7 Organic Geochemistry

7.1 Total organic carbon (TOC) content

High primary production of coastal waters, a stratified water column, anoxic bottom waters, low influx of clastic material (low dilution), and high supply of terrestrial organic matter may promote the formation of organic carbon-rich sediments (Calvert and Petersen 1992; Meyers 1997). Favorable conditions for the formation of argillaceous, organic carbon-rich sedimentary rocks, so-called black shales, are best known from the mid-Cretaceous where most of our present–day petroleum reserves were generated (Larson 1991; Langrock et al. 2003). Geological evidence indicated that organic-rich sediments could be deposited even in an open shelf until the early Paleozoic period, but they could be deposited only in a hydrologically isolated basin afterwards (Klemme and Ulmishek 1991). This change in the history of geological age is attributed to the evolution of benthic animals and bacteria (Klemme and Ulmishek 1991) and/or the increase of dissolved oxygen in the ocean (Berner and Canfield 1989).

The higher enrichment of organic matter in sediments is also one of the criteria for the identification of oil and gas source rocks. Various recent reviews have been puplished on preservation of organic-rich source beds (e.g. Brooks 1981; Daly and Edman 1989; Heydari et al. 1997; Tissot and Welte 1984). Preservation of the organic matter is controlled by conditions such as bottom water circulation rates, degree of oxygenation of bottom water, deposition rates, supply rate of terrestrial organic matter from the continents, and productivity in the surface water. Change in these factors creates highly variable quantities of organic carbon.

The organic carbon analyses in the study consist of 27 shale samples from the five areas. The total organic carbon (TOC) data for the analysed samples are given in figure19.

The amount of organic matter is variable from location to location according to the type of shale and their characteristic attributes. The black shale samples from Ataqa Formation of Carboniferous age recorded TOC values of 1.58 %, 1.65 % and 2.4 %. The Safa Formation black shale samples of Jurassic age gave the highest values: 4.13 %, 4.36 % and 4.52 %. These high TOC values of both formations may be related to the association of this black shale with coal beds. On the other hand the black shale of Duwi Formation of Cretaceous age which is associated with phosphate beds in Abu Tartur and Quseir show variable values ranging from 0.41% to 1.84 % TOC in Abu Tartur and 2.29 % to 2.92 % TOC in Quseir.

