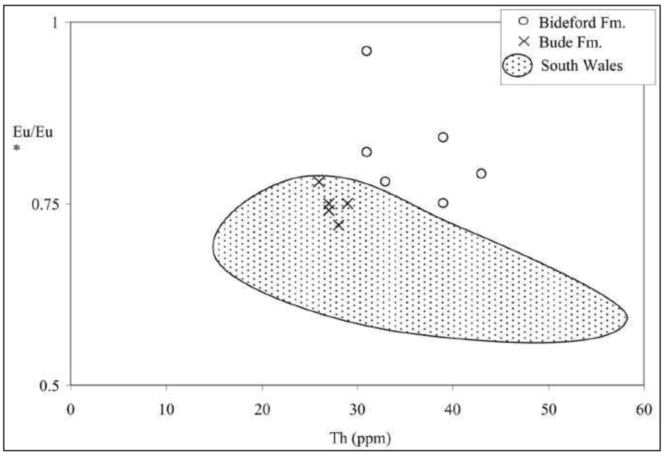

Figure 5. *Plot of Eu/Eu* against Th, with a South Wales field as defined in Diskin (2003).*

Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Dy	Er	Yb	Lu	Eu/Eu*	LaN/SmN	GdN/YbN	LaN/YbN
	ppm	ppm	ppm	ppm	ppm	ppm	pprn	ppm	ppm	ppm	ppm				
00-08/9	33.81	59.51	6.36	24.94	4.28	1.22	3.52	3.99	2.76	2.30	0.384	0.75	4.49	1.32	9.93
98-03/2	48.28	92.46	10.32	39.13	6.48	1.45	5.40	5.62	2.99	3.24	0.419	0.75	4.69	1.35	10.06
99-08/9	55.18	106.61	11.39	42.66	6.92	1.55	5.37	5.61	3.89	3.22	0.437	0.77	4.56	1.29	11.57
99-04/3	43.27	82.32	8.85	33.70	5.97	1.37	5.02	5.55	2.45	3.15	0.512	0.76	4.60	1.29	9.27
00-08/7	43.56	68.32	7.65	25.33	4.38	1.26	3.84	4.05	2.94	2.40	0.376	0.76	4.64	1.29	12.25
98-05/4	38.60	73.06	7.92	27.36	5.04	1.13	3.99	4.26	3.28	2.57	0.367	0.82	4.81	1.31	10.16
98-05/8	43.30	83.39	9.01	32.72	5.93	1.35	4.88	5.32	3.46	3.07	0.483	0.76	4.72	1.28	9.54
98-05/9	33.87	61.65	6.68	22.97	4.19	0.95	3.24	3.44	2.34	2.12	0.412	0.78	5.02	1.35	10.81
98-05/18	43.33	84.46	9.17	31.74	5.88	1.32	4.74	5.09	3.15	2.98	0.509	0.77	4.82	1.26	9.83
98-05/15	42.56	83.96	9.36	32.20	5.96	1.31	4.69	5.08	3.42	2.88	0.483	0.96	4.97	1.24	9.99
98-05/10	24.34	36.71	3.87	16.18	2.59	0.63	2.03	2.43	1.61	1.74	0.256	0.79	5.09	1.24	9.46
98-05/5	43.39	86.60	9.49	29.77	5.79	1.27	4.45	4.45	3.08	2.82	0.479	0.84	5.92	1.14	10.41
99-06/3	34.19	77.20	9.28	31.13	6.02	1.24	4.41	4.93	3.64	2.91	0.492	0.74	3.57	1.23	7.95
98-03/1	34.76	66.08	7.50	29.79	5.00	1.13	4.50	4.44	2.66	2.57	0.453	0.74	4.48	1.52	9.15
99-08/6	34.92	67.99	7.28	29.15	5.31	1.23	4.44	4.92	3.34	2.86	0.480	0.78	4.14	1.38	8.25
99-08/7	41.38	78.32	9.24	35.60	6.04	1.36	5.43	5.62	4.32	3.24	0.496	0.75	4.20	1.38	8.64
98-03/4	28.15	53.85	5.76	23.99	3.96	0.90	3.57	3.26	2.19	1.98	0.384	0.73	4.38	1.42	9.60
00-08/12	38.15	73.15	8.26	32.37	5.68	1.29	4.94	5.27	3.68	2.92	0.427	0.75	4.23	1.37	8.82
99-06/2	41.73	81.32	9.23	34.63	6.13	1.35	4.93	5.71	3.79	2.94	0.439	0.75	4.22	1.34	9.60
98-03/5	36.18	71.13	8.08	30.95	5.45	1.21	4.60	4.88	3.37	2.77	0.453	0.75	4.28	1.36	8.82
99-08/8	37.71	74.60	8.46	31.68	5.66	1.26	4.73	5.05	3.48	2.93	0.481	0.72	4.31	1.36	8.71

