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HEAVY MINERALS AND PROVENANCE OF THE PALEOZOIC SUFFI FORMATION, WESTERN DESERT, IRAQ.

By

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المعادن الثقيله ومصدرها في وحدة صوفي – الباليوزوى الصحراء الغربية – العراق

علي الجبـــوري و زكي حســن

تم تحليل المعـادن الثقيله لعشر عينات من وحدة صـوفي القتاتيـة (وتتبع الاردفين – الكربوني لمنطقة الصـحراء الغربية في العراق) . ويشتمل نطاق التمعدن على معادن معتمة وبتكـون من بيـريت ، المنبـت ، مـاجنتيت وهيمـاتيت وكذلك مـعـادن شـفـافـه تشـتمـل على الزيركـون ، النورمـالين الروتيل ، الجارنت ، الابيـدوت ، الكيـانيت والسـتروليت ، ليوكسين كلورايت وبيوتيت . ان طبيعة وتواجد هذه المعادن يدل على مصـدر صـخـور تتبع صـخـور القاعدة في العراق والتي تتكون من صخور متحوله وجرانيت وتتبع الدرع العربي الأفريقي (العربي – النوبي) من الزمن البريكاميري .

Keywords: Heavy minerals, Suffi Formation, Iraq, Provenance, Paleozoic.

ABSTRACT

Heavy minerals analyses were carried out on 10 samples from the clastic Suffi Formation (the Ordovician-Carboniferous unit in the western Iraqi desert). The suite of minerals consists mainly of opaque minerals including pyrite, ilmenite, magnetite and hematite and the non-opaques is represented by zircon, tourmaline, cutile, garnet, epidote, kyanite, staurolite, leucoxene, chlorite and biotite. The nature and occurrence of the above heavy minerals association reflect a source area of the crystalline basement rocks of Iraq. These basement rocks are coomposed of metamorphic rocks and granites complexes. They belong to the Arabian part of African (Nubio Arabian) Precambrian platform.

INTRODUCTION

The Suffi Formation is the oldest known formation in the western desert of Iraq, it belongs to Uppermost Ordovician - Carboniferous age [1].

Ten core samples were selected for the present study from the borehole KH5/6 drilled as a part of hydrogeological investigation in the western desert of Iraq (Fig. 1). The formation has been identified also in several boreholes in the neighbouring Rutba area. The lithologic composition of Suffi Farmation in different boreholes is dominated by clastic rocks maily of interbedded sandstone, siltstone, shale and occasionally marls and thin beds of dolomitic limestone.

The Suffi Formation can be correlated to the Paeozoic Saq and Tabuk Formations of Saudi Arabia and Jordan. These are represented mainly by continental deposition with some marine clastic interbeds.

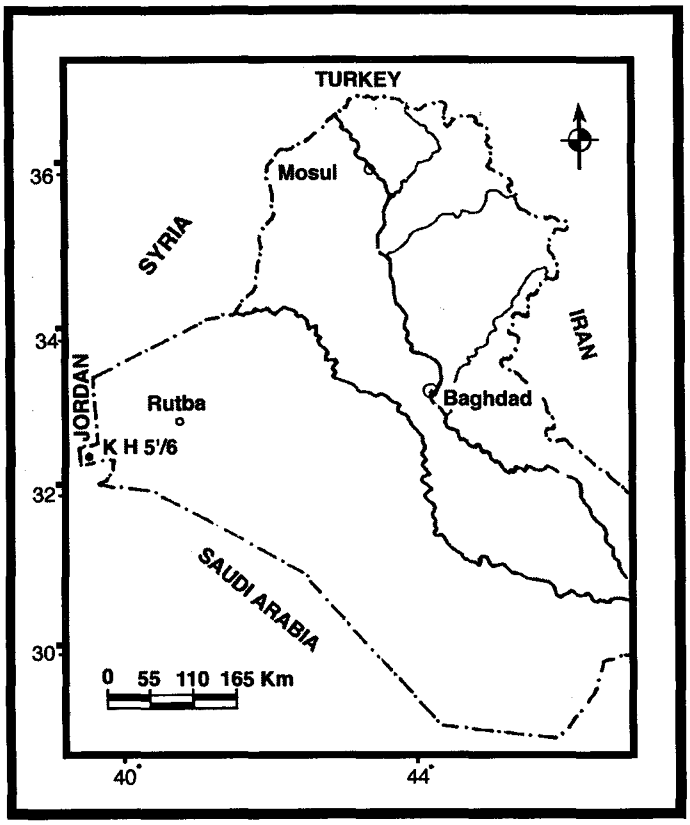

Figure (1) : The location map.

