Provenance of Injana Formation In Selected Areas by Studying Heavy Minerals

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Abstract

Injana Formation is an extensively exposed in Iraq; four cross sections have been chosen from Zawita, Tikrit and Tar Al-Najaf areas.. Systematic sampling has been performed and 24 rock samples were collected to heavy minerals study .The megascopic description in precise details is also attained. Heavy minerals investigation using polarized transmitted light microscopy and depending upon shapes of grains revealed there is intense effect of the Zagros provenance on the Injana sediments at Zawita and Tikrit sections in comparison with its effect on the Tar Al-Najaf sections. This effect proved by the presence of basic rocks on the Injana sediments of Zawita area corroborated with pyroxene and amphibole content which are confirmed by heavy minerals study. This work throws some light on the effects of acidic rocks of Arabian shield as the second provenance on the Injana sediments in the studied areas where it seems that the greater effect of this provenance is on Tar Al-Najaf sediments due to abundance of Zircon and Tourmaline in comparison with Zawita and Tikrit sections.
Key words: Injana, Heavy minerals, Zawita,Tikrit,Tar Al-Najaf

الخلاصة

ينكشف تكوين انجانة بشكل واسع في العراق. اختيرت اربعة مقاطع من ثلاث مناطق مختلفةهي: زاويتة، تكريت وطار النجف. تم جمع 24 نموذج صخري منها لدراسة المعادن الثقيلة باستخدام المجهر المستقطب النافذ للضوء، واعتماداً على الشكل الحبيبي تبين ان هناك تأثير شديد لحزام زاكروس على صخور تكوين انجانة في منطقتي زاويتة وتكريت مقارنة بمنطقة طار النجف وذلك من خلال وجودالمحتوى العالي للمعادن ذات الاصل الناري القاعدي وخاصة البايروكسين والامفيبول في المقطعين اعلاه. من جانب آخر يوجد مصدر ثاني لترسبات تكوين انجانة متمثلاً بالدرع العربي؛ حيث ان له تأثير كبير على منطقة طار النجف مقارنة بمنطقتي زاويتة وتكريت من خلال سيادة المعادن الثقيلة الغير مستقرة خاصة الزركون والتورمالين.

الكلمات المفتاحية : انجانة ، معادن ثقيلة ، زاويتة ، تكريت ، طار النجف

Inroduction

The out crops of Injana Formation are widely distributed in Iraq. It was studied by many authors due to its economic importance as raw and industrial materials. The formation was previously named as Upper Fars Formation and later changed, in Iraq, to Injana Formation (Jassim *et al.,* 1984 and Al-Rawi *et al.,* 1992). Four sections from three areas have been chosen at Zawita (Dohuk province), Tikrit (Salah Adden province) and Tar Al-Najaf (Al-Najaf province) for systematic sampling as shown in Figure (1).

Generally, Injana Formation (Late Miocene-Pliocene) represents detrital sediments as cyclotherm fining upward deposits of a fuvaitile environment. These sediments consist of sandstone well beds which are grey to reddish brown in color, very fine to very coarse in grain size, hard to friable in hardness and massive to laminated layers in thickness. In addition to the sandstone, the sediments consist of brown and grey mudstone beds. The heavy mineral study is particularly useful in product of sediment sources and sediment transport path. In fact, it is known that the heavy mineral assemblages have been used to trace the source of the basinal sandstones (Hibbard, 2002). The Present work aims to shade light on origin and source rocks of this formation by heavy minerals study in these sites.

Previous study

- Salvik & Al-Hashimi (1973) studied the formation in Injana area and showed that sediments
in Figure (1).
minerals study.

-Al-Katan(1985) noticed that corundum, tremolite,anthophyllite and glaucophane are present inInjana Formation at Sinjar and dohuk areas northern Iraq; however these minerals are rare or absent in the other areas.

- Al-Rawi and Mohammad (1987) mentioned that the source rocks of Injanja Formation sediments are mixture of igneous, metamorphic, and sedimentary rocks found within Ophiolite and Radiolite complexes, as well as, ancient carbonate rocks of Zagros highland in the Arabic shelf basin.

-Al-Kurukje (1989), in his investigation Injana Formation in northern Hemreen Mountain, confirmed that source of heavy minerals are metamorphic, acidic and plutonic igneous rocks, moreover ancient sedimentary rocks of oldest formations. He referred to short distant of heavy minerals transportation due to angularity of grains shape, in addition to predominant meta and unstable heavy minerals in comparison with ultra stable type.

- Al-Bassam, (1994) determined calcareous sandy clay bed of (1.0-1.5) m in thickness within Injana Formation in Tar Al-Najaf bearing celestite mineral.

-Al-Baidari,1997 found that ultrastable heavy minerals (zircon, tourmaline and rutile) concentrated in Tar Al-Najaf,whereas metastable type (pyroxene, epidote and garnet) concentrate at Tar Al-Said, when she studied the formation at Al-Najaf-Karbala area.

