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**Chemostratigraphy of Carboniferous and Permian sediments encountered in
well 49/12-6, Wenlock Field Southern North Sea (UKCS)**

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For

ATP Oil and Gas (UK) Ltd

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Introduction

Ichron Ltd were commissioned by ATP Oil and Gas to undertake a chemostratigraphic study on 15 samples from well 49/12-6 in the Wenlock Field of the Southern North Sea (UKCS). Ichron produced a scheme based on data acquired from wells 49/12-6, 49/12a-7 and 49/12a-8 in a previous study (Ichron, 2007) but there was some confusion regarding data generated for the 49/12-6 samples. A robust scheme was produced for wells 49/12a-7 and 49/12a-8 but it was difficult to relate the chemostratigraphic boundaries of these wells to 49/12-6 as many of the geochemical trends were different in this well. The close proximity (within 5 miles) of the three wells has enabled a robust lithostratigraphic scheme to be produced (Penny Whaling, ATP geologist- personal communication). Whilst there is strong agreement between the lithostratigraphic and chemostratigraphic correlations for wells 49/12a-7 and 49/12a-8, the original chemostratigraphic scheme produced for well 49/12-6 is in disagreement with the lithostratigraphic scheme. One possible explanation for this apparent discrepancy is that the cuttings samples from this well may have been mislabelled, either as they were collected at wellsite or subsequently. With this in mind, ATP asked Ichron to undertake a chemostratigraphy project on 15 cuttings samples from well 49/12-6 from a different sample set in order to determine whether the cuttings from the original study may have been mislabelled.

Analysis and results

The XRF (X-Ray Fluorescence) technique was employed to acquire data for 38 elements, in the range Na-U in the periodic table. The results are shown in table 1 with major and trace/rare earth element data quoted as % and ppm (parts per million values) respectively.