The aim of the present study is to investigate the heavy minerals in the clastic rocks of Suffi Formation and to determine their provenance. The heavy minerals were separated from the 2-4 phi fraction by floating off the light minerals in a heavy liquid "Bromoform" of specific gravity (2.9).

Lithology:

Figure (2) shows a simplified lithological section of the Suffi Formation at borehole KH 5/6 western desert of Iraq. The formation is dominated by clastic deposition of interbedded sandstone, siltstone and shale.

The detailed study of the petrography and mineralogy of the formation by Al-Juboury [2] revealed that sandstones are generally fine grained, gray and green, relatively coompact, finely laminated, sometimes cross bedded, commonly micaceous on bedding planeos with interbedded shales and silty shales.

Shales and siltstones are dominatly gray, purple and green, interbedded with sandstones, all commonly micaceous.

Sandstones are mainly quartzarenites and subarkoses, moderately well sorted. The cementing materials of the studied sandstone samples are dominated by carbonates, as scattered sparry calcite cement with patchy distribution. Secondary silica overgrowths are observed in quartzarenite of the Suffi Formation, otherwise chlorite is recorded in some of the studied samples mainly in the lower part of the formation (Fig. 2).

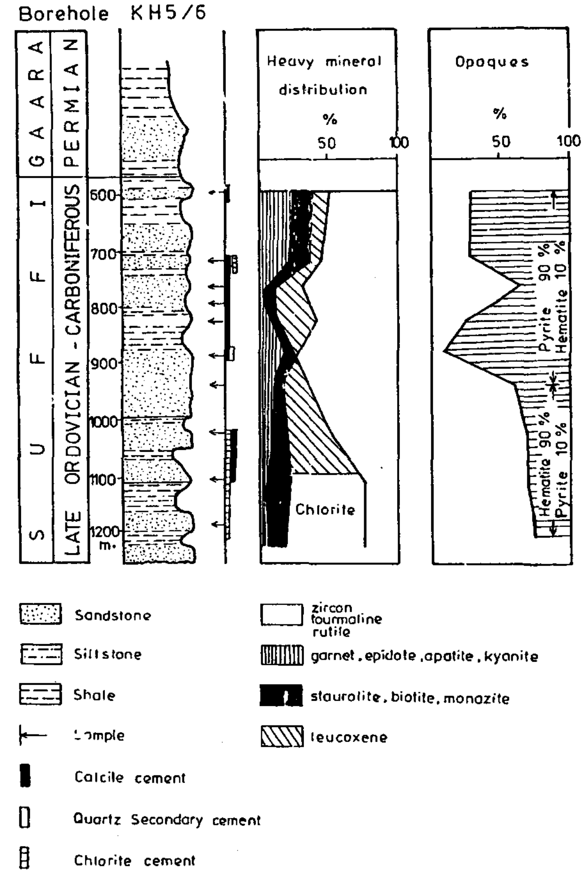

Figure (2) : Lithologic composition of borehole KH 5/6 showing heavy mineral distribution, opaques content, cement distribution and sampled horizons.

Continental sedimentation prevailed during the deposition of Suffi clastics. Kaddouri [1]referred to partial deposition of Suffi facies on a shallow platform within the tidal or subtidal zone with reducing conditon as indicated from the foraminiferal assemblage as well as the sediments.

The Suffi rock unit is overlain conformably by the Permian Ga'ara sandstone Formation.

Distribution of heavy minerals

The heavy mineral suite separated from the studied Suffi samples consists of the following minerals arranged in a descending order: opaques (pyrite, hematite, ilmenite and magnetite), zircon, tourmaline, rutile, leucoxene, chlorite, garneto, staurolite, epidote, biotite, kyanite, monazite and apatite (Fig.2).

The above association of heavy minerals is grouped according to their stability using Folk's [3] scheme in terms of opaques, ultrastable (zircon, tourmaline and rutile) and metastable (garnet, epidote and kyanite). The unstable minerals (pyroxene and amphibole) are very rare and recorded only as a green hornblende in one of the studied samples.

Chlorite is the abundant heavy mineral in the clastic rocks from the lower part of the studied section, reaching upto 55% of the recorded non opaque heavies, (Fig.2). In other samples (at depths 719, 1020-1060 mt) few grains of chlorite were recorded, so they are not included in figure (2). Petrographic study of the mentioned rocks revealed the presence of chlorite as common cementing matirial as grain coating anf pore filling cements and tend to corrode the quartz grains, therefore, Suffi chlorite is considered to be of a diagenetic origin [2]. Leucoxene shows an observed higher concentration in the heavy minerals of the investigated samples. (Fig.2).

