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Composition and origin of black shales from Quseir area, Red Sea, Egypt

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ABSTRACT

Black shales, occurring mostly within the Dakhla and Duwi Formations in the Quseir area are rich in organic matter. They can be described as bituminous calcareous foraminiferal claystone to bituminous argillaceous limestone. In places, the black shales are abnormally enriched in vanadium (0.8% V_2O_5) and other heavy metals, most markedly so near the contact with the Duwi Formation. The content of vanadium appears to be unaffected by the prevailing weathering.

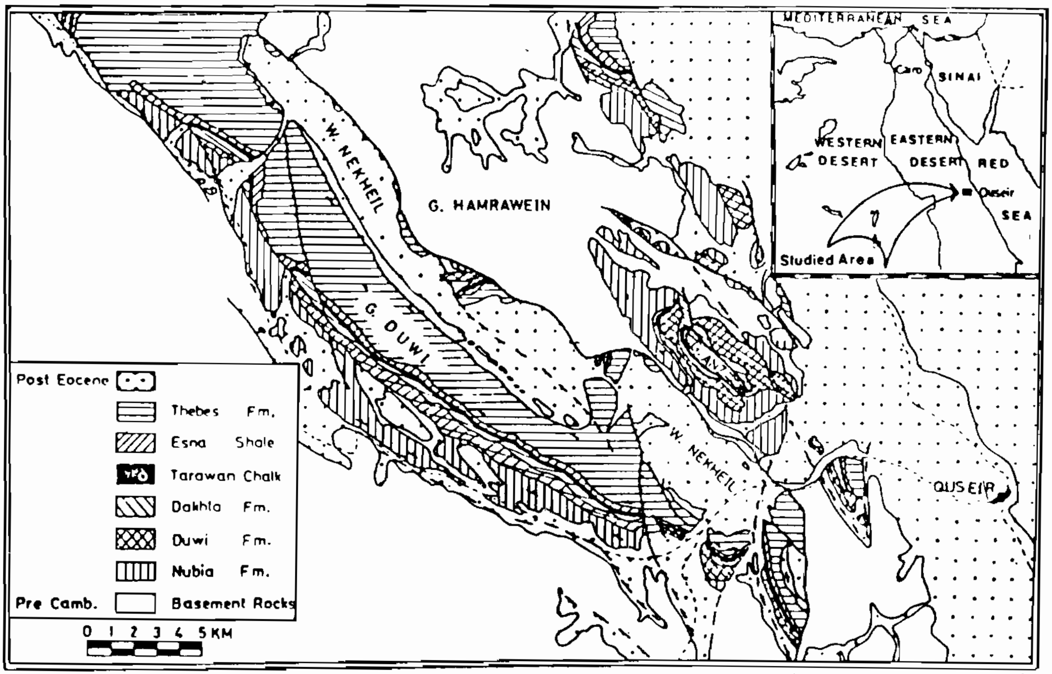
The black shales are composed of disordered poorly crystalline kaolinite, smectite, organophilic smectite, mixed-layer smectite-illite, quartz, calcite, ferroan dolomite, carbonate fluorapatite, gypsum, anhydrite, pyrite and organic compounds (mostly unsaturated molecules). The trace element content is classified into (a) a terrigenous association where Y, La and Ce are accumulated by clastics of biogenic origin; Ti and Zr in detrital minerals; Sc, Ga and Nb in kaolinite, while Co is mostly in smectite, (b) a carbonate association, including Pb, Sr and Mn, and (c) an organic association which includes Cd, Be, Zn, V and U. The U and Th equilibrium constants suggest no secondary radioactive enrichment.

The organic matter belongs to kerogen type II approaching type I, indicating deposition from a highly productive marine environment under anoxic bottom water. The black shales are a good energy donator and can produce an excellent clinker upon pyrolysis.

INTRODUCTION

The Quseir area in the Eastern Desert of Egypt (Fig. 1) is most notable for the presence of the phosphorites of Gebel Duwi Range discovered over 60 years ago. The shales of the Duwi Formation are interbedded with the phosphates of the overlying Dakhla Formation and are generally black to grey and rich enough in organic matter to warrant their description as black shales. The Duwi Formation of Campanian-Maastrichtian age (Said 1962), conformably overlies the Quseir Variegated Shale (Senonian) and underlies the Dakhla Formation (Maastrichtian-Danian).

Both fresh and weathered black shales from the Duwi and Dakhla Formations were sampled. The fresh samples were collected from shafts and adits in phosphate mines of El-Beida, El-Dabaa, Umm Hammad, Nasser, Nekheil and Faraa mines. A



(Modified after Abd El Razik, 1970)

Fig. 1. Geologic map of Quseir area and sketch map of Egypt (inset) showing the location of the study area.

non-weathered section was also sampled from a tunnel in El-Beida mine passing through the stratigraphic succession from the Duwi to the Thebes Formation. Weathered rocks were collected from the exposed surface section measured at the southern extension of Gebel Duwi.

ANALYTICAL METHODS

About fifty black shale samples were examined by different corroborative techniques in order to determine the precise organic and inorganic composition of the sediments. The techniques used were:

(a) *Mineralogical analysis.* Bulk as well as oriented clay-size fractions were analysed by X-ray diffraction using 540 W, Ni filtered, Cu-Kα radiation. The clay size fraction was separated by the pipette method. The infrared spectrum between 4000 and 400 cm^{-1} of samples mixed with KBr was recorded. Differential thermal and thermogravimetric analyses were done for most samples using a heating rate of 20°C/min up to 1200°C in standing air. Standardized DTA and DTG curves using synthetic and natural mixtures were used for quantitative mineral analysis.

