1. Introduction

Carbonaceous shales have a wide distribution on the Egyptian surface and in subsurface sedimentary sequences e.g. in sediments of predominantly Carboniferous, Jurassic, Cretaceous, Paleocene and Eocene age. The carbonaceous and black shales in Egypt gained interest since five decades when the phosphorite deposits were discovered and exploited. The phosphorites are intercalated with and capped by black shales that contain considerable amounts of organic matter and are enriched in trace elements, which may be of economic potential. The interest in the black shales all over the world in the last decades principally stem from the widespread recognition that black shales are important source rocks for petroleum or may be used as natural fuel resources. Various previous studies of the carbonaceous shales in Egypt concentrated on an individual location or an individual geological age. In this work the shales of the variety of Egyptian locations and stratigraphic ages are investigated focusing on their mineralogical and geochemical characteristics.

1.1 General geographical and geological setting of Egypt

Egypt forms the north-eastern part of the African continent and is situated between latitudes 22° and 31° north. The country covers an area of about one million km^2 and occupies nearly one-thirtieth of the total area of Africa. The largest part of Egypt consists of desert, the so called Western Desert, to the west of the Nile, the Eastern Desert, east of the Nile Valley and the Sinai Peninsula, delineating the north-eastern extension of the Sahara.

The structural elements of the Precambrian of the north-eastern margin of the African Shield (Arabian-Nubian massif) are the principal features that controlled the structural development of Egypt (Said 1962). The reactivation of these elements during the Paleozoic resulted in the development of large NNW–SSE striking interacratonic depressions (Klitzsch 1984).
From Late Precambrian to Mid-Cretaceous sediments all over Egypt were deposited in largely shallow and nearshore marine environments, interbedded with continental (fluvial) and deltaic sediments (Gindy 1983). At the end of the Lower Carboniferous, the post-Visean uplifting was accompanied by E–W fault systems and affected a large part of the NE African plate. As a result, most of the pre-Visean deposits were eroded from uplifted areas and were only preserved in the western part of Egypt. Marine strata in the northern Gulf of Suez (Said 1962) and fluvio-glacial sediments in the south were also encountered or preserved in the

Carboniferous (Klitzsch 1980, 1983a and 1983b). During the Permian and until the Lower or Middle Jurassic, continental to shallow marine sediments covered the northern part of Egypt.

After the disintegration of the large continent „Pangaea" in Jurassic time, the old structural patterns of Precambrian age, which had influence in the Early Paleozoic, were reactivated (Schandelmeier et al. 1987). The result was a stepwise subsidence of the intracratonic depocenters that gave rise to the formation of the Dakhla and Assiut basins (Hendriks et al. 1987). Until Early Cretaceous time, clastic sedimentation was predominant. Starting from the Cenomanian and ending in the Senonian, the structural differentiation of the NE African plate was increased and the major marine transgression of the Tethys, that deepened to the north and advanced southwards, reached its maximum extension in the Lower Eocene. The Upper Cretaceous sediments in southern Egypt consist of variegated shales upon which, (in the intracratonic depocenters), a thick sedimentary succession follows. The sediments are of shallow marine origin with some lateral and vertical lithological changes, in which the phosphate deposits are intercalated.

1.2 Location of the studied areas

In this work 144 samples were selected from five different locations and different geological ages to represent all the carbonaceous shales of Egypt (Fig.1).

1.2.1 Abu Zinema area in Southwest Sinai (Carboniferous)

In this location 12 samples were selected from the carbonaceous (black) shale located within the middle part of sandstones of the Ataqa Formation of Carboniferous age at Bedaa–Um Thora district (long. 33° 13' East and lat. 29° 3' North) in Southwest Sinai. The Paleozoic sediments are exposed in the south-central parts of Sinai, primarily in the Um Bogma area east of Abu Zinema and at Abu Durba.

1.2.2 Al-Maghara coal mine in North Sinai (Jurassic)

From Al-Maghara coal mine about 70 km south of the Mediterranean Sea at long. 33° 10' and 33° 35' E and latitudes 30° 35' and 30° 10' N. North Sinai, five samples of carbonaceous (black) shale which is associated with the main coal bed of Safa Formation of the Jurassic age (Al Far 1966), were collected.