Table 1. 'New' geochemical data for well 49/12-6

Depth ft	SiO2	Al2O3	Na2O	MgO	P2O5	K2O	CaO	TiO2	MnO	Fe2O3	SO3	Cl	
10920	72.06	4.94	0.54	3.64	0.06903	1.34	3.14	0.2301	0.03377	1.33	1.20	0.6152	
10950	59.83	8.42	0.76	3.72	0.07716	1.87	2.47	0.4206	0.01971	3.01	1.36	1.185	
10980	64.13	6.36	0.72	3.76	0.07173	1.50	3.26	0.3825	0.02046	2.61	1.63	0.8289	
11010	62.08	6.84	0.81	3.46	0.07774	1.66	3.82	0.4076	0.02128	2.70	1.54	0.9105	
11040	61.24	6.61	0.62	3.10	0.06856	1.64	4.16	0.3978	0.02229	2.76	1.62	0.9104	
11080	46.18	5.73	0.73	3.35	0.0366	1.30	12.28	0.3711	0.0201	2.17	6.32	0.863	
11100	55.29	5.70	0.69	3.28	0.0463	1.47	10.01	0.3183	0.02475	2.47	3.91	0.6968	
11140	54.44	4.03	0.60	2.85	0.032	1.10	14.10	0.2238	0.02023	1.72	7.99	0.3054	
11170	63.61	6.11	0.75	2.67	0.0607	1.59	5.84	0.3553	0.02378	2.58	3.50	0.4677	
11200	61.10	6.41	0.59	2.15	0.06163	1.57	5.92	0.3671	0.02128	2.59	2.94	0.4981	
11230	62.33	5.85	0.61	2.35	0.0522	1.53	7.40	0.3283	0.02376	2.61	4.07	0.4511	
11260	54.01	5.61	0.72	2.78	0.0415	1.49	12.02	0.3161	0.02552	2.54	6.71	0.4208	
11290	54.41	3.85	0.57	2.38	0.00069	1.07	12.74	0.1954	0.01752	1.56	11.60	0.2972	
11320	48.60	3.14	0.48	3.30	0.00069	0.97	14.83	0.1439	0.03444	2.11	10.98	0.3741	
11350	41.70	13.69	0.77	2.14	0.0455	2.09	9.59	0.8392	0.00663	5.55	3.22	0.876	
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Depth ft	Ga	Sc	V	Cr	Ni	Cu	Zn	Se	Br	Rb	Sr	Y	U
10920	0.5	27	144.2	57.3	8.7	10.2	100.6	1.3	20.4	35.3	235.5	24.2	1.3
10950	0.5	61.2	379.8	61.5	15.9	6	309.3	1.5	25	63.2	427.3	35.2	2
10980	0.5	39.5	236.5	100.3	13.7	9.3	382	1.5	21.1	46.3	343	35.4	1.8
11010	0.5	44	246.5	68.9	15.2	12.7	937.7	1.4	23.8	50	347.4	33.8	2
11040	0.5	42.1	209.3	79.7	13.5	16.6	328.9	1.4	27.7	49	422.9	32.5	2.1
11080	0.5	0	216.3	69.4	20.8	30	227.5	1.1	17.7	35	944.8	23.9	3.1
11100	0.5	0	196.3	70.5	22.1	60.8	1044	1.2	16.6	39.8	792.6	24.3	2.8
11140	0.5	0	178.9	44	26.8	75.5	289.1	1.2	7.2	25	1061	19.1	3.5
11170	5.1	8.4	273.2	93	20.3	21.8	380.1	0.8	10.6	41.7	540.2	21.4	2.2
11200	0.5	10.7	189.2	73.4	20.7	39.2	203	0.9	10.3	42.3	527.6	22.4	2.2
11230	5.4	0	147.9	66	16.9	22.5	608.8	0.8	11.6	37.1	626.4	19.9	2.5
11260	4.6	0	138.1	62.3	22.3	29.9	1022	0.9	7.9	33.8	920.4	22.4	3.2
11290	4.1	0	115.7	51.5	17	31.6	818.3	0.8	5.7	22.2	991.5	13.9	2.9
11320	0.5	0	178.9	38.5	22.5	35.8	290.2	1	8.1	18.8	1250	15.8	3.6
11350	17.1	0	251.3	150.2	75.4	20.4	160.8	0.7	9	91.5	651.6	33.9	3.9
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Depth ft	Zr	Nb	Mo	Sn	Sb	Ba	W	Au	Hg	Tl	Pb	Bi	Th
10920	167.5	4.4	1.4	12.8	6.7	3694	10.3	0.1	1	1.8	469.6	5.4	9.5
10950	125	5.3	1.5	30.8	4.7	12080	10.2	0.1	1.8	2.3	620.6	6.4	14.2
10980	167	5.9	1.5	25	6.3	7594	7.4	0.1	1.3	2.2	652.8	6.7	14.8
11010	172.3	5.3	1.5	22.6	3	7196	10.1	0.1	1.2	1.9	544	5.8	14
11040	161.1	5.4	1.1	12.9	4.5	5684	10.1	0.1	1.4	1.8	511.1	5.7	13.3
11080	146.9	4.6	1.5	12	3	3745	13.6	0.1	2	1.7	317.5	4.3	9.4
11100	137.2	4.4	1.8	16.3	6.3	3379	17.3	0.1	1	1.6	346.7	4.6	10.2
11140	111.3	3.4	1.7	18.8	3	2644	26.6	0.2	1.7	1.4	281.4	3.9	7.9
11170	157.2	6.6	1.5	28	3	7573	20.8	0.1	1.4	1.1	178.1	2.9	8.1
11200	145.4	6.3	2.4	21.6	3	4679	12.2	0.1	1.4	1.4	229	2.9	9
11230	186.9	6.5	2.4	15.6	3	3042	14.3	0.1	1.6	< 1.0	159.6	2.9	7.3
11260	168.4	6	2.7	7.8	5.5	2232	11.7	0.1	1.9	1.1	202.7	3	8.1
11290	113.4	4.1	1.7	9.3	3	1587	16.9	0.1	1.7	< 1.0	107	2.2	5.5
11320	55.8	2.6	3.4	16.7	3	2964	11.6	0.1	1.8	1.3	219	2.8	6.6
11350	144.6	18.5	2.3	11.1	3	3346	9.7	0.1	3	1	114.2	2.2	12.8