(b) *Chemical analysis.* The major oxides: SiO_2, P_2O_5, SO_3 and loss on ignition (LOI) were determined gravimetrically, S^{2-} and CO_2 were determined gravimetrically after being distilled. Al_2O_3, Fe_2O_3, CaO, MgO and MnO were determined twice by atomic absorption and X-ray fluorescence using Cr-Kα radiation. FeO was determined titrimetrically while TiO_2 by spectrophotometric method. Na_2O and K_2O were determined by flame photometric method. The trace elements were analysed twice using the inductively coupled (argon) plasma (ICP) and the X-ray fluorescence using $K\alpha$ radiation of both W and Mo. The natural radio-isotopes of U and Th series were analysed by gamma spectroscopy. Twenty g of -200 mesh samples in sealed aluminium containers were kept for 21 days prior to analysis in order to attain equilibrium in Ra^{226} and Bi^{214} and to assure equilibrium of Th series with thoron because of its shorter half life.

(c) *Organic compounds analysis.* Five samples were analysed by Rock Eval MK II pyroanalyser and Leco CR 12 carbon determinator. The hydrocarbons and evolved gases were detected by gas chromatography, using flame ionization and thermal conductivity detectors, respectively. About 40 samples were analysed for their content of C, H and N in doublets using the Bregl and Dums methods.

PETROGRAPHICAL CONSIDERATIONS

The black shales studied are composed mainly of bituminous calcareous foraminiferal claystone to argillaceous limestone which consist of argillaceous material with abundant calcareous foraminiferal tests. The tests are usually filled with sparry calcite, chalcedonic-quartz or framboidal pyrite, but are occasionally partly, or even completely, unfilled. Skeletal apatite and "collophane" grains and pellets ranging between 1 and 8% occur within these claystones. Subrounded detrital quartz grains of silt size and rare fine rounded grains of chamosite are recorded in amounts ranging between 1 and 5%.

The recorded planktonic foraminiferal tests belong to Rotallidea and Buliminidea. The organic matter is disseminated or entrapped between the finely laminated argillaceous matrix, which may suggest sedimentation under reducing and relatively calm depositional environments. The sediments underlying the black shales, which belong to the upper part of the Duwi Formation, are petrographically divided into four microfacies, namely: (a) Siliceous phosphates composed of heterogranular and highly rounded phosphate intraclasts and fragmented calcareous oyster shells cemented by chalcedony, (b) Siliceous shale composed of laminated and ferruginated shale entrapping foraminiferal tests, skeletal apatite and fine detrital quartz, (c) Micritic limestone enriched in burrows filled with phosphate clasts and dispersed pyrite, and cemented by sparite, and (d) Microsparite which shows signs of aggrading recrystallization.

MINERALOGY

A qualitative estimation of the clay minerals composing the separated clay-size fraction was made from interpretation of the XRD analysis of glycol-treated and heated slide mounts. The areas under the basal peaks were measured in preference to peak height. The peak areas of the non-clay minerals were measured from XR diffractograms of the bulk samples.

The broad, diffused and low-intensity basal d-spacing both of kaolinite and smectite, may indicate their poorly crystalline nature. Smectite in black shale exhibits strong tendency to form complexes with a remarkable variety of organic molecules which are introduced into the interlayer space and give rise to well defined interlayer spacings. The nature of the organic compounds cannot be deduced from the measured reflection owing to the coincidence of a large number of reflections (Moum *et al.* 1973; Nemecz 1981). The latter denoted such organic-rich smectite as "organophilic smectite". The identification of such smectite is possible by treating an oriented clay size by ethylene glycol that causes the expansion of the 001 reflection to 17 Å (as normal for most smectite), but heating at 250°C for 10 h without rehydration decreases the spacing to about 13–14 Å. This decrease in the interlayer spacing is essentially due to oxidation of organic compounds. Moum *et al.* (1973) reported that the 001 reflection of such organic-rich smectite was shifted to 14 Å when treated with H_2O_2 as a result of the removal of the organic molecules. The interlayer organic molecules seem to be less susceptible to the prevailing oxidation than the outer molecules, hence the coherence between organophilic smectite and total organic carbon (T.O.C.) is not always strong.

However, the Ca-, Na-, and "organophilic" smectites, along with kaolinite, are the main clay minerals composing the black shales of the Quseir area. Illite-smectite mixed layer (with dominant smectite) occurs instead of smectites in the black shales collected from surface exposures, probably due to conversion of smectite on weathering as described by El-Kammar & Basta (1983). The ratio between the peak areas under the 001 reflection at 10 Å of the glycolated slide mount to that at 12–14 Å of the oriented slide, was considered as a relative measure of illite in its mixed layer.

The main non-clay minerals detected in the present study can be summarized as follows:

(1) *Carbonates.* The abundance of calcite and dolomite (Table 1) is calculated from the DTA and DTG diagrams. Calcite dominates over dolomite and is a major constituent of the shales studied. The high ratio of the d-spacings of dolomite (2.89 Å/2.19 Å) suggests a ferroan nature which often dominates in carbonates embedded in shales (McHargue & Price 1982).

