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Chromite Enrichment in the Recent Fluviatile Sediments, North Iraq

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أغناء معدن الكرومايت في الترسبات النهرية الحديثة، شمال العراق

علي اسماعيل الجبوري صباح أحمد اسماعيل محسن محمد غزال
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تمتاز الترسبات النهرية الحديثة في شمال العراق بزيادة نسبة معدن الكرومايت ضمن مجموعة المعادن الثقيلة فيها . يهدف البحث الحالي إلى دراسة معدنية وجيوكيميائية معدن الكرومايت في محاولة لمعرفة توزيعه وعوامل اغناءه ومصدره تشتمل المعادن الثقيلة على مجموعتي المعادن المعتمة وغير المعتمة . تؤلف المجموعة الأولى حوالي ٥٠٪ من مجموع المعادن الثقيلة كما يمثل الكرومايت نسبة أكثر من ٨٠٪ من مجموع معادنها في شمال العراق .

كما تشتمل المعادن غير المعتمة على : ابيدوت، كارنيت، تورمالين، روتايل، ستوروولايت، كايانايت، زركون، أوليفين، كلورايت، مسكوفايت، بايروكسين وامفيبول . لقد أوضحت دراسة معدن الكرومايت بحيود الأشعة السينية أنه من النوع المنيوم كرومايت، كما أظهرت نتيجة تحليله الجيوكيميائي بأنه غني بالالمنيوم وفقير في نسبة الحديد مما قد يعزي إلى تأثير عمليات التغير على الكرومايت بفعل عوامل النقل وإعادة الترسيب (دهك الرواسب) الأمر الذي يؤدي إلى زيادة تركيز الالمنيوم على حساب الحديد . إن إغناء الكرومايت في الترسبات الحديثة في شمال العراق قد يعزي إلى تواجده ضمن معقد الاوفيولايت في طوروس - زاجروس وإعادة نقله وترسيبه من عدة تكاوين فتاتية قديمة في شمال العراق، كما قد تؤدي بعض العوامل الترسيبية والمورفولوجية للأنهار في تركيز وإغناء هذا المعدن .

Key Words: Chromite distribution, Heavy minerals Provenance, Recent sediment, North Iraq.

ABSTRACT

The Recent sediments from North Iraq are characterized by a higher content of chromite. This paper deals with the mineralogy and geochemistry of chromite in the heavy mineral assemblages from Recent fluvial sediments in an attempt to elucidate its distribution and source rock. The heavy fraction is composed of iron oxides and chromite forming about 50% of the total heavies. Chromite forms up to 80% of the opaque minerals at some areas in North Iraq. The non-opaque heavy minerals are composed of epidote, garnet, tourmaline, rutile, staurolite, kyanite, zircon, olivine, chlorite, muscovite, pyroxene and amphibole. XRD analysis revealed that chromites are mainly aluminian chromite. Geochemical study shows that chromite is depleted in Fe and enriched in Al, such enrichment being related to the effect of alteration that leaches iron from chromite in the presence of suitable conditions assisting this alteration. Chromite is akin to podiform Alpine-type chromites. Higher concentration of chromite favours the addition of ophiolite complex of the Zagros-Taurus belt as well as recycling of chromite from older formations in North Iraq. Another factor controlling this obvious enrichment of chromite is the hydraulic equivalent and meandering morphology of the rivers.

INTRODUCTION

Chromite is one of the abundant opaque minerals that is recorded in the heavy mineral fractions from North Iraq, both in the Recent and older detrital deposits [1-5]. At some localities from North Iraq, the Recent sediments are characterized by higher content of chromites. This paper involves the results of investigation of the heavy detrital minerals in the sands at selected areas of North Iraq.

Attention has been focused on the enrichment of the chromite in the studied samples, its distribution and source rocks, with a detailed mineralogy and geochemistry of the chromite grains.

Fifteen samples were collected from the Recent fluviatile sediments of the Tigris River and its upper reaches and tributaries, as well as some small rivers and wadis from North Iraq (Fig. 1). Each sample is representative of the taken samples in each locality within an area of about 2 m^2 in the meandering parts of the rivers.