Interpretation of results

Table 2 shows a comparison between the original and new datasets, with respect to Rb, Zr, Ga, Fe, Al, K and Mg for samples at 10920', 11010', 11040', 11080', 1110', 11170', 11230', 11260' and 11320' (i.e. the samples for which duplicate datasets are available). Clearly, there is a close match between the values of Rb, Fe, Al and K for most samples but this does not hold true for Zr, Ga and Mg. The average Zr and Ga values are respectively 20.04ppm higher and 9.36ppm lower in the new dataset, while the original Mg concentrations are 1.54% lower.

Table 2. 'New' and original geochemical data for Rb, Zr, Fe, Al, K and Mg in well 49/12-6

Depth ft	Rb new	Rb original	difference	Zr new	Zr original	difference	Ga original	Ga new	difference			
10920	35.3	38.5	3.2	167.5	169.3	1.8	15.1	0.5	-14.6			
11010	50	42.5	-7.5	172.3	145.4	-26.9	11.6	0.5	-11.1			
11040	49	56.2	7.2	161.1	148.3	-12.8	13.4	0.5	-12.9			
11080	35	41.2	6.2	146.9	111.9	-35	9.7	0.5	-9.2			
11100	39.8	41.7	1.9	137.2	99.2	-38	13.9	0.5	-13.4			
11170	41.7	46.7	5	157.2	152.5	-4.7	12.2	5.1	-7.1			
11230	37.1	43.3	6.2	186.9	165.7	-21.2	10.6	5.4	-5.2			
11260	33.8	35.6	1.8	168.4	117	-51.4	10.6	4.6	-6			
11320	18.8	21	2.2	55.8	63.6	7.8	5.2	0.5	-4.7			
Average	37.83	40.74	2.91	150.37	130.32	-20.04	11.37	2.01	9.36			
Depth ft	Fe2O3 new	Fe2O3 original	difference	Al2O3 new	Al2O3 original	difference	K2O new	K2O original	difference	MgO new	MgO original	difference
10920	1.329	1.49	0.161	4.94	4.87	-0.06	1.336	1.057	-0.279	3.64	2.01	-1.63
11010	2.703	2.704	0.001	6.84	5.82	-1.02	1.662	1.322	-0.340	3.46	1.90	-1.56
11040	2.763	3.168	0.405	6.61	7.59	0.97	1.639	1.677	0.038	3.10	1.78	-1.32
11080	2.173	2.182	0.009	5.73	5.96	0.23	1.303	1.372	0.069	3.35	1.72	-1.63
11100	2.467	2.433	-0.034	5.70	5.88	0.18	1.466	1.309	-0.157	3.28	1.52	-1.76
11170	2.578	3.094	0.516	6.11	6.74	0.64	1.586	1.521	-0.065	2.67	1.37	-1.30
11230	2.606	2.77	0.164	5.85	6.35	0.50	1.534	1.401	-0.133	2.35	0.98	-1.37
11260	2.54	2.56	0.02	5.61	5.20	-0.41	1.488	1.258	-0.230	2.78	1.38	-1.41
11320	2.107	1.596	-0.511	3.14	2.49	-0.65	0.965	0.811	-0.154	3.30	1.20	-2.10
Average	2.36	2.44	0.08	5.61	5.66	0.04	1.442	1.303	-0.139	3.10	1.54	-1.56

In addition to the aforementioned elements, Figure 1 illustrates that the U/P and Cl values are significantly different between the two datasets. This diagram also shows that most of the key element and ratio trends, as well as values, are completely different. For example, concentrations of Zr are shown to be lowest in P1 and P3 and elevated in P2 and P4 in the original dataset. Although this holds true for P1 in the new dataset, Zr values are very similar in P2, P3 and P4. The most striking differences between the two datasets relate to Ga/Fe and U/P as profiles plotted for these parameters display completely different trends. Moreover, although there is a reasonably close match between the values of Rb

and K between the two datasets (Table 2), the Rb/K profile plotted for the new dataset shows that P4 yields much higher ratios than in P2 and P3. This is not true with respect to the original dataset. There are some similarities between the Cl, Mg and Fe/Al trends, though the values for these elements are different.