Table 4. *Rare earth element data*

Relative LREE-HREE enrichment – depletion can be shown by plotting La_N/Sm_N against Gd_N/Yb_N for the Culm Basin (Figure 6 shown with a South Wales field, from Diskin, 2003). The Bude and Bideford formation data plot in non-overlapping fields, the Bude Formation generally shows less LREE enrichment, and the Bideford Formation sediments show more LREE enrichment. Conversely the Bude Formation shows a little more HREE depletion than the Bideford Formation. This suggests that while the sediment source for both sedimentary units is similar, that the Bideford Formation may be more strongly influenced by an Archaean crustal input. All of the Bude Formation data falls into the South Wales field (Diskin, 2003), while none of the Bideford Formation data do, suggesting a possible genetic link between the sediments of the Bude Formation and those of the same age in South Wales.

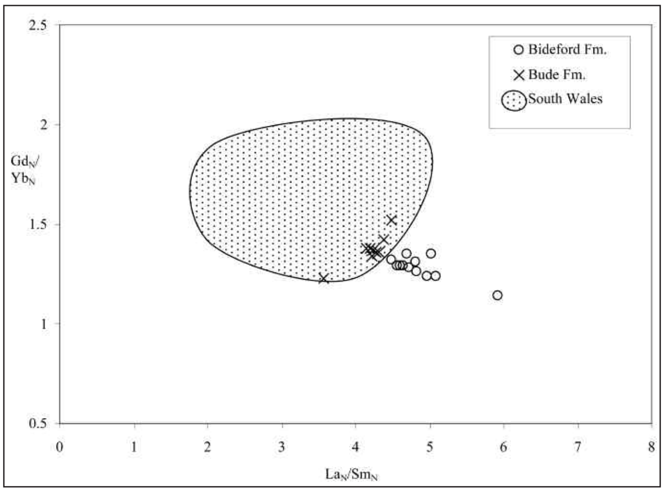

Figure 6. *La_N/Sm_N plotted against Gd_N/Yb_N for the Bude and Bideford formations with the South Wales field (Diskin, 2003).*

Figure 7 shows Gd_N/Yb_N plotted against Eu/Eu* for the Culm Basin (shown with a South Wales field, Diskin, 2003). Here we can see the comparatively higher HREE and the slightly lower Eu/Eu* in the Bude Formation. While there is some overlap with both falling into the Post-Archaean field from McLennan *et al*. (1990), differences between the two data sets can be observed. The McLennan *et al*. (1990) Post Archaean field overlaps quite strongly with their Archaean field. Bideford Formation data generally falls closer to their Archaean field, with some data points falling within it, again suggesting a possibly stronger Archaean influence.

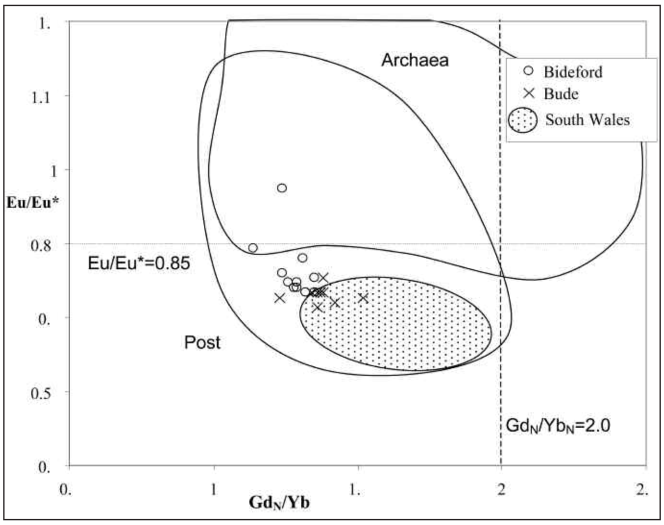

Figure 7. *Gd_N/Yb_N against Eu/Eu* for the sediments in this study, plotted against fields from McLennan* et al. *(1990).*

CONCLUSIONS

There is REE evidence to suggest that there is a significant difference between the geochemistry of the sediments of the Bude and Bideford formations of the Culm Basin, with the Bideford Formation appearing to be more strongly influenced by Archaean sedimentary input. There also appears to be a strong geochemical similarity between the sediments of the Bude Formation and sediments of the same age in South Wales. This indicates that the structural and sedimentological relationship between the Bude and Bideford formations needs further investigation.

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