GENERAL GEOLOGY OF NORTH IRAQ

Iraq is divided into six physiographic provinces (Fig.1a), each with its distinctive geological environment [6]. North Iraq (area of study) lies within the Zagros Mountains and Foothills provinces and partly within the Jezira province.

The Zagros Mountains to the north consist of NW-trending parallel ridges of folded upper Paleozoic and Mesozoic age limestones, and a Nappe of metamorphosed lower Paleozoic rocks along the Iranian borders. The Foothills province consists of mainly Upper Miocene and Pliocene coarse detrital sediments which are gently folded along a NW-SE axis parallel to the structural trend of the Zagros Mountains. To the west is the Jezira province that consists of relatively undisturbed Miocene and Pliocene limestone and gypsum, and poorly consolidated Pleistocene detritus [6].

The Tigris River has its origin in the Taurus Mountains in Turkey, travelling a distance of 1718 km. In Iraq it forms the boundary between the Jezira and Foothills provinces until its junction with the Lesser Zab River. Three major tributaries in Iraq, the Greater Zab, Lesser Zab and Diyala Rivers, all drain the Foothills and Zagros Mountain. In addition, the Lesser Zab drains the Nappe zone. Samples of the present study are collected from different rivers that drain the Foothills as well as the folded zone of the Zagros Mountains province from North Iraq (Fig.1b).

Heavy mineral assemblages

The samples were washed on a 0.38 mm sieve to remove the finer material. The portion retained on the sieves ranges in size from medium to very fine sand (0.25-0.063 mm). Some of the studied samples contain

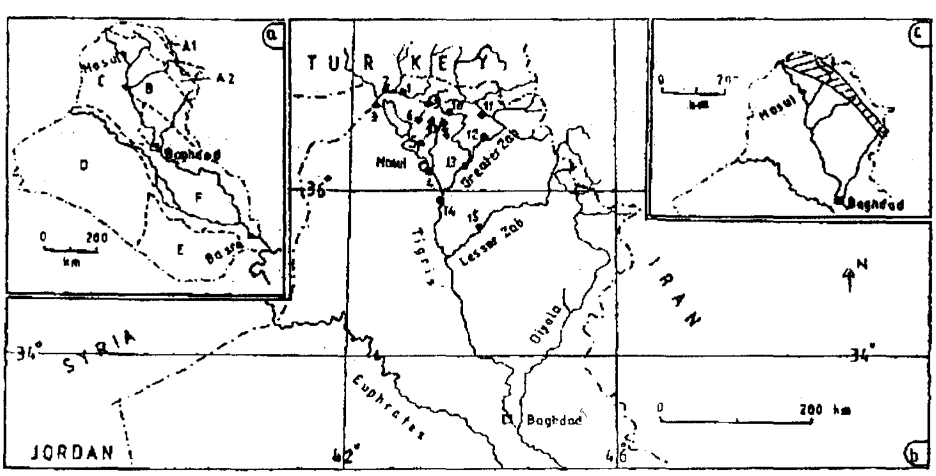

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Figure (1): a. The physiographic provinces of Iraq. Provinces are: Zagros Mountains (Folded zone "A1"; Nappe zone "A2"), Foothills "B", Jezira "C", Northern- "D" and Southern- "E" Deserts and Mesopotamian Plain "F". b. Enlarged part of northern Iraq and sample locations. c. Distribution of the Gercus Formation in Iraq (Source Al-Rawi [3].

a high percentage of carbonates. These were washed in dilute (10%) hydrochloric acid before being sieved. A 10 gram sample of the sandy portion was separated into heavy and light fractions using bromoform (sp. gr. 2.9). Additional separation of chromite from the heavy fractions was done using Clerici SYMBOL 162 \f "Symbol" \s 14 s solution (sp. gr. 4.3) in order to accumulate chromite grains for the next mineralogical and geochemical investigations.