In summary, there are some similarities between the two datasets, but given the differences in both profile shapes and the values of many elements/ratios it is likely that the analysed materials are different.

Figure 2 shows that it is possible to use the new dataset to define chemostratigraphic package and unit boundaries in well 49/12-6 using similar criteria to the definition of such boundaries in 49/12a-7 and 49/12a-8. In all three wells Zr is low in package P1, increases sharply at the P1:P2 boundary and remains high throughout P2. Package P3 occurs at the top of the Leman Sandstone Formation and is defined by lower Zr. Definition of P2:P3 boundary is made with a lower level of confidence in well 49/12-6 as only two samples are assigned to P3, of which one yields Zr concentrations consistent with a P3 interpretation. The uppermost sample of well 49/12-6 (at 10920') produces higher Zr values than would be expected within package P3 but a possible explanation for this apparent inconsistency is that this sample may contain some 'caved' material from the overlying Silverpit Formation. The unit P2-A:P2-1 and P2-1:P2-2 boundaries are based on an upward increase in Rb/K and a decrease in Ga/Fe respectively. These boundaries are easily defined in 49/12-6, as they are in 49/12a-7 and 49/12a-8, but it is clear that though the Ga/Fe and Rb/K trends are similar, both ratios are significantly lower in 49/12-6 (note difference in scale of profiles in Figure 2). The reasons for this are likely to relate to the fact that the new and original samples were analysed on different Xepos XRF machines. Though the calibrations, accuracy, precision and resolution of the two machines are similar, it is noted (from the analysis of standard reference materials) that K values are slightly higher and Ga lower when analysed by the new Xepos machine. As this machine was used to analyse the 'new' samples from well

49/12-6, but not the 49/12a-7 or 49/12a-8 samples, it is not surprising that Rb/K and Ga/Fe ratios are generally lower in 49/12-6. It is significant, however, that the trends plotted for these key element ratios are similar in all three wells. Using the previous dataset, it was not possible to define the package P2 unit boundaries of well 49/12-6 and the chemostratigraphic scheme proposed for this well was very different to that of 49/12a-7 and 49/12a-8 (Ichron, 2006). Using the new dataset for 49/12-6, however, it is possible to define the P1:P2 and P2:P3 package boundaries as well as the P2 unit boundaries with confidence. It is not possible to recognise the P2-1 subunits or subunit P2-2b but this may be a function of the relatively low number of samples analysed from this well. Subunit P2-2i is defined by low Zr concentrations in wells 49/12a-7 and 49/12a-8 and as P2-2b is not defined in the former well, it is not possible to differentiate P2-2a from P2-2c on geochemical grounds alone. It is highly probable that subunit P2-2b is also present in this well but that it has not been sampled.