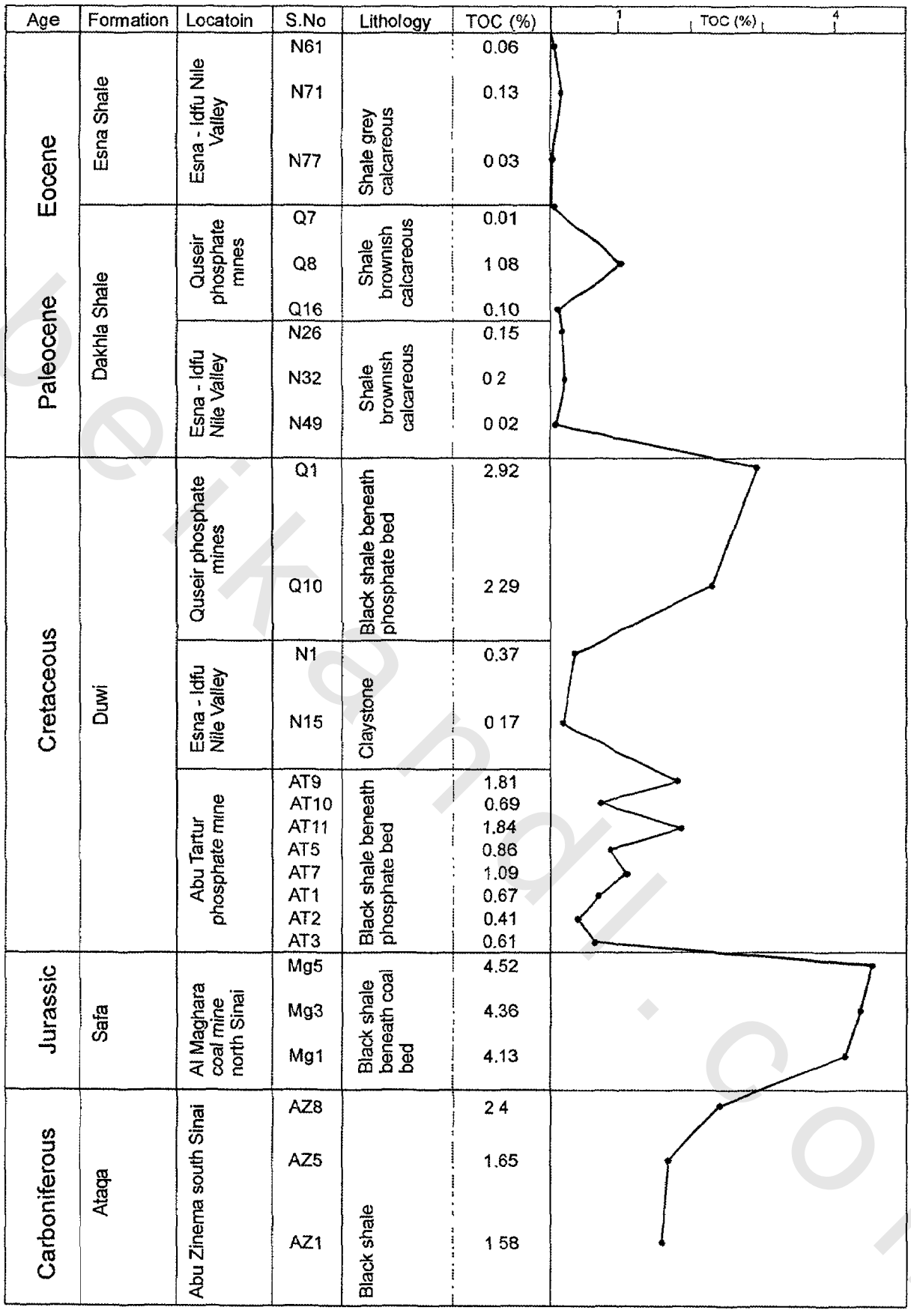

Fig. 19: Stratigraphic position of the studied shales and compositeTOC (%) profile (vertically not to be scaled)

The obtained values in Dakhla Shale and Esna Shale from the Nile Valley show very low values of less than 0.5%. This indicates the oxydization of organic matter in these formations in the outcrops.

7.2 Rock-Eval pyrolysis

Rock-Eval pyrolysis provides information on the quantity, type and thermal maturity of the associated organic matter as well as its hydrocarbon potential. Details of the analytical methods have been reported by Espitalie (1977), Tissot and Welte (1984) and Peters (1986). In Table 4 Rock-Eval pyrolysis results for 10 bulk rock samples are listed.

Table 4: The TOC and Rock-Eval results of the studied shales

	Location	APT ID	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	PP (mg/g)	PI (wt ratio)	HI (mg HC/ g TOC)	OI (mg CO2/ g TOC)	TOC (%)
AT10	Abu Tartur	23580	0.01	0.18	0.49	418	0.19	0.06	25	68	0.72
AT11		23581	0.03	0.91	1.41	431	0.94	0.03	44	68	2.06
AT7		23582	0.02	0.84	0.42	425	0.86	0.02	75	38	1.12
AT1		23583	0.03	0.25	0.43	424	0.28	0.10	37	64	0.67
AT3		23584	0.01	0.09	0.35	418	0.10	0.09	15	57	0.61
Q1	Quseir	23585	0.05	1.12	1.56	425	1.16	0.04	41	57	2.72
Q10		23586	0.03	1.10	0.21	412	1.13	0.03	98	19	1.12
Mg1	Al Maghara	23587	0.10	6.23	0.45	427	6.33	0.02	113	8	5.51
Mg3		23588	0.18	10.21	1.36	432	10.38	0.02	195	26	5.24
Mg5		23589	0.15	7.73	2.60	432	7.88	0.02	161	54	4.79

The hydrogen index (*HI*) vs. oxygen index (*OI*) diagram is shown in Figure 20 indicating the main types of organic matter of the different formations. These indices can often be directly related to the atomic can H/C and O/C ratios, and interpreted in the same way as a van Krevelen diagram (Espitalie 1977; Tissot and Welte 1984). Most of the samples are scattered in type III kerogen. Very low HI of 25 to 98 mg HC/g TOC and relatively low to medium OI of 19 to 68 mg CO_2/g TOC are observed for the Duwi Formation samples of Abu Tartur and Quseir phosphate mines. On the other hand samples of Safa Formation of Al Maghara coal

mine show low HI of 113 to 195 mg HC/g TOC and very low OI of 8 to 54 mg CO_2/g TOC. These low HI values of less than195 mg HC/g TOC is due to bad preservation of organic matter.