The heavy minerals were examined under the binocular microscope, with the estimation of the abundance ratios of each of the heavies according to the method suggested by Rittenhouse [7]. The heavy minerals which are present in the studied samples are opaque minerals (chromite, magnetite, hematite, ilmenite, pyrite and goethite), epidotes (epidote, zoisite and clinozoisite), garnet, tourmaline, rutile, staurolite, kyanite, olivine, zircon, chlorite, muscovite, pyroxenes and amphiboles. The relative abundance of these heavies in the Recent sediments are present in Table (1). The content of heavy minerals in the above size fractions generally exceeds 1%.

The heavy mineral assemblage and their nature indicate a combination of igneous and metamorphic source rocks as well as recycling from older sedimentary sources. In comparison with the older clastic deposits from North Iraq, mainly in the Foothills province, it appears that the bulk of the present heavy minerals were from the older Kolosh (Paleocene-Lower Eocene), Tanjero (Upper Cretaceous), Gercus (Middle Eocene), Injana (formerly Upper Fars, Upper Miocene) and Mukdadiya (formerly Lower Bakhtiari, Pliocene) Formations, as shown below:

Mukdadiya (Pliocene) [2]: Heavy mineral suites include: opaque minerals (magnetite, hematite, chromite and ilmenite), epidote, pyroxene, amphibole, biotite, chlorite, muscovite, garnet, tourmaline, staurolite, kyanite, rutile, apatite and zircon.

Injana (Upper Miocene) [5]: Opaque minerals (magnetite, hematite, chromite and pyrite), epidote, hornblende, garnet, pyroxene, zircon, tourmaline, rutile, staurolite, actinolite, glaucophane, kyanite, chlorite and muscovite.

Gercus (Middle Eocene) [3]: Opaque minerals (mainly chromite and hematite, magnetite and ilmenite), spinel, rutile, hornblende, zircon, leucoxene, tourmaline, chlorite, garnet, muscovite, biotite, pyroxene, topaz, kyanite, apatite and sphene.

Kolosh (Paleocene-Lower Eocene) and Tanjero (Upper Cretaceous) [4]: Opaque minerals (magnetite, chromite and ilmenite), epidote, hornblende, pyroxene, garnet, tourmaline, rutile, zircon and chlorite.

It is shown from the above comparison that the suites of heavy minerals of the Gercus clastics are composed largely of chromite, hematite aggregates, magnetite, ilmenite and spinel. The chromite reaches up to 60% of the total heavies [3].

The Gercus Formation consists of a sequence of fining-upwards cycles that was deposited in a NW-SE trending belt that extending from northern to eastern Iraq (Fig. 1c) and continuing northwestwards into Turkey, and have similar equivalent in Southeast Iran (Kashkan Formation).

The opaque minerals form about 50% of the total heavy minerals studied and chromite forms up to 80% of the opaque minerals in the fine size fraction of the sandy portion at some areas in North Iraq (Alqosh and Zawita area, localities 7, 9 and 10; Fig. 1). Both areas were located in the Foothills province in which the Gercus sediments are distributed. The authors believe that the bulk of the chromite in the Recent sediments from North Iraq was recycled from the Kolosh, Tanjero and Gercus Formations as well as other younger clastic formations.

Table (1) : Relative abundance of heavy minerals in the sandy portion from Recent fluviatile sediments of northern Iraq. A (Very Abundant, > 60%), A (Abundant, 60-30%), (Fairly Abundant, 30-15%), VC (Very Common, 15 - 7.5%), C (Common, 7.5 - 3%), FC (Fairly Common, 3-2%), S (Scarce, 2 - 1%), R (Rare, < 1%), -- (absent).