(2) *Sulphates.* Gypsum (mainly) together with some anhydrite were identifed by XRD, IR and quantitatively calculated by DTA. The sulphate minerals occur as secondary fillings that dominate in the weathered samples, probably due to the breakdown of sulphide minerals such as pyrite.

(3) *Phosphates.* The apparently isotropic apatite (i.e. collophane) and anisotropic apatite are petrographically distinguished. Both varieties produce an XRD pattern similar to that of carbonate-fluorapatite which is the main constituent of the Egyptian phosphorites (El-Kammar 1985). The phosphate clasts are probably reworked from the older phosphorites of the Duwi Formation.

(4) *Quartz.* The quantitative measurement of its modification peak at 570°C in DTA suggests very limited contribution in the black shales studied (Table 1).

(5) *Sulphides.* Pyrite is the only sulphide detected by XRD and by its DTA exothermic oxidation reaction at 480°C. Upon weathering, pyrite is pseudomorphosed into goethite and/or hematite.

Table 1. DTA data for the black shales of Quseir area, Egypt

		Clay minerals %				Non-clay minerals %							
Locality	Sample Number	Kaolinite	Smectite	Mixed layer	Clays	Quartz	Calcite	Dolomite	Apatite	Gypsum	Anhydrite	Halite	Pyrite
Beida	1	34	24	—	58	1	37	—	4	—	—	—	—
Tunnel	3	51	3	—	54	3	14	2	6	21	—	—	—
	4	7	—	—	7	3	84	—	—	3	—	—	—
	7	32	8	—	40	1	41	5	—	12	—	—	—
	11	62	—	7	69	1	15	—	—	10	—	5	—
Dabaa	1	21	—	—	21	2	20	2	26	—	—	—	3
	4	25	12	—	37	5	23	2	24	—	3	—	—
	7	31	14	—	45	3	27	2	15	—	2	—	2
	11	12	16	—	28	7	31	—	20	—	7	—	—
Umm Hammad	vi 4	19	—	—	19	7	17	2	22	28	2	—	3
	iv 3	25	21	—	46	6	22	1	23	2	—	—	—
	i 4	30	17	—	47	2	28	1	16	1	2	—	2
Cross Cut	1 1	32	—	10	42	1	34	2	13	—	2	—	3
	2 1	37	13	—	50	2	32	1	9	—	3	—	tr
	3 1	23	—	6	29	1	56	1	2	9	—	—	—
Nekheil	C	—	16	—	16	3	63	—	12	—	3	—	3
Nasser	2	—	52	—	52	6	9	1	28	—	3	—	—
	3	—	16	—	16	3	20	4	30	18	3	—	—
Faraa	5	37	23	—	60	1	20	—	—	15	1	—	3
Beida	3	13	35	—	48	5	5	2	5	35	—	—	—

(6) *Organic matter.* This produces an exothermic plateau in the temperature range 260–450°C, which may sometimes be differentiated into smaller plateaux. The IR spectrogram of the organic matter is characterized by absorption bands at 2920 and 2850 cm^{-1} which may be interpreted as vibrations of CH_2 groups and at 3450 cm^{-1} to OH stretching. These bands may suggest the presence of an unsaturated bitumen, possibly gilsonite.

INORGANIC GEOCHEMISTRY

The chemical analyses of the black shales of the Quseir area are shown in Table 2 and compared to those of the black shales from the U.S.A. (Vine & Tourtelot 1970; McKelvey *et al.* 1986). The black shales studied are relatively enriched in Ca, Mn, heavy metals (except Cu), Be and Sr, and depleted in Al, K, Na, Ga, Ba and Ag, suggesting relative impoverishment in the terrigenous admixture (Table 2 and Fig. 2). The major and trace elements in the black shales studied can generally be classified into three genetic associations:

(a) *Terrigenous association.* This includes SiO_2, Al_2O_3, Fe_2O_3, TiO_2, K_2O and possibly Na_2O. The trace elements Nb, Sc, Ga, Co, La and Ce are strongly correlated with each other as well as with the major terrigenous constituents: Al_2O_3, TiO_2 and K_2O. The elements Nb, Sc and Ga are intimately related to the peak area of the basal d-spacing of kaolinite, whilst Co is more strongly associated with smec-

Table 2. Composition of the black shales of Quseir area, Red Sea, Egypt

Major oxides wt %	Present work			Average* (black shale)
	Minimum	Maximum	Mean	
SiO_2	4·02	48·52	27·72	—
Al_2O_3	1·75	19·54	7·65	13·22
Fe_2O_3	0·85	4·99	2·23	2·86
FeO	0·28	3·60	0·70	—
TiO_2	0·08	0·89	0·37	0·33
CaO	12·39	46·42	21·82	2·10
MgO	0·73	21·20	2·17	1·17
K_2O	0·12	1·07	0·42	2·41
Na_2O	0·10	0·64	0·32	0·94
MnO	0·004	0·03	0·01	0·019
P_2O_5	0·61	6·50	2·81	—
S	0·08	8·80	2·71	—
LOI 100°C	0·75	8·41	3·82	—
LOI 500°C	3·28	26·62	12·16	—
LOI 1000°C	6·20	42·40	19·43	—
Carbon	1·90	23·40	9·45	3·53
Hydrogen	0·30	2·90	1·51	—
Nitrogen	0·10	0·50	0·24	—