Below is a brief description of the observed heavy minerals in the Suffi clastics:

Opaques: The observed opaque minerals are pyrite, heomatite, ilmenite and magnetite. Most of the grains are angular to subangular grains with a lesser amount of subrounded grains. Vertical Variation in the opaque distribution is shwon in figure [2], higher concentration of pyrite and ilmenite reaching 90% is recorded of the minerals of Suffi clastics at depths (600-900) meters. Below these depths, hematite shows higher concentration than pyrite and ilmenite.

Ultrastable minerals: Zircon is found as colourless and yellow, small prismatic, bipyramidal and some are subrounded and zoned, others are turbid and contian inclusions (Fig. 3).

Figure (3): Photomicrographs of heavy minerals collected from Suffi Formation at depth 700 meters.
(A) Bipyramidal colourless and prismatic yellow zircons grains, Ordinary light, X 10.
(B) Zoned zircon, L (Leucoxene), O (Opaques, mainly pyrite). Ordinary light X10.

Tourmaline displays different pleochroic colours, brown, green, yellow, golden yellow and blue varieties in prismatic, oval and rounded grains. Fine dust like clouds of opaque iron oxides, spherical cavities, euhedral zircon grains are the common inclusions in many of the observed tourmaline (Fig. 4 & 5).

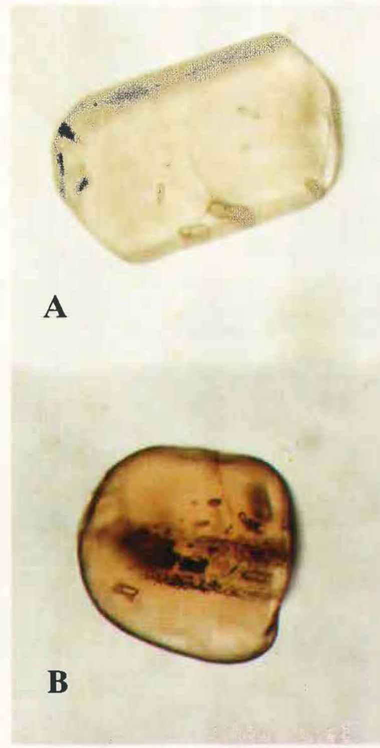

Figure (5): Tourmaline grains from Suffi Formation, depth 800 meters.
(A) Golden yellow tourmaline. Ordinary light, X20.
(B) Blue tourmaline. Ordinary light, X40..

Figure (6): (A) Rutile, euhedral prismatic, dark red grain (R); Leucoxene (L); Opaques "mainly hoematite" (O); Zircon (Z); Clinozoisite (C), depth 930 meters. Ordinaty light, X10.
(B) Garnet of dissoluted grain and etched surfaces filled by diagenetic hoematite, depth 760 meters. Ordinay light, X40.

Rutile is represented by dark reddish brown variety, the grains of which are generally prismatic ('Fig.6).

Metastable minerals: Members of this grooup arranged in a descending order are garnet, epidote, kyanite and apatile.

Garnet is represented as angular, subangular colourless and rose varieties. It has been affected

by intrastratal solutions and showing etched surfaces filled by disgnetic hematite (Fig.6), the same feature had been noted by Walker [4].

Epidote is typically cloudy yellowish green grains with spongy mineral aggregates ('Fig.7)

