RELATIONSHIP BETWEEN ELEMENTS AND MINERALS IN UPPER JURASSIC SUBSURFACE SEDIMENTS FROM THE WINTERBORNE KINGSTON AREA, SOUTHERN ENGLAND

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Abstract

Study of the chemical and mineralogical data of sediments of the Oxford Clay and Kellaways Formations indicated that all major elements in association with minor elements e.g., Cr, Ni, Cu, Ba, Rb, La, Th, Ce and Nb, with the exception of Ca which showed its association with smectite, reside in the octahedral, tetrahedral and the inter-layer positions of the remaining clay mineral species. Elements of the chalcophile group (S, Ni, Cu, Pb, Mo and Fe^{+2}), have shown their affiliation with pyrite and organic carbon present in these sediments. Concentration of the chalcophile elements in these sediments indicated that the sediments were deposited under reducing enviroments.

Introduction

The relationship between the mineral phases and the elements present in the marine sediments has been investigated by many research workers including Nichollas and Loring (1960 and 1962), Tourtelot (1964), Gad ***et al.*** (1969) Curtis (1969), and Weaver and Pollard (1973). The present author, undertook this study, having two objectives in mind. Firstly, to trace the relationship between the elements and minerals and, secondly, to gain some insight regarding the physcio-chemical conditions, experienced by these sediments, in the areas of the provenance and sedimentation. Prior to this study, these sediments were not investigated for this particular aspect.

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The sediments investigated, are composed of quartz, pyrite, calcite, feldspars, organic carbon and total clays (illite + chlorite + kaolinite + smectite) were analysed for eight major (Si, Al, Na, K, Mg, Ca, Ti, Fe) and sixteen minor (Cr, Ni, Cu, V, Mn, Pb, Zn, Ba, Sr, Rb, Zr, Nb, Th, La, Mo, Ce and Y) elements.

Materials and Methods

Sixty three core samples of the Oxford Clay and Kellaways Formations of the Upper Jurassic from the Winterborne Kingston Dorset area, provided by the Institute of the Geological Sciences, London, have been investigated in the present study.

Techniques

(i) ***Analysis of Elements***: Telsec B-300 Beta-probe and Philips PW-1212 X-ray Flourescence Spectrometer, were used for the analysis of major and minor elements, respectively. For details regarding the preparation of samples and the working of the equipments, see Baig (1982 & 1983).

(ii) ***Analysis of Minerals***: Philips PW-1010 X-ray Diffractometer, was employed for the analysis of clay and non-clay minerals in the sediments studied.

Methods of the the sample preparation and the estimation of the clay minerals abundances, have been described in detail elsewhere (Baig, 1982 & 1984).

Analysis of the Data

The chemical and mineralogical data obtained, in the first instance, was fed to the Computer, at the University of Southampton, for determining the possible correlations that might exist between the elements and minerals, using Clayton's (1972) correlation programme. The correlations indicated by this programme, are tabulated in Table-1. R-mode factor analysis programme of Mather (1970), modified by Clayton (1970), was also used utilizing the results of the chemical data only, to confirm the results of the correlation programme. R-mode factor analysis has been found very useful in the interpretation of the vast geochemical data of sediments and rocks (Papavasilliou, 1979: Hirst, 1974: Cosgrove, 1973 and Baig, 1982). This programme reduces the huge data into few and meaningful factors, which are easy to interpret and describe.

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Results & Discussion

A summary of the correlations shown between the elements and mineralogical data of the samples studied is presented in Table-1, whereas Table-2 shows the groups of elements arranged by the R- mode factor analysis and the possibe phases which can hold these elements. A very strong positive correlation, significant at 99.99% level, of Total Clays (illite + kaolinite + chlorite + smectite), with the major elements, e.g., Ti, Si, Al, Fe, Mg, Na, K, and minor elements e.g., Cr, V, Ni, Ba, Ce, La, Th, Cu, Rb, Zr, Nb, and Y, is indicated in Table-1. This association is the most expected one, because these elements reside in the octahedral, tetrahedral and the inter-layer positions of the clay mineral (Weaver and Pollard, 1973: Van Olphen and Fripiat, 1979: Cosgrove, 1973). Table-1 also shows strong positive correlation between these elements and the individual clay mineral i.e. illite, kaolinite, and chlorite, confirming the relationships interpreted above.