Trace elements ppm	Minimum	Maximum	Mean	Average** (sea water, ppb)	Enrichment factor $\times 10^5$	Average (black shale)
Li	3	117	25	180	0·002	—
Be	0·3	25	8·2	0·0006	137	1
Sc	3	19	9·8	0·0006	163	10
V	85	4150	964	2·5	3·9	150
Cr	120	777	428	0·3	14·3	100
Co	5	23	14	0·05	2·8	10
Ni	20	210	120	1·7	0·7	50
Cu	25	168	73	0·5	1·5	70
Zn	141	4125	868	4·9	1·8	300
Ga	4	29	11	0·03	3·7	20
Sr	175	989	628	8000	0·008	200
Y	20	66	41	0·001	410	30
Nb	7	43	16	0·01	16	—
Ba	35	250	109	2	0·5	300
La	3	110	58	0·003	193	30
Ce	1	75	40	0·001	400	—
Pb	39	130	80	0·03	27	20

* Vine & Tourtelot (1970). ** Krauskopf (1979). — not detected.

tite (Fig. 3). The elements Y, La and Ce are extremely enriched in the black shales studied, compared with that for average sea water (Table 2). The biogenic detritals such as "collophane" and apatite debris accumulate, preferentially, the rare earths in the octahedral sites of Ca in apatite lattice. The high enrichment factor of Sc and Be may also suggest their possible accumulation with rare earths in apatite. The chondrite-normalized values of La and Ce show a significant depletion of Ce over La, which may indicate a possible marine environment of deposition.

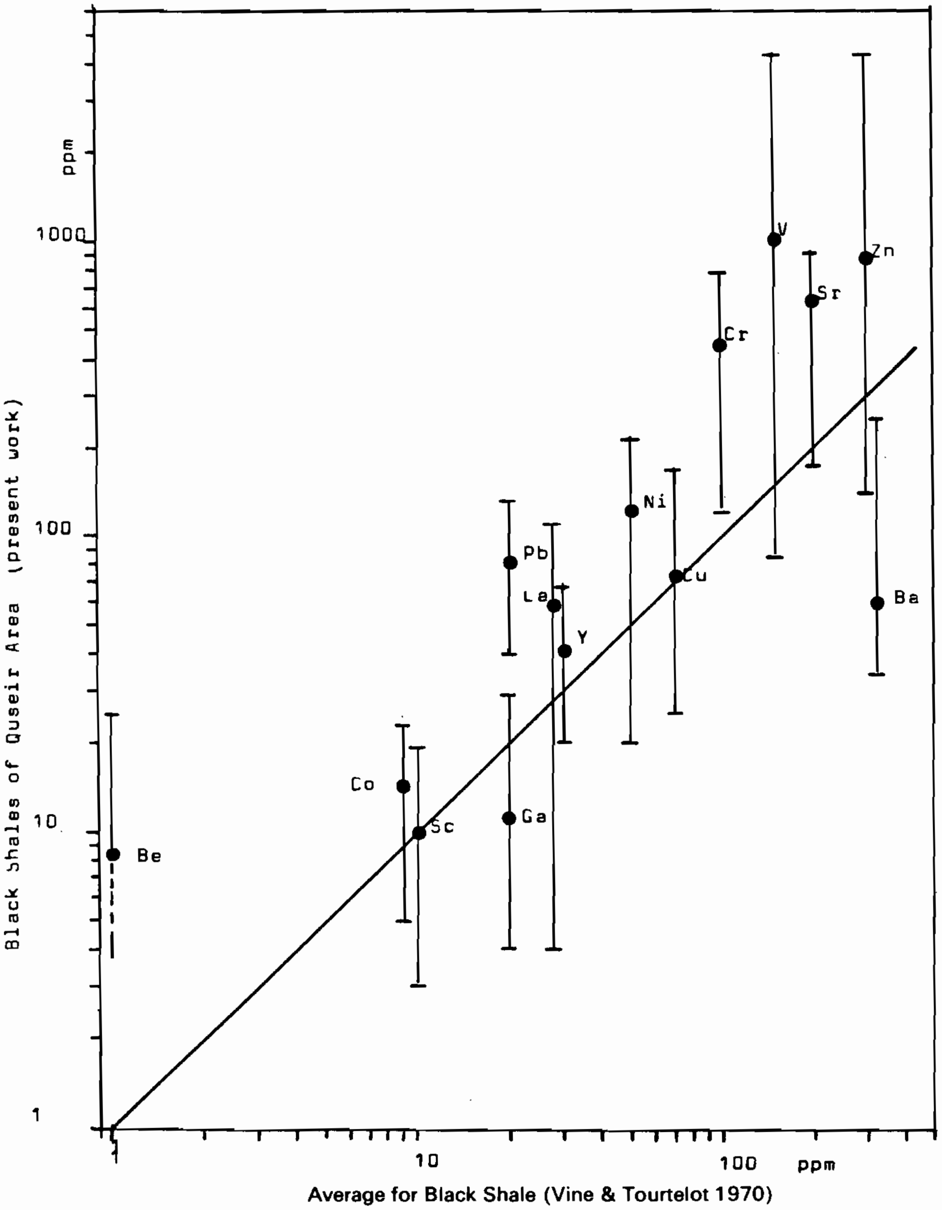


Fig. 2. Enrichment of trace elements in Quseir black shales.