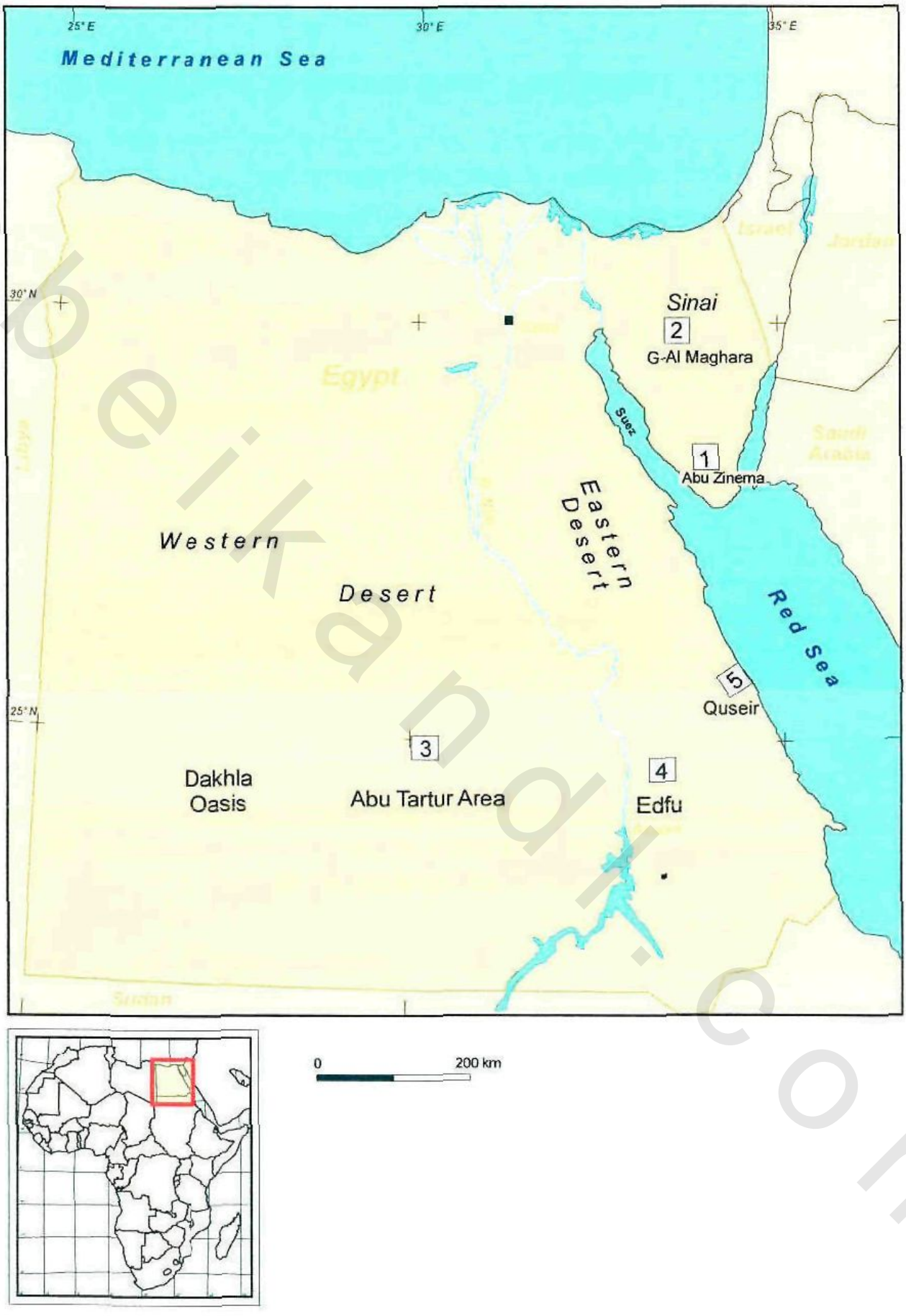

Fig. 1: Location map of the study areas in Egypt.

In North Sinai a complete Jurassic section is exposed at Gebel Al-Maghara. During the Jurassic and Cretaceous periods there was no significant change in the depositional framework. The Jurassic sequence below the Cretaceous at Gebel Al-Maghara can be divided into six alternating continental and marine formations.

1.2.3 Abu Tartur phosphate mine in Western Desert (Cretaceous - Eocene)

The Abu Tartur phosphorites, which were first described by Hermina et al. (1961), are situated in the middle latitudes of Egypt about 60 km to the west of El Kharga town (lat. 25° 26' N and long. 30° 02' E). The Abu Tartur plateau forms an extended escarpment which bounds the Dakhla–El Kharga depression to the north. The semi-oval plateau covers an area of 1200 km^2. It is covered by Early Tertiary limestones. From the long wall sector at Abu Tartur phosphate mine 12 samples from the carbonaceous (black) shale of Duwi Formation were collected. It is of Upper Campanian to Lower Maastrichtian age (Said 1962).

1.2.4 Esna-Idfu region in Nile Valley (Cretaceous - Eocene)

The Esna-Idfu region is situated east of the Nile Valley between latitude 25° 05' and 25° 30' N and longitude 32° 30' and 32° 50' E. About 80 samples were collected to represent the exposed rock units, as a composite section stratigraphically subdivided from top to base into:

Esna Formation	Paleocene - L. Eocene
Tarawan Formation	U. Palaeocene
Dakhla Shale	Maastrichtian - Paleocene
Duwi Formation	U. Campanian - L. Maastrichtian
„Nubia Sandstone"	Pre-Campanian

1.2.5 Qusier phosphate mine in the Red Sea coast (Cretaceous - Eocene)

The Qusier and Safaga areas are part of the Eastern Desert of Egypt at the Red Sea Coast, and gained importance since five decades when the phosphate deposits of the Gebel Duwi Range were discovered and exploited. The region extends in a northwest direction along the western coast of the Red Sea from south of Qusier to Safaga, between latitude 25° 50' and 26° 67' N and longitude 33° 45' and 34° 25' E, covering an area of about 500 km^2.