The results of the correlation programme and the R-mode factor analysis of the chemical and mineralogical data of the sediments studied (Table-2) bring out the associations exhibited by the elements and minerals in this study. Occurrence of the major (Al, K, Na, Mg, Fe) and minor (Ni, Cr, Cu, Ce) elements, in the octahedral, tetrahedral sheets and the inter-layer positions of the clay minerals, observed in the present study, were also noted earlier, during the leaching study of the same sediments (Baig, 1982). The strong positive correlation of the Total clays (illite + chlorite + kaolinite + smectite), with the mojor and minor elements, shown in Table-1, strongly supports the above relationships.

The relationship of S, Pb, Zn, Cu, Mo, Ni, Fe^{+2}, V, and phosphorus with the sulphide phases and organic carbon, in these sediments, is confirmed by the very strong positive correlation demonstrated by these elements, with pyrite and organic carbon (Table-1). This association is typical of the sediments deposited under the reducing environments (Weaver and Pollard, 1973: Hirst, 1974: Calvert, 1976).

Calcite, is the only carbonate phase present in these sediments and it has shown very strong positive correlation with the bi- valent Ca, Sr, Mn, Pb, and P, significant at 99.99% level (Table-1). These elements, being bi-valent can be easily substituted for Ca^{+2}, in the carbonate phase.

The strong positive correlation demonstrated by the organic carbon with the typically known detrital (Lithophile) elements e.g., Ti, Al, Mg, Na, K, V, Cr, Ni, Ba, La and Rb (Table-1), strongly suggests that the organic carbon, present in these sediments, is detrital (terrestrial) in origin, and was transported to the site of the deposition, with the detritus, from the source areas.

The relationship between Si, Zr, Nb ad Fe^{+3}, with the resistate phases (Feldspars, Quartz, Zircon etc.), present in these sediments can be explained in the light of the findings of Mohr (1959a), Nichollas & Loring (1962), and Gad, ***et al***. (1969). According to these

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Table1: Showing relationships between the Main Mineral Phases, Chemical Elements and Depth in the Bulk Rock Samples of the Oxford Clay and Kellaways Sediments.

ELEMENTS	DEPTH	ILL	KAOL	CHLR	SMECT	TClays	C_{org}	Pyt	Cal.	QTZ
SiO_2	+2	+2	+2	+2	-2	+2		-1	-2	
TiO_2	+2	+2	+2	+2	-2	+2	+2		-2	-2
Al_2O_3	+2	+2	+2	+2	-2	+2	+2		-2	-2
$Fe_2O_3(T)$	+2	+2	+2	+2	-2	+2	+2	+2	-2	-2
MgO	+2	+2	+2	+2	-2	+2	+2		-2	-2
CaO	-2	-2	-2	-2	+1	-2	-2		+2	+2
Na_2O	+2	+2	+2	+2	-2	+2	+2		-2	-2
K_2O	+2	+2	+2	+2	-2	+2	+2		-2	-2
S	+2	+2	+2		-2		+2	+2		-2
P_2O_5		-1		-2		-2		+2	+2	
V	+2	+2	+2	+2	-2	+2	+2		-2	-2
Cr	+2	+2	+2	+2	-2	+2	+2		-2	-1
Mn	-2	-2	-2	-2		-2	-2		+2	+1
Ni	+2	+2	+2	+2	-2	+2	+2	+2	-2	-2
Ba	+2	+2	+2	+2	-2	+2	+2		-2	-2
Ce	+2	+2	+2	+2	-2	+2			-2	
La	+2	+2	+2	+2	-2	+2	+2		-2	-2
Th	+2	+2	+2	+2	-2	+2			-2	-2
Pb								+2		
As										
Zn							+1	+2		-2
Cu	+2	+2	+2	+2	-2	+2	+2	+2	-2	-2
Rb	+1	+2	+2	+2	-2	+2	+2		-2	-2
Sr		-1	-1	-2	+1	-2			+2	
Y	+1			+1	-1	+2			-2	
Zr				+1		+2		-2	-2	
Nb	+1	+2	+2	+2	+2	+2			-2	
Mo	+1	+2	+2	+1	+2	+1	+1	+2	-1	-2
Fe^{+2}	+1	+2	+2		-2	+1	+2	+2		-2
Fe^{+3}		+2	+2			+1	+2	+2		-2
C_{org}	+1	+2	+2	+2	-2	+2	+2	+2	-2	-2
Co_2	-2	-2	-2	-2	+2	-2	+2		+2	+2
Depth	+2	+2	+2	+2	-2	+2	-2	+2	-2	-2
ILL	+2	+2	+2	+2	-2	+2	+2	+2	-2	-2
KAOL	+2	+2	+2	+2	-2	+2		+2	-2	-2
CHLR	+2	+2	+2	+2	-2	+2			-2	-2
SMECT	-2	-2	-2	-2	+2	-2		-2	+2	+2
TClays	+2	+2	+2	+2	-2	+2			-2	-2
Pyt.	+2	+2	+2		-2					-2
Cal.	-2	-2	-2	-2	+2	-2			+2	+2
QTZ	-2	-2	-2	-2	+2	-2		-2	+2	+2