Locality	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Chromite	A	VC	FC	R	FC	FC	VC	FC	VC	A	FC	FC	FC	S	R
Magnetite	FA	C	FC	FC	C	FC	VC	A	FC	VC	FA	VC	VC	VC	C
Hematite	C	FC	VC	FC	C	FA	FC	FC	VC	VC	VC	C	C	FC	C
Ilmenite	C	FC	--	--	S	--	FC	VC	R	C	FC	VC	C	R	S
Pyrite	--	--	S	--	FC	R	--	R	--	R	S	S	S	--	--
Goethite	FC	FC	VC	FC	--	FA	--	R	FC	R	C	C	S	C	S
Epidote	FC	VC	FA	C	A	VC	VC	FC	FC	C	C	C	C	VC	A
Garnet	R	S	C	FC	FC	C	--	R	R	R	--	FC	FC	C	C
Tourmaline	--	R	C	FC	FC	C	FC	R	S	--	FC	FC	FC	FC	R
Rutile	FC	C	C	FC	FC	R	R	R	S	S	--	FC	C	FC	R
Staurolite	R	R	--	--	FC	--	S	R	R	R	R	S	S	S	--
Kyanite	R	R	--	FC	FC	--	--	R	R	--	S	S	S	S	--
Olivine	R	R	--	--	R	R	R	R	R	R	--	S	C	VC	S
Zircon	--	R	--	--	R	--	--	R	--	--	FC	FC	S	C	--
Chlorite + muscovite	C	VC	FA	VA	R	C	--	FC	R	R	C	C	C	C	C
Pyroxene	R	C	FC	FC	FC	R	--	FC	--	R	VC	C	C	C	C
Amphibole	--	C	FC	--	R	R	--	FC	--	R	C	C	C	C	VC

Localities : 1. Khabour River before junction with Tigris River, 2. Kabour after junction. 3. Tigris before the lake, 4. Rashidiya, 5-Al-Malah valley, 6. Faida, 7. Alqos, 8. Gomel Al-Khazir, 9. Zawita 1, 10. Zawita 2, 11. Barzan, 12. Greater Zab, 13. Al-Kalak, 14. Namrud. 15. Lwesser Zab.

Factors controlling the enrichment of chromite

Several ideas have been recorded in the literature concerning the accumulation of heavy minerals in the fluvial and stream sediments. Rubey (1933) in Wolf [8] estimated settling velocity to be the most important segregating mechanism accounting for the close association of small high-density grains with low-density but larger mineral grains in a sediment, together with such factors as density and hardness of the minerals, difference in original size of the grains in the source rocks, degree of abrasion during transportation and degree of sorting at the site of deposition. On the other hand, Rittenhouse [7] attributed the distribution of heavy minerals in stream beds to varying hydraulic conditions at the time and place of deposition, equivalent hydraulic size of each of the heavy minerals, availability of the minerals, and unknown factors.

In the present study, the content of heavy minerals in the fraction 0.25-0.063 mm generally exceeds 1%. The chromite is enriched in the finer fraction 0.063 mm (4ϕ) (very fine sand) rather than the medium sand 0.25 mm (2ϕ). Such enrichment may related to several factors:

1. The studied area of North Iraq lies not far from the main ophiolitic complexes of Iraq and Turkey. These complexes were enriched with chromites [9 and 10]. The weathered chromites were transported and recycled to the present area.
2. Recycling of chromites from the older clastic formations (mainly Gercus Formation) that contain more than 60% of chromite in the heavy mineral suites studied [3].
3. The geologic setting of the studied areas are adjoining the hydraulic equivalent of the rivers and the current energy that carries the finer particles.
4. The morphology of the rivers, from which the samples were taken, is characterized by meandering. Generally, the heavies are well accumulated in those parts of rivers rather than others.
5. The chromite has a specific gravity of (4.6) and is of small mean grain size. These characteristics may be responsible for the concentration of chromite grains in the finer grain size rather than coarser. This conclusion coincides with the ideas suggested by Osovetskii [11] who concluded that the overall content of smaller grain size heavy minerals increases in going from medium to fine detrital varieties.
6. Chromite grains comprise the bulk studied opaques, which include also magnetite and ilmenite. These opaque minerals have specific gravity within the range of 4.3-5.2, are largely restricted to the finer size grades 0.125-0.063 mm (3 ϕ - 4 ϕ), and microscopically show comparable shapes (euhedral to subhedral). Their similar size, shape and specific gravities led Luepke [12] to conclude that such characteristics effectively eliminate any differential sorting of these minerals and promote its better accumulation in the Recent fluvial and beach sediments.