Conclusions

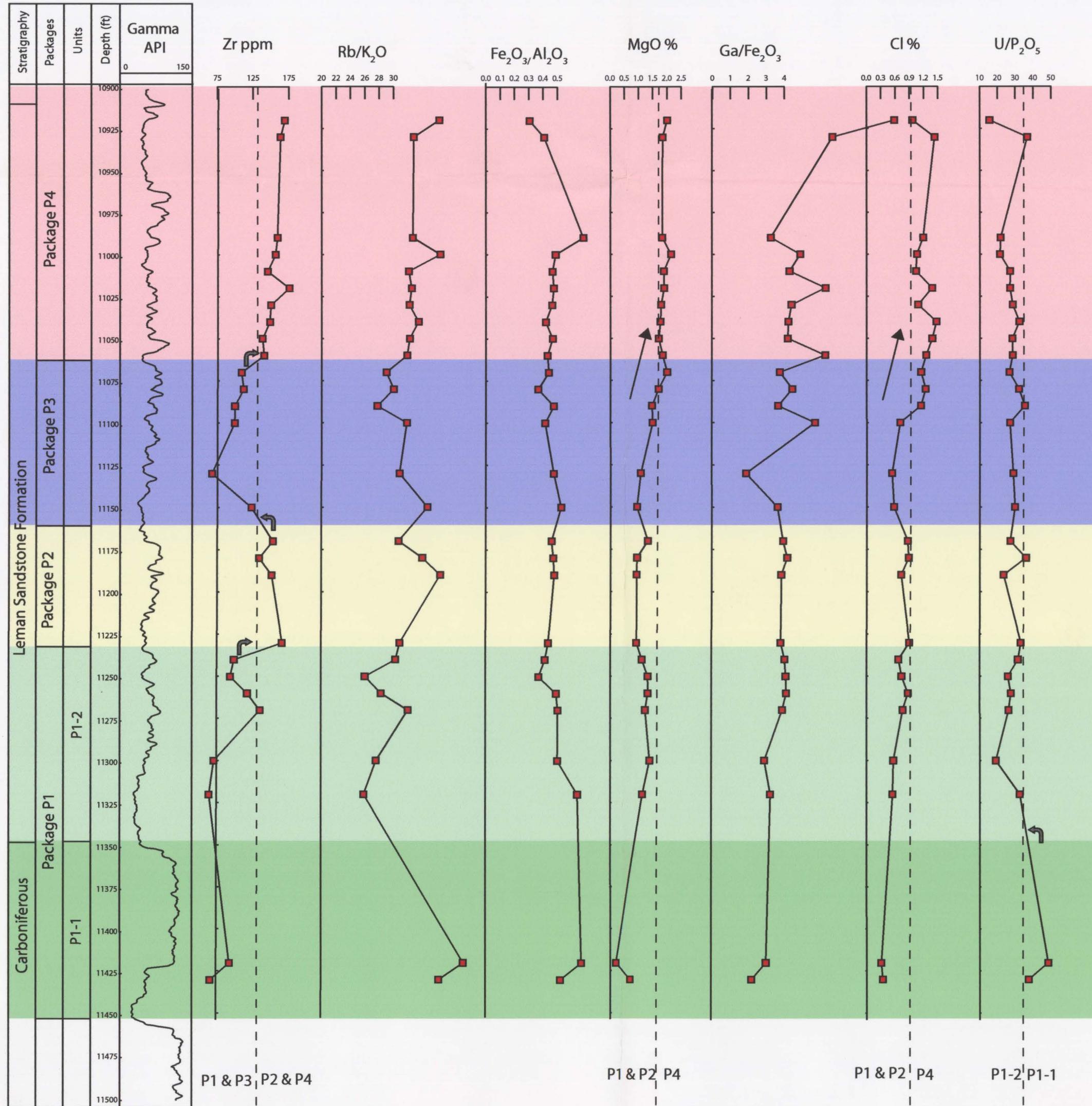
In conclusion, there are some similarities between the previous and new datasets for well 49/12-6 but, as there are also significant differences between the two datasets, it is probable that the original cuttings samples were either mislabelled or contaminated prior to analysis. It unclear, however, if this mislabelling/contamination took place as the samples were collected at wellsite or subsequently. It is now possible to use the new dataset for well 49/12-6 to define the chemostratigraphic zones recognised in nearby wells 49/12a-7 and 49/12a-8. The fact that most chemostratigraphic zones are recognised in all three study intervals adds confidence to the placement of correlative boundaries.