(b) *Carbonate association.* This is mainly represented by Ca which occurs in the form of calcite. The strong relationship between CaO (or calcite peak area, 3.03 Å) and both Sr and Pb (Figs 4 and 5) may indicate their existence in the calcite lattice, substituting for Ca^{2+}. This association includes also MgO and MnO.

(c) *Organic association.* This includes the organic components C, H, N and S which seem to be responsible for accumulation of unusual amounts of some trace elements,

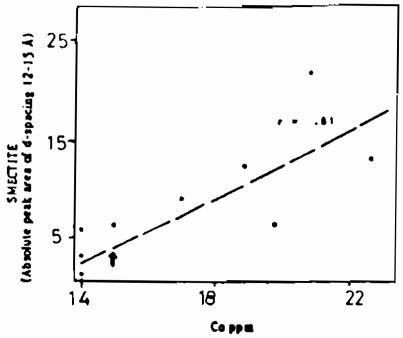


Fig. 3. Peak area of smectite *v*. Co content.

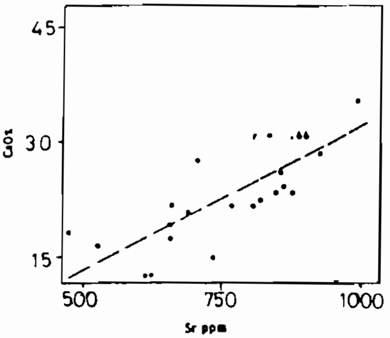


Fig. 4. Relation between CaO and Sr.

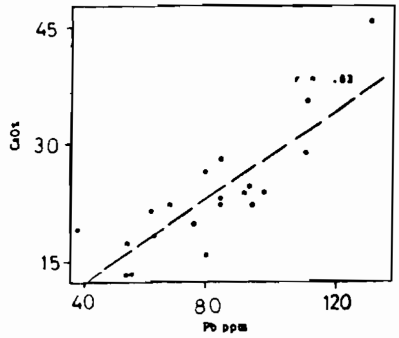


Fig. 5. Relation between CaO and Pb.

especially V. This gives rise to a geochemically distinct zone denoted in the present study as the "vanadiferous zone", which is also enriched in some other trace elements including Zn, Cr and Pb (Fig. 2).

THE VANADIFEROUS ZONE

The black shales at the contact between Duwi and Dakhla Formations contain an abnormally high vanadium content (0.8% V_2O_5). This thin (30 cm thick) zone characterizes the contact between the two formations. Similar vanadiferous zones with similar litho-stratigraphic relations (but different ages) have been reported elsewhere in the world (Coveney & Martin 1983; Poole & Desborough 1985; McKelvey *et al.* 1986).

Although the vanadiferous zone is confined to organic-rich black shales, V does not show any marked correlation with the main organic constituents (C, H, N, S). However, the strong association between V and Be (Fig. 6), the latter being a micro-organic association, supports the view that the initial accumulation of vanadium is related to organic activity but there is no simple straightforward explanation for the process by which such unusual concentration of V, as well as other metals, accumulated in the black shales. It seems likely that the accumulation of vanadium may have been related to long exposure of organic-rich sediments to

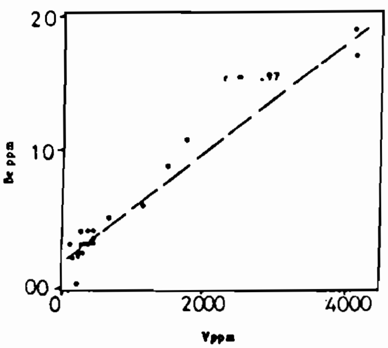


Fig. 6. Relation between V and Be.

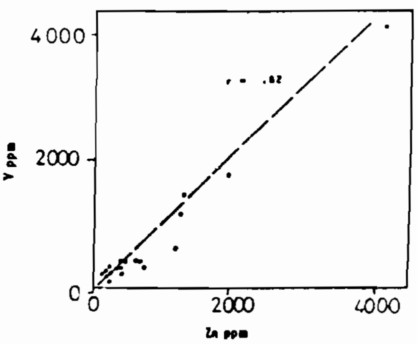


Fig. 7. Relation between V and Zn.

temporarily and locally V-rich sea water. The source of such V-rich water might be volcanic ash (Premovic *et al.* 1986) or certain species of organisms which concentrate several metals (Rankama & Sahama 1950; Prevot & Lucas 1980). The accumulation of vanadium may be accomplished chemically after the death of the organisms (Holland 1984) in the form of vanadyl porphyrin (Ekstrom *et al.* 1983; Miller *et al.* 1984).

The relationship between V and Zn in the black shales (Fig. 7) shows that the Zn content of a weathered V-rich sample is seriously depleted, suggesting preferential mobilization of Zn upon weathering. McKelvey *et al.* (1986) reported that inorganic vanadium compounds survived in the weathered zone of the vanadiferous black shales of the Phosphoria Formation.