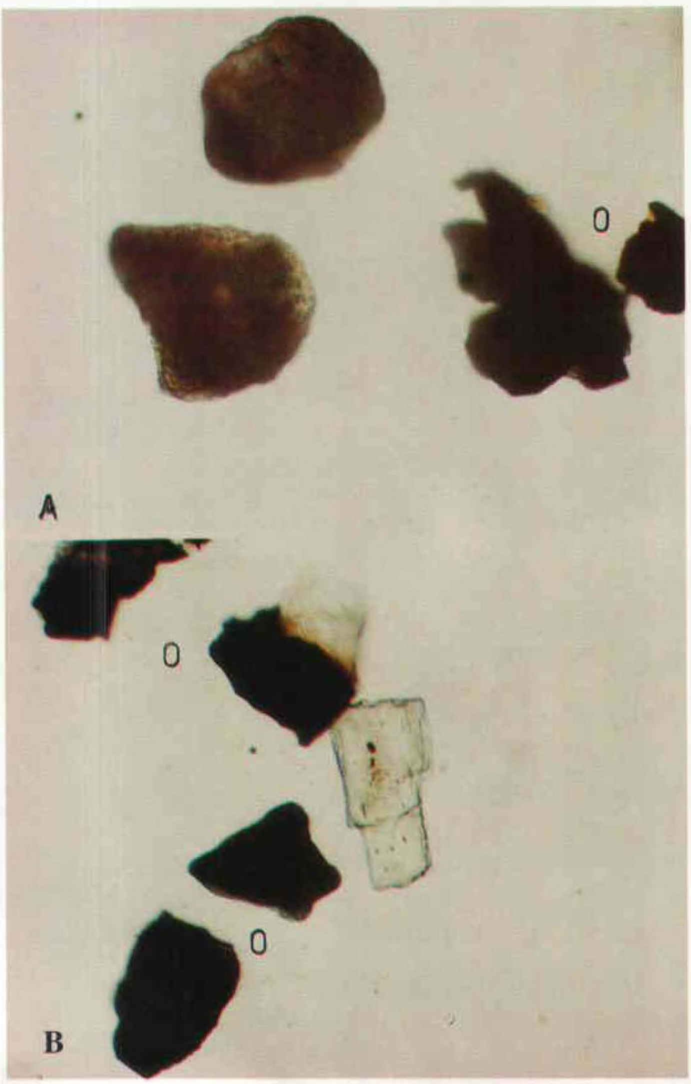

Figure (7): (A) Epidote of cloudy spongy aggregates; Opaques (O), depth 930 meters.
Ordinary light, X20.
(B) Kyn=anite, elongate grey-green grain; Opaques (O), depth 800 meters.
Ordinary light, X10.

The similar aggregates were believed by Smale [5] to be epidote and quartz.

Clinozoisite grains of pale green prismatic habit with a weak but distinctive pleochroism and high birefringence are recorded in some of investigated samples (Fig.6).

Kyanite is observed as grayish to green in colour, with good cleavage and elongated (Fig. 7). Apatite is present in a very small amount as elongated, prismatic colourless grains. Other recorded heavy minerals are staurolite, monazite and biotite.

Staurolite is represented by a brownish yellow variety which shows pleochroism to golden yellow (GFig.8). A pronounced conchoidal fracture with numerous sinuous lines of minute opaque inclusions are observed in the studied grains, that are believed to be carbonaceous materials [6]. Monazite is clear egg-shaped grains, a few of them contain inclusions.

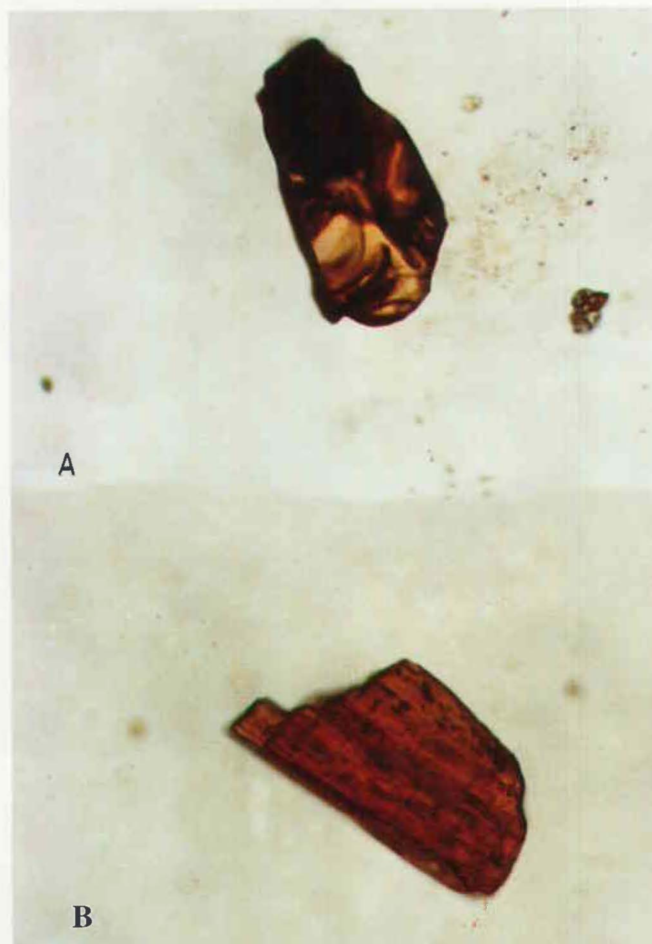

Figure (8): (A) Staurolite, golden yellow with conchoidal fracture and carbonaceous materials, depth 800 meters. Ordinary light, X20.
(B) Biotite, red brown plates with alteration along cleavage lines, depth 930 meters. Ordinary light, X20.