Note:

n = 60

±2 = (r ≥0.32) indicates 99.99% significance level.

±1 = (r ≥0.25) indicates 95.00% significance level.

Abbreviations:- ILL-Illite; KAOL-Kaolinite;CHLR-Chlorite; SMECT-Smectite; TClays-Total Clays; Pyt-Pyrite; Cal.-Calcite;QTZ-Quartz; $Fe_2O_3(T)$-Total iron

Table 2: Summary of the associations of elements and minerals, as suggested by the R-mode factor Analysis of the chemical data of sediments investigated.

Phases	Elements Associated with Phases
Total Clays(illite + Kaolinite + Chlrote + Smectite)	Si, Ti, Al, Mg, Na, K, Fe (Total), Cr, Ni, Ba, Ce, La, Th, Cu, Rb, Y, Zr, Nb, Fe^{+3} and H_2O^+
Sulphides, Organic Carbon	Fe(Total), S,P,Ni, P, Zn, Cu, Mo, Fe^{+2}, Organic carbon
Calcite	Ca, Mn, Sr, Pb, P
Resistate Phases	Si, Zr, Nb, Ce, and Fe^{+3}

authors, Zr can occur as detrital grains in association with other resistate phases such as quartz, feldspars etc. Sediments of the Kellaways Formation showed the highest con centration of Zr and Nb alongwith the resistate phases quartz and kaolinite, confirming the relationship of these elements with the resistate minerals in the sediments studied. The association of Nb with total clays and resistate phases has been described by Cosgrove (1973). Goldschmidt (1954), Rankama and Sahama (1950), stated that Nb^{+5} (0.72 Å) can easily be substituted for Ti^{+4} (0.75 Å), Mg^{+2} (0.80 Å), Zr^{+4} (0.80 Å) and Al^{+3}(0.61 Å), having close similarity of the ionic radii. This information strongly supports that some of the Zr and Nb in the sediments studied, is also present structurally bound in the clay minerals. The asociation of Fe^{+3} with resistate phases many be due to iron oxide coatings on the resistate phases, a common phenomenon in the marine sediments (Cosgrove, 1973 and Papavasilliou, 1979).

Conclusions

From the results of the present study it may be concluded that: Elements of the lithophile group (Al, Si, Ti, Mg, K, Na, V, Cr, Ni, Ba, Th, La, Rb, Zr, etc.) are associated with the clay mineral species, in which they reside in the octahedral, tetrahedral sheets and the inter layer-positions.Elements of the chalcophile group (Fe^{+2}, S, P, Ni, Cu, Mo, Pb, Zn etc.) are associated with the sulphide phases, particularly pyrite, present in these sediments.

Some elements e.g., Cr, Ni, Cu, Mo and Fe^{+2}, are associated with the organic carbon, due to the prevalence of reducing environments. Organic carbon, present in the sediments, is of detrital origin.

Calcium, is associated with smectite and the carbonate phase present in these sediments.

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Acknowledgements

The author gratefully acknowledges, Dr. M.E. Cosgrove, for the guidance in this research work, professor R.W. Nesbitt for the permission to use the Laboratory facilities of the Geology, Deptt., and the Director, Institute of the Geological Sciences, London, for the borehole samples, used in this study.

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