The U content of the black shales (12–33 ppm, Table 3) is quite similar to that of the vanadiferous black shales of McKelvey *et al.* (1986). The U/Th ratio ranges from 2·1–7·2, which is 7 to 25 times higher than that of average shales (Krauskopf 1979),

Table 3. Active and mass concentrations of radioactive nuclides in the black shales of the Quseir area, Red Sea coast, analyzed by Gamma Spectrometry Method

Nuclides	KeV	Beid Tunnel (N-2)	Umm Hammad VI (N-4)	Cross Cut 3 (N-2)	Beida (N-3)
			Mass concentrations		
Ra-226		4·75 ± 0·3 × 10^{-6}	11·3 ± 0·8 × 10^{-6}	4·08 ± 0·3 × 10^{-6}	5·77 ± 0·4 × 10^{-6}
U-238 (99·28% Natural U)		14·00 ± 1	33·4 ± 2·2	12 ± 0·9	17 ± 12
Th-228		0·89 ± 0·1 × 10^{-9}	1·67 ± 0·1 × 10^{-9}	0·49 ± 0·09 × 10^{-9}	0·59 ± 1·2 × 10^{-9}
Ra-228		2·62 ± 0·3 × 10^{-9}	1·73 ± 0·3 × 10^{-9}	1·60 ± 0·3 × 10^{-9}	1·42 ± 0·3 × 10^{-9}
Th-232 (100% Natural Th)		6·60 ± 0·5	4·63 ± 0·5	3·80 ± 0·5	4·00 ± 0·6
K-40 (0·01% Natural K)		0·61 ± 0·05	0·53 ± 0·06	0·41 ± 0·06	0·40 ± 0·06
K total		5090 ± 430	4410 ± 500	3450 ± 520	3390 ± 530
Cs-137		ND	ND	0·68 ± 0·23 × 10^{-9}	ND
			Active concentrations		
Pb-214	351·9	171·80 ± 19·47	427·25 ± 48·22	157·46 ± 18·34	216·60 ± 24·79
Bi-214	609·3:1120·3	175·09 ± 14·90	408·86 ± 33·90	144·86 ± 13·66	208·01 ± 18·65
Ac-228	338·4:911·1	26·41 ± 2·69	17·42 ± 2·99	16·12 ± 3·04	14·37 ± 3·68
Ti-208	583·1	27·02 ± 3·01	20·34 ± 3·17	14·82 ± 2·85	17·75 ± 3·56
Bi-212	727·1				
K-40	1406·8	156·5 ± 13·2	135·80 ± 15·4	106·00 ± 15·9	104·4 ± 16·2
Cs-137	661·66	ND	ND	2·17 ± 0·74	ND

indicating secondary enrichment which must have taken place immediately after deposition, as the uranium equilibrium constant is almost equal to unity. This constant measures the activity of the uranium series isotopes in the black shales studied compared with reference shales that already have uranium in equilibrium (not affected by secondary processes).

ORGANIC GEOCHEMISTRY

The source bed potential and the organic geochemistry of the black shales in Egypt have not been well evaluated. However, three distinguishable types of organic matter have been detected by the Rock Eval pyrolysis of representative black shales from the study area. The first type represents a kerogen of type II approaching type I (Fig. 8), such as the black shales of the Nekheil mines, where the total organic carbon is highest (TOC = 20%, about 60% of which is pyrolyzable). The carbon index, hydrocarbon precursor and quality index are here also higher than in the black shales from the other localities. The second type is represented by two samples from Nasser and Umm Hammad mines where the kerogen is of type II proper. The hydrogen index and oxygen index of this type are similar to those of the preceding type, but the TOC is much less ($\simeq 10\%$). The third type is represented by one sample from Faraa mine where the black shale is weathered and its kerogen intermediate between types II and III. Any single black shale sample may contain a mixture of different organic compounds, as shown by the different exothermic reactions at 330°, 395° and 415°C, obtained by the DTA (Fig. 9).

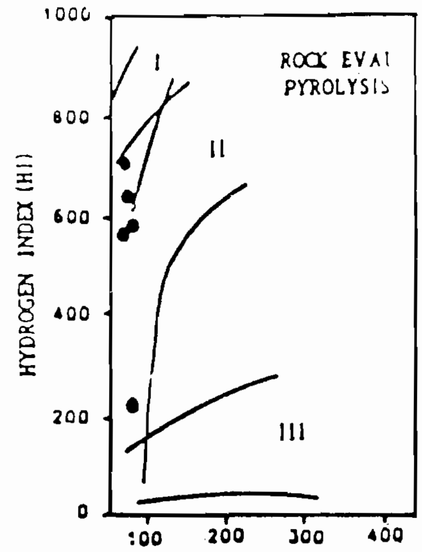


Fig. 8. Relation between hydrogen index and oxygen index in the samples analysed by Rock Eval pyrolysis.