Biotite is red brown plates with intense pleochroism (Fig 8). The biotite shows also some alteration to hematite and iron oxides along their cleavage lines. This feature indicates insitu weathering of heavy minerals in sandstones.

Leucoxene is found as translucent, pale yellow to amber, with a white procelain like appearance and highly worn grains (Figures 3 and 6), commonly associated with altered ilmenites.

Chlorite is typically pale grass-green with distinct pleochroism. In occasional flakes some oxidation had occurred resulting in a change of colour from green to greenish brown or brown colours.

Discussion and Provenance:

The distribution of opque minerals (mainly pyrite, hematite and to a lesser amount ilmenite and magnetite) in the Suffi Formation shows vertical variation in the studies rocks (Fig.2). Such variation is indicated by predominance of pyrite (nearly 90%) of the opaques in the sandstones at depths 600-900 meters. Below this depth, hematite is dominated more than pyrite and ilmenite. The variation of pyrite and hematite contents amy reflect the changing in environmental conditons froom refuced to oxidized conditons in the formation of these authigenic minerals. The difference in oron minerals is imposed by changing environmental conditons (from continental to marine) rather than inheritance from parent rocks.

Leucoxene shows also variation of the studied rocks (Fig.2). This mineral is dominated in the non-opaques of the Suffi clastics especially in the sandstones rich in hoematite. Leucoxene is one of the modifications of titanium dioxide (TiO2) minerals, it appears to be either highly birefringent or isotropic [7]. The isotropic variety is hydrated TiO2 and included in the term of doelterite, and the term leucoxene restricted to microcrocrystalline, anhydrous, lime free, highly birefringent TiO2 mineral. The present leucoxene is believed to be an alteration product of ilmenite and biotite, such alteration is the most important source of Ti for the diagenetic titanium minerals. The present ilmenites show partial alteration while biotites show common alteration along their cleavage planes (Fig. 8), and leucoxene after biotite is common [8]. In this regard, oxidizing conditons may facilitate release of Ti from biotite [9]. On the other hand, alteration of biotite during diagenesis may contribute necessary cations to the formation of authigenic clays, mainly Fe-rich chlorite and occasinally pyrite in reducing condition, whereas alteration of biotite is mainly association of illite and hematite under oxidizing conditions [10].

The variation in Fe and Ti minerals in the Suffi Formation may have been related to the change in the sedimentary environment between continental and marine. Such changes are considered to be a common phenomenon on the stable part of the platform of Iraq, which is dominated by continental sedimentation interrupted by several breaks and short time marine transgressions [11]. These changes were a reflection of local as well as regional uplift affecting this area at the beginning of Upper Cambrian and lasted till the Silurian or Early Devonian.

Other recorded heavy minerals are considered to be detrital. Ultrastable minerals (zircon, tourmaline and rutiel) from an average of more than 55% of the non-opaque heavies (Fig.2).

Zircon is, among the most stable minerals, commonly found in rocks. It survives erosion, transportation, deposition and disgenesis with much less alteration than most other heavy minerals [12]. The dominance of angular and prismatic euhedral ziecons (Fig.3) indicates the inheritance from the source rocks (acid igneous rocks and their pegmatites, also from older metamorphic rocks. Buday [11] refers that basement rocks of Iraq are composed of metamorphic rocks and granites crystalline complex. They belong to the Arabian part of Aftrican (Nubio-Arabian) Precambrian platform. This provenance is considered also to the present tourmaline. Blue variety of tourmaline is of pegmatitic origin while brown variety is of granitic type described by Krynine [13]. The recorded rounded to subrounded zircon and tourmaline grains indicate that they were derived from a pre-existing sediments. Rutile, a very durable heavy mineral, is derived from metamorphic rocks [14]. Apatite and monazite may produced together from acidic plutonic and metamorphic sources.

The presence of garnet, epidote, staurolite and kyanite points to the contribution from metamorphic sources. Metamorphic and granitic sources appear to have become more important in the origin of Suffi Formation reinforcing the conclusions derived from the stufy of quartz grains [2]. In this study mono-as well as polycrystalline quartz were observed. They commonly contain inclusions of vacuoles, spherulitic zircon and tourmaline, acicular apatite, muscovite and iron oxides.

The effect of intrastratal solutions is indicated by several features affecting on detrital heavy minerals. Garnet shows etched pits and corroded grains as a result of dissolution and diagenesis by intrastratal solutions [4 and 15]. The observed etch pits is recorded in those garnets of calcite cemented sandstones. Calcite cements may have been important in the formation of garnet etching pits.

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