MINERALOGY

The chromite grains are well concentrated in the heavy fraction of the finer sandy portions. These grains range from sharply euhedral octahedra to subrounded forms. Optically, the mineral is quite opaque and appears under binocular microscope (oblique illumination) as smooth, brilliant and jet-black, especially the worn grains, with a pronounced conchoidal fracture for the broken ones.

X-ray Analyses

Mineralogical investigation for the chromite is performed using XRD technique, with a Philips 1730 diffractometer (Cu α radiation, Ni filter). The diffraction pattern (Fig.2) revealed that generally the chromites are of the aluminian variety. The chromite is normal with the unit cell a° =8.24. The followings are the intensity (I/Io), lines (hkl) and d-values for the studied chromite.

Serial number	Intensity	(hkl)	d (λ)
1	10	111	4.766
2	30	022	2.909
3	100	113	2.479
4	55	004	2.047
5	8	224	1.668
6	20	115	1.578
7	40	044	1.459

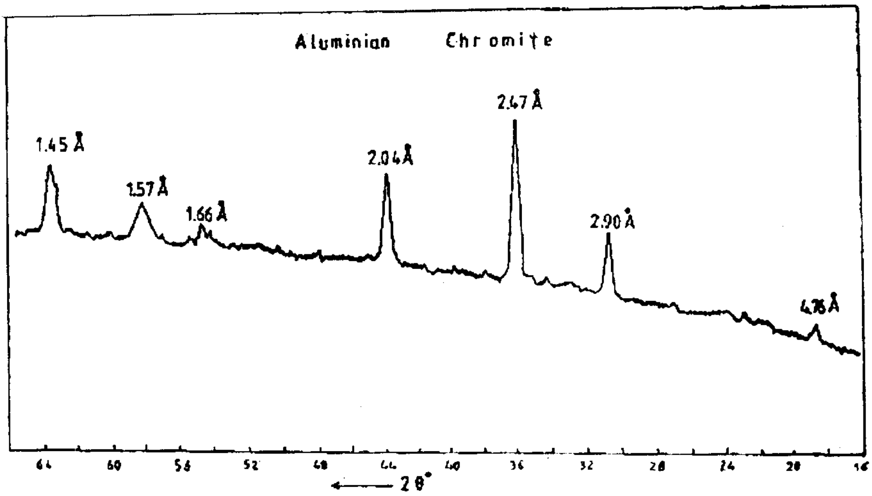

Figure (2): Diffractogram pattern of the studied Aluminian Chromite (Cu α radiation, Ni-filter). Sample taken from zawita, locality 9.

GEOCHEMISTRY OF THE CHROMITE

Geochemical analysis of the chromite grains using atomic absorption spectrophotometry (AAS) shows that the chemical composition of the studied chromites is relatively constant (Table 2). Each sample contains an average of 100 grains. The samples are taken from those localities that were enriched with chromite (locality 7 and 9, Table 1, Fig.1b). The technique of analysis is carried out at the laboratory of Chemistry Department, Baghdad University. The accuracy and precision depend on using of international and internal standards in addition to duplicates. The analyses show that the studied chromite grains are highly enriched in Al_2O_3, but with lower Cr_2O_3 and total Fe contents, as compared with other chromites that were separated from the ophiolitic complexes of Iraq and Turkey [9, 13 and 10].

The chromites of the Recent sediments of North Iraq have been plotted (Fig.3) to show the variation of Cr_2O_3, Al_2O_3 and Fe_2O_3 in comparison to the podiform and stratiform chromites from the Alpine-type peridotite and Stillwater complex in Montana respectively [14], as well as the chromites from the Iraqi Zagros ophiolitic complexes (Mawat, Penjwin and Bard-i-Zard) and those of the Ortakale region of Turkey. The figure shows that the Recent sediment chromites are aluminian chromite and more akin to the podiform Alpine-type, and on an average it may compared with other chromites from the ophiolitic complexes of Iraq and Turkey.