At present, most of the mines in Quseir and Safaga are abandoned due to the low grade of the remaining phosphate deposits, the current exploitation of phosphates from Abu Tartur phosphate mine and the effect of international competition of Moroccan and Jordanian ores. The phosphate in some mines is usually intercalated with and capped by shales. Typically, the Egyptian phosphates are shallow marine deposits of a general Upper Cretaceous age. Their maximum intensity of deposition was associated with a transgressive shoreline of the Late Campanian or Early Maastrichtian Sea which encroached from North to South over the northern slope of Africa. From Qusier phosphate mines 35 samples from Duwi and Dakhla formations were collected.

1.3 Distribution of carbonaceous shales in Egypt

The black shales are widely distributed in Egypt in several horizons of different geologic ages. No serious approach had been made to evaluate their geological as well as their economic significance. This may have been due to the lack of interest in developing and using these economically important deposits as a source of fuel, most probably due to the competition of oil. Ball (1916) and Hume (1927) were the first authors who recorded in outcrops Cenomanian marls and sandstones which contain hydrocarbons in the form of oil and asphaltic matter at many localities, e.g. Wadi Abu Quda, Itala el-Zur and Nazzazat, Gulf of Suez area.

Said (1962) mentioned that some carbonaceous shale bands containing plant remains of Paleozoic age are recorded at Rod El Hammal, Wadi Araba. Oil shales were also reported from Cabal Tanka, Wadi Matulla, North Ras Gharib, Abu Shaar, Judal, and Ras Dib. In the Fayum region to the west of Gharaq and Wadi Maela, the Middle Eocene limestone is bituminous. The middle chalky limestone to the east of Tura is distinctively bituminous.
The oil shales are present in different Upper Cretaceous-Lower Tertiary formations: Duwi Formation (Phosphate bearing rock), Dakhla Shale and Esna Shale in the region between Safaga and Quseir in the Red sea coast. The Dakhla Shale possesses the horizon richest in organic matter. The Dakhla Shale directly overlies the upper phosphate bed. The average amount of oil yielded by Fischer assay from Cretaceous oil shale amounts to 20 - 45 gal/ton (Robison and Tröger 1983; Tröger 1984). Black shales also occur in many localities in the Western Desert. Among the important localities of oil shale is the one recorded in Abu Tartur area which yield considerable amount of oil (Tröger 1984).

1.4 Previous studies on black and carbonaceous shales in Egypt

Various authors have attempted to provide some information on the geology and the sedimentology of the black and carbonaceous shales in Egypt. However, many points concerning their origin and potential still need further clarification. Higazy and Hussein (1955) measured the uranium content of some black shales and phosphates from the Quseir - Safaga district. Mustafa and Ghaly (1964) studied the carbonaceous shales from different localities in Egypt (Galala area, Buda Valley and Quseir area). Malak et al. (1977) studied the mineralogical, petrography and organic geochemical characteristics of black shale in Safaga-Quseir area. Robison and Tröger (1983) studied the geology and organic geochemistry of Dakhla shale from Quseir, Sibaiya and Abu Tartur. Tröger (1984) determined the oil yield by Fischer assay and estimated the total volume of all potential organic-rich Cretaceous strata of Quseir-Safaga and Abu Tartur areas. Ganz (1984) proposed a genetic model for the organic rich phosphate-bearing Dakhla Shale. Darwish (1984) studied the stratigraphy and organic chemistry of the black shales in the Quseir-Safaga area. Khaled et al. (1987) studied the geochemical characters of the oil shales and their extractable bitumina within the Duwi Formation in the Quseir-Safaga district.

The black shales in Egypt were also studied petrographically, mineralogically and geochemically by many workers (El-Kammar 1987; Ganz 1987; Germann et al.1987; El-Kammar et al.1990; Ibrahim 1992; El-Kammar 1993; Ismael 1996; Ahmed 1997; Sediek and Amer 2001; Ghandour et al 2003; Ibrahium et al.2004). Most of the previous studies were carried out on black shales of the Eastern Desert (Quseir-Safaga district); however, little was done on the Western Desert and Sinai. Thus this study focuses on the carbonaceous and black shales from both, the Eastern and the Western Desert as well as Sinai.

1.5 Scope of the present work

Egyptian carbonaceous and black shales have drawn the attention because of their geological and economic significance (as a source rock and raw material). The present work aims to provide detailed geological, mineralogical, geochemical, petrographical information and to determine the economic potential of some Egyptian carbonaceous shale, which stem from five different geological ages. For these carbonaceous shales the depositional conditions are studied.