○ Nekheil mine △ Faraa mine
● Nasser mine ■ Umm Hammada mine

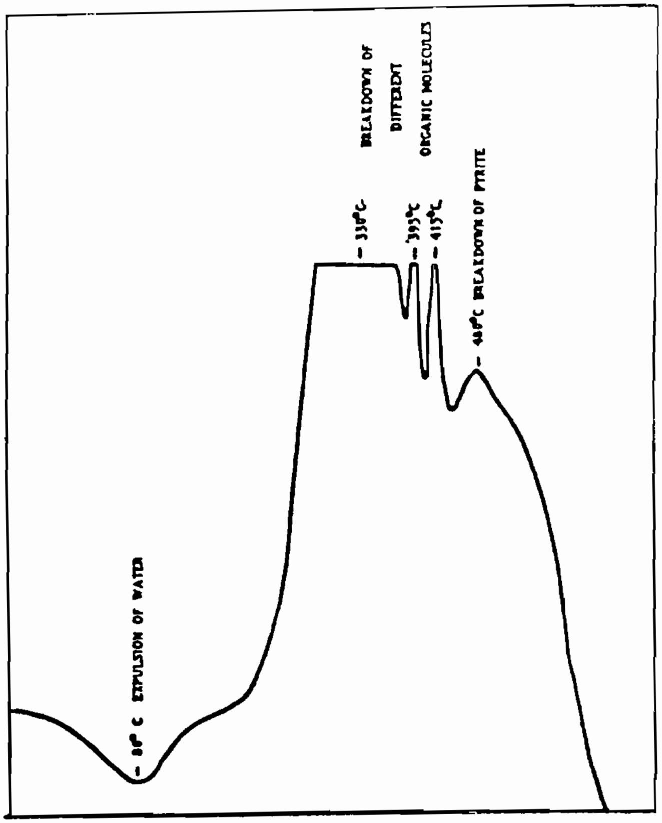


Fig. 9. Differential thermal analysis curve showing several exothermic reactions related to various organic molecules of pyrite and organic matter.

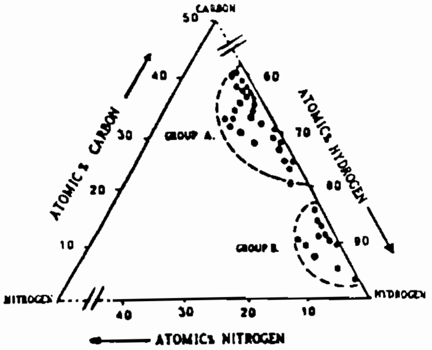


Fig. 10. Relation between atomic percentages of C, H and N.

The organic matter of black shales from the study area was described by Ganz (1984) as kerogen of type II degrading to type III as a result of weathering activities, rather than by the increasing contribution of terrestrial organic matter. Although Troger (1984) believes that the Egyptian black shales were not buried enough to reach the oil window, these shales should be suitable energy donators particularly for Portland cement industry for which the residual clays and active lime may produce good clinker.

The relationship between C, H and N (At.%) indicates that the analysed samples fall into two clusters (Fig. 10). Most samples occur in the cluster having a higher ratio of C/H, suggesting a significant proportion of unsaturated olefins which are absent in the natural crude oil (Tissot & Welte 1978). The second cluster represents samples having a lower C/H ratio, probably indicating more saturated organic molecules. The presence of saturated and unsaturated organic compounds, as a result of degradation by oxidation in the black shales of Quseir area was also demonstrated by Khaled *et al.* (1987).

GENESIS OF THE QUSEIR BLACK SHALE

The Upper Cretaceous–Lower Tertiary boundary in Egypt, like in many other countries, consists of the sedimentary association: black shale-phosphate-chert-dolostone. The contacts between these facies can be either gradual or abrupt. This Upper Cretaceous–Lower Tertiary boundary is believed to be deposited during the late Cretaceous transgression of North Africa (Issawi 1972; Kamel 1982; Richardson 1982). This marine transgression would create a relatively deep, nutrient-rich continental shelf, with a high organic productivity and hence an enhanced potential to accumulate organic matter in the oxygen-poor zone and thus form black shales. The similarity in the n-alkanes in the black shale-phosphate-chert association reflects a common source of organic matter (Bein & Amit 1982).

The quantity and quality of organic matter is mostly controlled by biological productivity in the depositional marine environment. The preservation of organic matter depends in turn on the sedimentation-erosion rate and the oxygen level, among other factors. The existence of the unusually metal-enriched zone (the vanadiferous zone) in the Quseir black shale reflects probable fluctuations in sedimentation rate during the deposition. A very high organic productivity dominated by certain types of marine organisms and a low rate of sedimentation accompanied by anoxic bottom water conditions seem to be the most favourable factors for the deposition of the metal-enriched zone. Higher rates of sedimentation may have prevailed during the deposition of the rest of the formation and reduced the concentration of metals related to biological sources.

REFERENCES

Bein, A. & Amit, O. 1982. Depositional environment of the Senonian chert, phosphorite and oil-shale sequences in Israel as deduced from their organic matter composition. Sedimentology **29**: 81–90.

Coveney, R.M. Jr & Martin, S.P. 1983. Molybdenum and other heavy metals of the Mecca Quarry and Logan Quarry Shales. Economic Geology **78**: 132–49.

Ekstrom, A., Fookes, C.J.R., Hamley, T., Loeh, H.J., Miller, S.A. & Taylor, J.C. 1983. Determination of the crystal structure of a petroporphyrin isolated from oil shale. Nature **306**: 173–74.

El-Kammar, A.M. 1985. Geochemistry and REE patterns for terrestrial and marine skeletal apatites from Egypt. Journal of the Japanese Association of Mineralogists, Petrologists and Economic Geologists **80**: 21–33.

El-Kammar, A.M. & Basta, E.Z. 1983. Chemical weathering of the economic phosphates of Abu Tartur, Western Desert, Egypt. Chemical Geology **38**: 321–28.

Ganz, H. 1984. Organic-geochemical and palynological studies of Dakhla Shale profile, Southeast Egypt. Part B. Origin of the organic matter and its relation to phosphorite formation. Berliner Geowissenschaffliche Abhandlung (A) **50**: 363–74.

Holland, H.D. 1984. The chemical evaluation of the atmosphere and the oceans. Princeton University Press, U.S.A., 582pp.