The origin of Al-rich varieties of chromite occurs only in the Alpine-type peridotite bodies and peridotite nodules in basaltic volcanic rocks [15]; whereas Hutton [16] has shown that high percent of alumina appears to be general in chromian spinels from ultrabasic rocks. The podiform chromite deposits are the sole source of high alumina ores, in which Al_2O_3 exceeds 20 percent and Cr_2O_3 commonly exceed 65 percent [14]. This relation appears to be suitable for the studied chromite.

Table (2): Chemical compostion and structural formulae of the studied chromite and from ophiolitic complexes. Atoms on the basis of 32 Oxygen. A = Chromite from Alqosh area, locality 7; B = chromite from Zawita area, locality 9 (Fig. 1b). C and D = Chromite from Ortakale region, Turkey [10]. E = Chromite from Penjwin area, Iraq [9]. F = Chromite from Mawat area, Iraq [9].

	A	B	C	D	E	F
Cr2O3	43.88	44.65	52.89	55.12	54.05	49.14
Al2O3	32.63	33.91	16.69	14.90	9.22	19.18
Fe2O3	13.92	11.67	16.67	18.20	26.97	18.15
MgO	9.42	8.94	12.64	12.94	9.30	13.50
Total	99.85	99.17	98.89	101.16	99.54	99.97
Cr^{3+}	9.25	9.48	11.14	11.61	11.38	10.35
Al^{3+}	10.26	10.73	5.24	4.68	2.89	6.02
Fe^{3+}	2.79	2.36	3.34	3.65	5.40	3.64
Mg^{2+}	3.74	3.58	5.02	5.14	3.69	5.36
Cr/Cr + Al	0.47	0.47	0.68	0.71	0.80	0.63
Mg/ Mg + Fe	0.57	0.60	0.60	0.58	0.41	0.60

* Fe_2O_3 = Total iron as Fe_2O_3

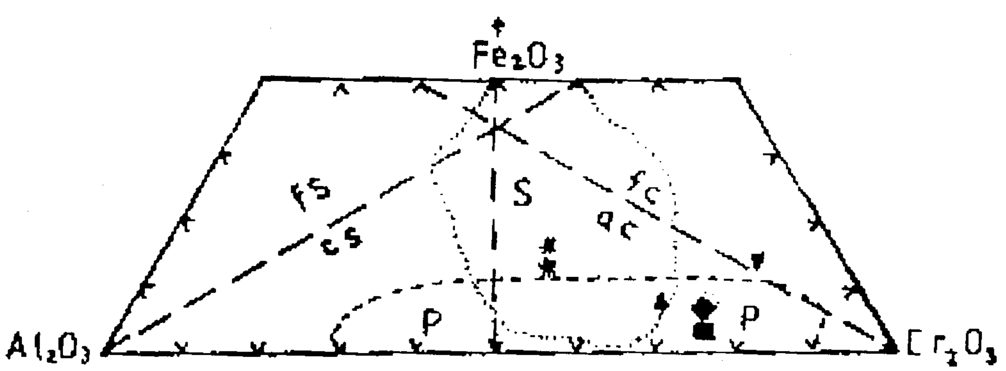

Figure (3): Cr2O3, Al2O3, Fe2O3 variation in chromite from the Recent sediments (present study) in comparison with other chromites separated from ophiolitic complexes of Iraq and Turkey (After Thayer [14]). Symbols: Solid triangles "up and down" are the average chromites from Mawat and Penjwin in Iraq respectively [9], solid diamond is the average chromite from Bard-i-Zard [13], solid square is the average chromite from Ortakale Region in Turkey [10], asterisks are the samples A and B (the present study) from Alqosh area "locality 7" and from Zawita area "locality 9" respectively. P= Podiform chromite, S = Stratiform chromite, fc = ferroan chromite, ac = aluminian chromite, fs = ferroan spinel, cs = chromian spinel.