References

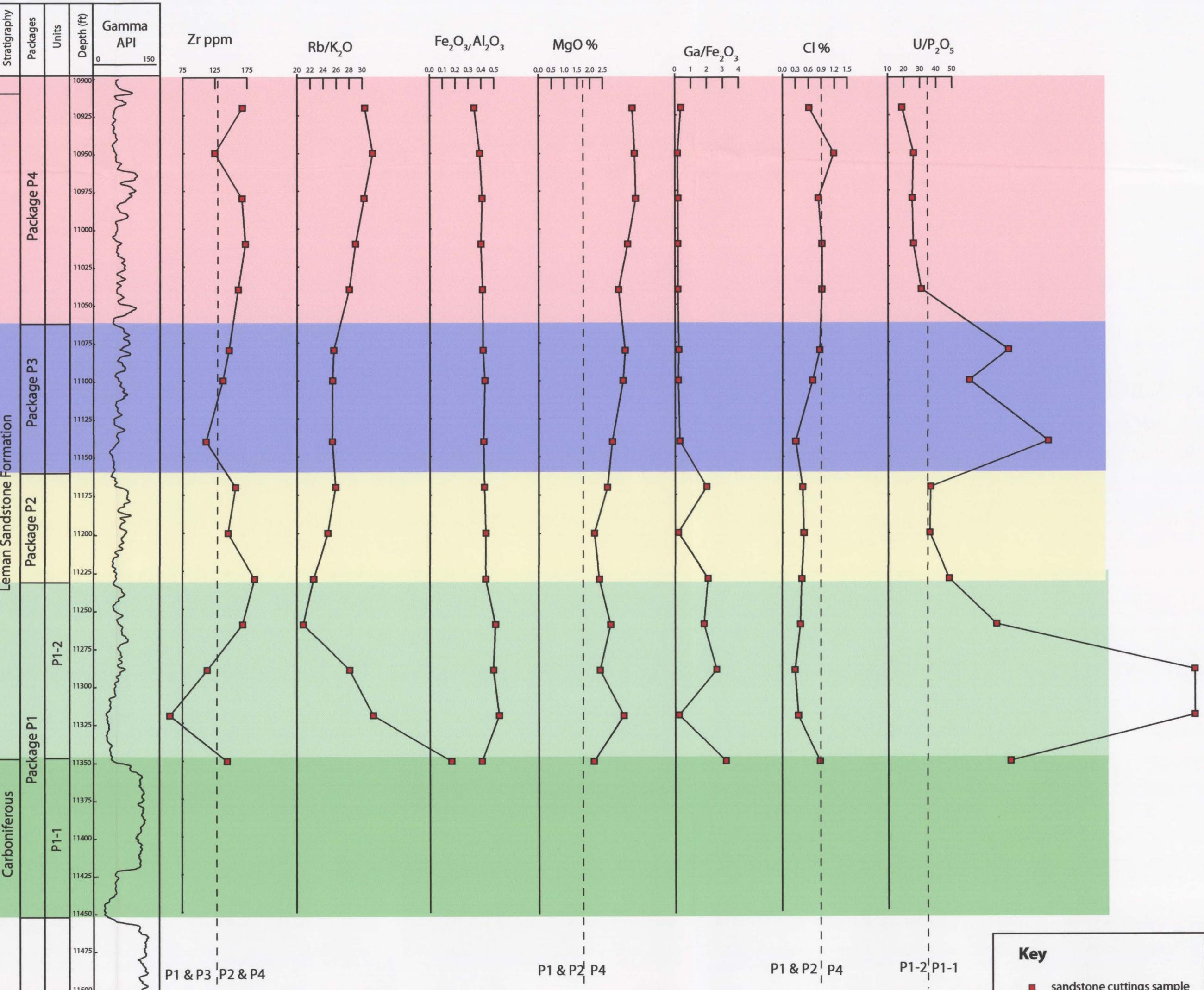
- Ichron Ltd, 2007. Chemostratigraphy of Carboniferous and Permian sediments encountered in wells 49/12-6, 49/12a-7 and 49/12a-8, Wenlock Field, Southern North Sea (UKCS). Unpublished Ichron Ltd report 07/1076/C