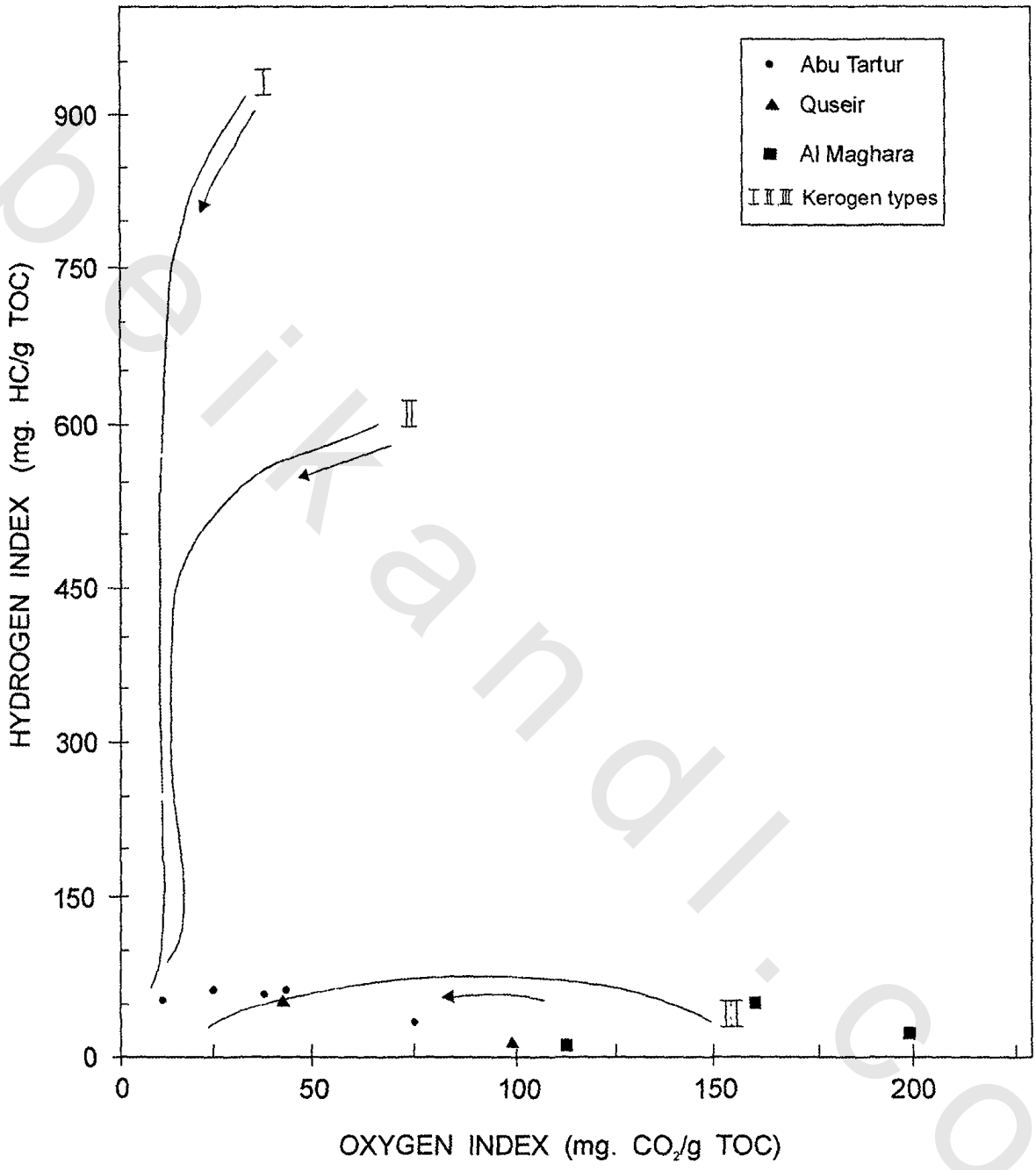

Fig. 20: Van Krevelen-type plot of Rock-Eval data for the studied bulk samples.

7.2.1 Hydrocarbon source potentials

The hydrocarbon genetic potential (PP) in mg/g is determined from the sum of (S_1+S_2) peaks. The PP values of the Duwi Formation in Abu Tartur range from 0.1 to 0.94 mg/g and 1.13 to 1.16 mg/g in Quseir. The Duwi Formation therefore displays values below typical average hydrocarbon yields of source rocks >2.5 mg HC/g rock (Tissot and Welte 1984). Whereas the samples of Safa Formation in Al Maghara coal mine show values in hydrocarbon yields of 6.33 to 10.88 mg/g rock.

7.2.2 Determination of thermal maturity (Tmax)

The determination of the degree of maturity of the sedimentary organic matter is an essential parameter in order to characterise a petroleum source rock. It is the main cause of hydrocarbon generation and transformation. The T_{max} is the temperature at the maximum point of the S_2 peak, used in Rock-Eval pyrolysis. The studied samples of Duwi Formaion in Abu Tartur and Quseir phosphate mines, as well as samples of Safa Formation in Al Maghara coal mine are immature with T_{max} values between 412-432 °C. This low Tmax value indicates that the organic matter has not generated a substantial amount of hydrocarbon. This result is in correspondance with the T_{max} value of 428 °C obtained by Mostafa and Younes (2001) for the Safa Formation in the Al Maghara coal mine.