In Table (2), the Cr/Cr + Al ratio of the Recent sediment of Cr_2O_3 and higher Al2O3 content. The Mg/Mg + Fe ratio ranges from 0.57 to 0.60. These results are comparable to those obtained by Cocherie et al. [17], that less Cr_2O_3 and more Al2O3 contents with Mg/Mg + Fe ratio between 0.42 and 0.59 are suitable for disseminated chromite in harzburgite due probably to subslidus re-equilibration processes rather than those of disseminated chromite in dunite that shows higher Cr_2O_3 content. Harzburgite with subsidiary dunite and pyroxenite are suggested to be the main intrusive facies of the ultramafic rocks of Iraqi ophiolitic complexes. The disseminated type of chromite is recorded as accessory type in these complexes as compared to the common massive (podiform) type chromite [13].

Alteration of detrital grains of chromite in sedimentary environment has been discussed by Mihalik and Saager [18]. They showed that the major proportion of the chromite grains which form a common constituent of the heavy mineral suite in the Basal Reef of Witwatersand system, South Africa, is rimmed by altered borders showing higher reflectivity. They suggested also that the rounded form of the Witwatersand chromite indicates the transportation over a considerable distance. Such transportation with subsequent alterations are responsible for the higher iron and chromium content and the lower magnesium and aluminum that leads to the higher reflectivity of the chromite borders.

The lower Fe content in the studied chromite may be attributed to the effect of alteration on the Recent sediment chromite that leaches iron through weathering and transpotation (for short distance) from the source rocks in the presence of suitable conditions assisting this alteration. The persence of common sharply euhedral octahedra shapes of chromite indicates such short distance transportation. Immature chemical weathering of the ophiolites of Zagros thrust zone under highly oxidizing and alternating wet and dry conditions resulted in unique composition of the weathering products from which a suite of heavy minerals, consisting essentially of chromite grains, was quickly flushed away during the wet seasons to be deposited in various local environment, along a nearby elonga ted trough, which included deltaic, floodplains and alluvial fans and even a shallow marine environment [19]. These conditions may assist in the alteration and leaching of iron from the Recent sediment chromite. The higher content of chromite in the fluviatile sediments of North Iraq is reflected in the higher Cr content in the Recent sediments and soil of North Iraq. Jawad Ali [20] has concluded that higher concentrations of Cr in the Recent Tigris River sediments are higher than those of Euphrates River sediments due to a provenance richer in ultramafic source for the Tigris samples. He concluded also that the higher concentration of Cr is mostly incorporated with chromite rather than entering the structure of clay minerals.

CONCLUSIONS

1. The heavy mineral suite of the Recent fluviatile sediment from North Iraq generally includes opaque minerals (chromite, magnetite, hematite, goethite and ilmenite) and the non-opaques (epidote, garnet, tourmaline, rutile, staurolite, kyanite, chlorite, muscovite, pyroxene and amphibole).
2. Chromite is very abundant at some localities of North Iraq reaching up to 80% of the opaque minerals. This mineral is concentrated in the fine-sand size fraction.
3. Microscopically, the mineral is quite opaque and ranges from sharply euhedral octahedra to well rounded forms with a smooth, brilliant, jet-black appearance and shows a pronounced conchoidal fracture for the broken grains.
4. Mineral identification by XRD shows that the mineral is aluminian chromite. This is supported by chemical analysis of chromite, which revealed its enrichment with Al_2O_3. but depleted amounts of Cr_2O_3 and total iron content.
5. The comparison with the chromite separated from the ophioliticc Zagros Taurus complexes of Iraq and Turkey, appears that all the chromites fall within the podiform chromite field. There is fundamentally lenticular concentration of chromite ranging from massive to disseminated and it occurs in peridotite complexes of the Alpine-type.
6. Higher concentration of chromite favours the addition of

recycling from older clastic formations mainly the Eocene Gercus Formation, as well as Kolosh and Tanjero Formations.

7. Hydraulic equivalent, setting velocity and meandering morphology of the rivers from which the samples were taken all affect the accumulation of chromite, whereas the specific gravity and the overall small sizes of the chromite grains are responsible for the better concentration in the finer grade sizes.

REFERENCES

[1] Philip, G., 1968. Mineralogy of Recent sediments of Tigris and Euphrates Rivers and some of the older detrital deposits. Jour. Sed. Petrology, 38 (1),< 35 - 44.