Chemostratigraphic Characterisation: New and Previous datasets

49/12-6 (previous dataset)



49/12-6 (new dataset)



Key

- sandstone cuttings sample
- ↗ significant trend
- ↑ general trend (e.g. upwards increasing)

Figure 1. Chemostratigraphic profiles plotted for new and previous geochemical datasets. The chemostratigraphic zonation is based on variations in the previous dataset. Both datasets were derived from the same well but from different sets of cuttings samples. All depths are in feet and all samples take the form of sandstone cuttings.

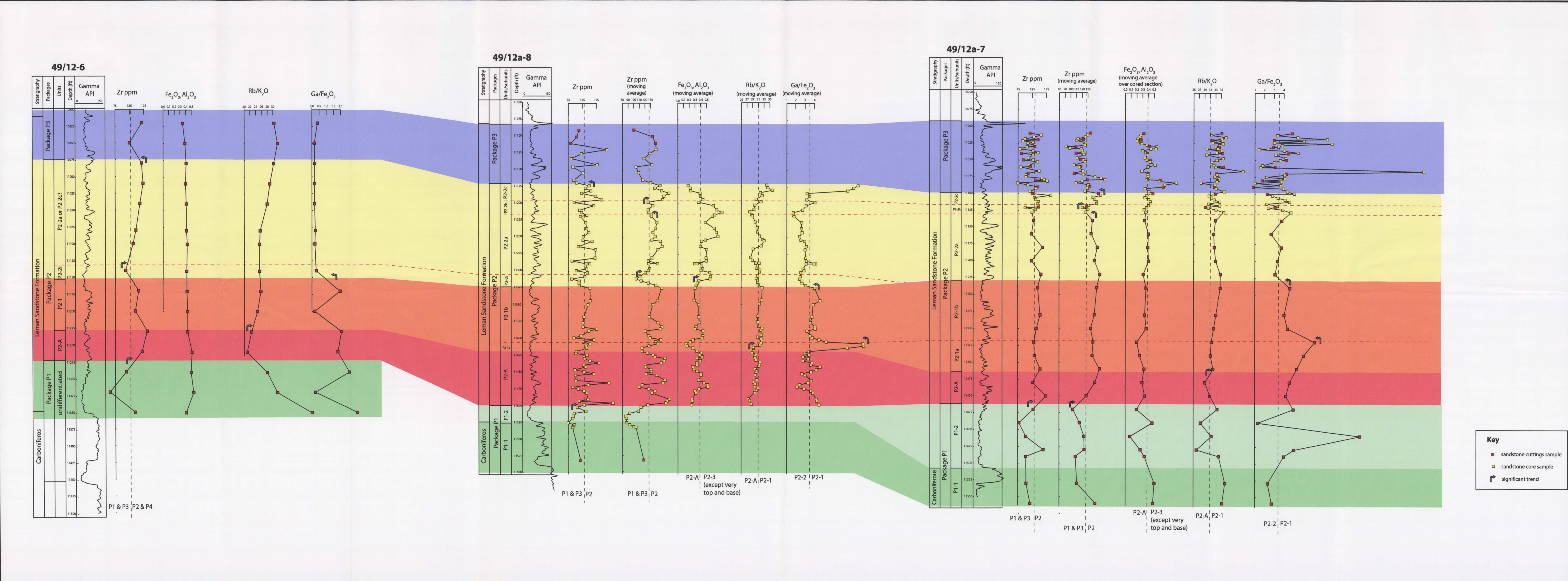


Figure 2. Chemostratigraphic correlation of the Leman Sandstone Formation in wells 49/12-6, 49/12a-8 and 49/12a-7, based on data acquired from sandstone core and cuttings samples. Differentiation of units P1-1 and P1-2 are based on data acquired from the sandstone dataset. All depths are in feet with relevant core shifts applied.