Issawi, B. 1972. Review of Upper Cretaceous-Lower Tertiary stratigraphy in Central and Southern Egypt. Bulletin of the American Association of Petroleum Geologist **58**: 1448–63.

Kamel, O.A. 1982. Origin of the Egyptian phosphorites. Annals of the Geological Survey of Egypt **12**: 237–54.

Khaled, K.A., Abdel Ghany, A.R., Abdel Rahman, A.A. & El-Fadly, A. 1987. Lateral variation of the geochemical characteristics of some oil shale beds in Quseir-Safaga Environs, Eastern Desert, Egypt. The Fourth Symposium on Phanerozoic and Development in Egypt. El-Azhar University, Cairo, Egypt (Abstract).

Krauskopf, K.B. 1979. Introduction to geochemistry. McGraw-Hill Inc., 617pp.

McHargue, T.R. & Price, B. 1982. Dolomite from clay in argillaceous or shale-associated marine carbonates. Journal of Sedimentary Petrology **52**: 873–86.

McKelvey, V.E., Strobell, J.D. & Slaughter, A.L. 1986. The vanadiferous zone of the Phosphoria Formation in western Wyoming and southeastern Idaho. U.S. Geological Survey Professional Paper **1465**: 27pp.

Miller, S.A., Hambley, T.W. & Taylor, J.C. 1984. Crystal and molecular structure of natural vanadylporphyrin. Australian Journal of Chemistry **37**: 761–66.

Moum, J., Chatty, N.R. & Ayyar, T.S.R. 1973. A natural 17 Å montmorillonite-organic complex from Alleppey, Kerala State, India clays. Clay Minerals **21**: 89–95.

Nemecz, E. 1981. Clay minerals. Akademiai Kiado, Budapest, 547pp.

Poole, F.G. & Desborough, G.A. 1985. Metal concentrations in marine black shales. U.S. Geological Survey Circular **949**: 43–44.

Premovic, O.I., Pavlovic, M.S. & Pavlovic, N.Z. 1986. Vanadium in ancient sedimentary rocks of marine origin. Geochimica et Cosmochimica Acta **50**: 1923–31.

Prevot, L. & Lucas, J. 1980. Behaviour of some trace elements in phosphorites: geochemistry, occurrence, genesis. SEPM Special Publication **29**: 31–40.

Rankama, K. & Sahama, J. 1950. Geochemistry. Chicago University Press, Chicago, U.S.A., 912pp.

Richardson, M. 1982. A depositional model for the Cretaceous Duwi (Phosphate) Formation, south of Quseir, Red Sea coast, Egypt. M.Sc. Thesis, South Carolina University, U.S.A.

Said, R. 1962. The geology of Egypt. Elsevier, Amsterdam, 377pp.

Tissot, B.P. & Welte, D.H. 1978. Petroleum formation and occurrence. A new approach to oil and gas exploration. Springer Verlag, 538pp.

Troger, D. 1984. The oil shale potential of Egypt. Berliner Geowissenschafliche Abhandlung (A) **50**: 375–80.

Vine, J.D. & Tourtelot, E.B. 1970. Geochemistry of black shale deposits. A summary report. Economic Geology **65**: 253–72.

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تركيب وأصل الطَّفلة السوداء بمنطقة القصير ، البحر الاحمر ، مصر

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خلاصة

تقع الطفلة السوداء في الجزء الاسفل من تكوين الداخلة بمنطقة القصير ، وهي غنية بالمواد العضوية ، ويمكن وصفها بأنها صخر طيني بتيوميني غني بالحفريات الدقيقة الكربوناتية . والطفلة السوداء التي تلي تكوين الضوي مباشرة تحتوي على نطاق به تركيزات عالية من الڤاناديوم تصل الى ٠,٨٪ من خامس اكسيد الڤاناديوم .

وتتكون الطفلة السوداء من كاولين غير منتظم ضعيف التبلور ، واسمكتيت ، واسمكتيت عضوي ، وكوارتز ، وكالسيت ، ودولميت حديدي ، وكربونات فلوراباتيت ، وجبس ، وأنهيدريت ، وپيريت ، ومركبات عضوية متعددة غير مشبعة في أغلبها . وعند التجوية يفقد الاسمكتيت العضوي مادته العضوية ويتحول إلى الإسمكتيت العادي ، ولكن يبدو أن محتوى الڤاناديوم لا يتأثر بهذه التجوية .

وتتجمع عناصر *Ce, La, Y* بواسطة الامتصاص على حبيبات معادن الطين ، وعناصر *Zr, Ti* بواسطة المادة الفتاتية ، وعناصر *Nb, Ga, Sc* بواسطة معدن الكاولين ، وعنصر *Co* بواسطة معدن الإسمكتيت . أما العناصر *Mn, Sr, Pb* فتتجمع مع معادن الكربونات ، في حين ان عناصر *V, Zn, Be, Cd, U* تتجمع بواسطة المواد العضوية . ولقد وجد أن معامل الإتزان لعنصري *Th, U* يدل على أصلهم الأولي . وتتبع المواد العضوية نوع *II* وتقترب من نوع *I* من الكيروجين ، وهي مواد ترسبت تحت ظروف بحرية غير هوائية . وتعتبر الطفلة المدروسة مصدراً جيداً للطاقة ، ويمكن أن تنتج « كلينكرا » عالي الجودة عند تحللها حرارياً .