[2] Jawad Ali, A. and Khoshaba, B. N., 1980. Petrography and heavy mineral studies of Lower Bakhtiari Formation. Iraqi Geol. Soc., 11 (1), 16- 36.

[3] Al-Rawi, Y., 1980. Petrology and sedimentology of the Gercus Red Beds Formation (Eocene), northeastern Iraq. Iraqi J. Sci., 21 (1), 132 - 188.

[4] Al-Juboury, A. I. and Amin, M. A., 1989. Mineralogical and geochemical studies of Tertiary-Cretaceous turbiditic sandstones, Shaqlawa, NE Iraq. Zanco (Sci. J. Salahaddin Univ.), 2. 106 - 122.

[5] Al-Juboury, A. I., 1994. Petrology and provenance of the Upper Fars Formation, nothern Iraq. Acta Geol. Universitatis Comeenianae, Bratislava, 50, 45 - 53.

[6] Berry, R. W., Brophy, G. P. and Naqash, A., 1970. Mineralogy of the suspended sediment in the Recent history of the Mesopotamian Plain. Jour. Sed. Petrology, 40 (1), 131 - 139.

[7] Rittenhouse, G., 1943. Transportation and deposition and deposition of heavy minerals. Geol. Soc. Amer. Bull., 54, 1725 - 1780.

[8] Wolf, K. H., 1976. Handbook of strata-bound and stratiform ore deposits, 1. principles and general studies, volume 3, supergene and surficial ore deposits, textures and fabrics. Elsevier Sci. Company, Amsterdam.

[9] Buda, G. and Al-Hashimi, W. S., 1977. Petrology of Mawat Ophiolitic Complex. Jour. Geol. Soc. Iraq, X, 69 - 98.

[10] Tüysüz, N., 1993. Characteristics and origin of chromite occurrences in Ortakale(Sarikamis-Kars) region, E-Turkey. Geol. Bull. Turkey, 36, 151 - 159.

[11] Osovetskii, B. M., 1974. Relation between the mineral composition Lithology and Mineral Resources, 9 (1), 76 - 87.

[12] Luepke, G., 1980. Opaque minerals as aids in distinguishing between source and sorting effects on beach-sand mineralogy in south-wester Oregon. Jour. Sed, Petrology, 50 (2), 489 - 496.

[13] Al-Jawadi, M. R., 1980. Petrology and geochemistry of the Bard-i-Zard serpentinites and associated chromites occurring around Rayat, Northeast Iraq. Unpubl. M. Sc. Thesis, Mosul University.

[14] Thayer, T. P., 1964. Principal features and origin of podiform chromite deposits and some observations on the Guleman-Soridag district, Turkey. Econ. Geology, 59, 1497 - 1524.

[15] Irvine, T. N., 1967. Chromian spinel as a petrogenetic indication, part 2: petrologic applications. Canadian Jour. Earth Sci., 4, 71 - 105.

[16] Hutton, C. O., 1950. Studies of heavy detrital minerals. Bull. Geol. Soc. America, 61, 635 - 710.

[17] Cocherie, A., Auge, T. and Meyer, G., 1989. Geochemistry of the platinium-group elements in various types of spinels from the various ophiolitic complex, Greece. Chem. Geology, 77, 27 - 39.

[18] Mihalik, P. and Saager, R., 1968. Chromite grains showing altered borders from the Basal Reff, Witwatersand system American Mineralogist, 53, 1543- 1550.

[19] Dhannoun, H. Y. and Al-Dabbagh, S. M. A., 1990. The distribution of the Fe, Mn, Ni, Cr and Co between the acid- soluble and Fe-oxides and hydroxides and matrix fractions of the Gercus Red Beds of northeast Iraq. Chem. Geology, 82, 57 - 68.

[20] Jawad Ali, A., 1984. Some trace element analysis of Pliocene Molasse and Recent Euphrates and Tigris fluviatile sediments. Chem. Geology, 45, 213 - 224.