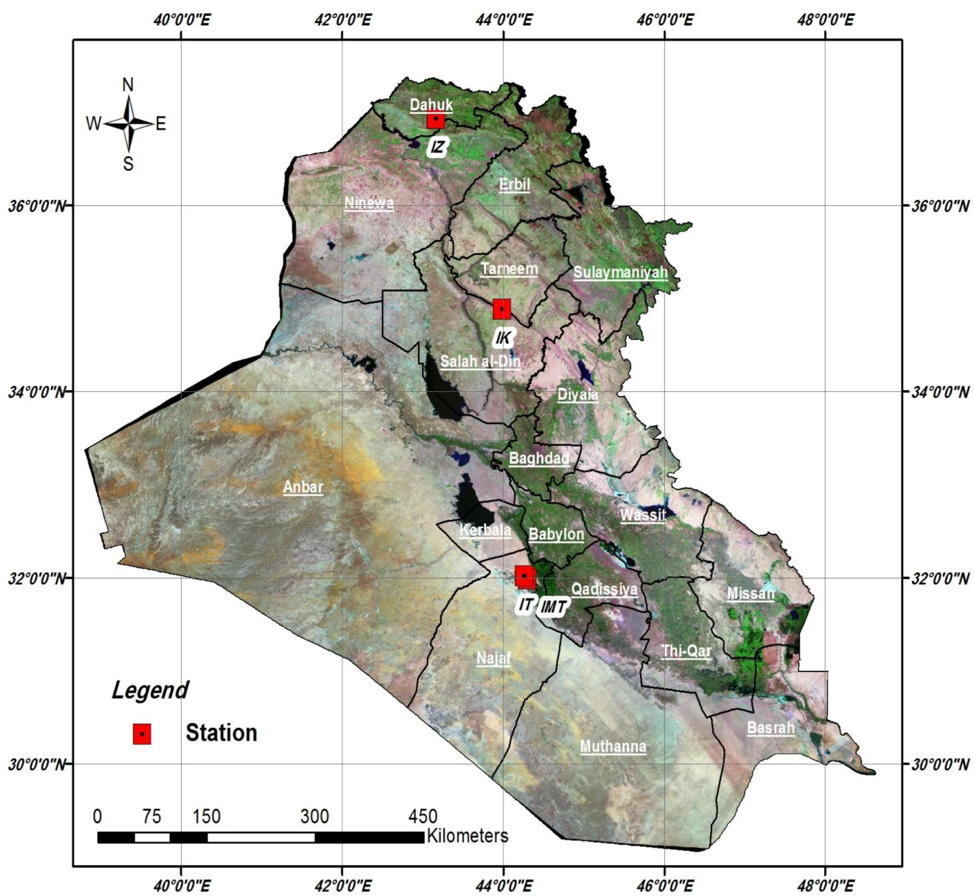

Figure-1: Location map of studied areas;IZ= Zawita section, IK= Tikrit section, IT and IMT=Tar Al-Najaf sections

Location and geological setting

1-One cross section has been selected at Zawita site named(IZ) with latitude (36°93′4″- 36°98′ 8″ N) and longitude (43°16′1″- 43°16′6″ E).It is exposed in the middle of the eastern north limb of Keri Rabatki anticline which extends from west to east and belongs to Gara anticline.

2-Also one section has been chosen (IK) at Tikrit area. The section is exposed in the middle of the north limb of Himreen north anticline, about (60km) to the north-east of Tiktit city, closed to the Tikrit- Kirkuk paved road. The section is appointed with latitude (34°88′6″- 34°
anticline extends from northeast to southwest
northeast to southwest.

3- Two sections were selected in Tar Al-Najaf area for sampling. The first section (IT) is about 12km west Al –Najaf city, determined with latitude (32°04′3″- 32°05′0″ N) and longitude (44°23′5″ - 44°23′9″ E). ; the second one section (IMT) is about 5km west of Al – Najaf city, exactly is close cross high way with Tar, near northern boundary of cemetery. It is accurately determined with latitude (32°00′9″- 32°01′4″ N) and longitude (44°27′9″- 44°28′3″ E)
(44°27′9″- 44°28′3″ E).
lower contact of the formation with Fatha Formation is not exposed in this section, but the upper contact was detected in first appearance of the pebbly sandstone bed of Al-Mukdadia Formation, and the contact is gradational.

Tikrit section represents foothill zone of unstable shelf. The total thickness of the section is about (550 m). The lower contact with Fatha Formation exposed based on the first appearance of fabric layer of gypsum and the contact is gradational. The upper contact is gradational and detected in first appearance of pebbly sandstone of Al-Mukdadiya Formation.

The total thickness of Tar Al-Najaf section (IT) reaches to 26m, whereas (IMT) is about 24 m . The investigated area represents transition zone between stable and unstable shelves. The lower contact with Fatha Formation was not exposed, but the upper contact dedected when the first pebbly sandstone of Dibbdiba Formation appeared. The contact is gradation.

Method of work and material

To achieve the purpose of this study, the procedure was conducted hereinafter:

1- The field work included carefully sampling of four sections (IZ from Zawita area, IK from Tikrit area and IMT with IT from Tar Al- Najaf area) that were chosen from the outcrops for detailed study. The location of the geological sections was determined depending on the presence of exposures of the Injana Formation, so that the sections represent all lithological succession in the studied areas, as much as possible. G.P.S. was used to record the coordinates (geographic coordinates) and the elevation above the sea level of all section localities. in addition to the number of the collected sample and its position on the geological sections.

2- Laboratory work concentrated on selecting of (24) samples and segregating sand fraction of (250-63) micrometer from the other size and cement materials, then heavy liquid (bromoform) with specific gravity of 2.89 used to separate the heavy fractions. This separation was carried out according to the method suggested by (Carver,1971 and Mange &Maurer, 1992). Each heavy fraction samples were washed on filter paper with acetone, dried out and part of them mounted on glass slides with Canadabalsam for heavy minerals study by binocular polarized microscope.The Preparation and separation heavy minerals were achieved at Applied Geology in Science College/ Babylon University.

In this work, the quantitative analyses were performed; the results are listed in Tables 1, 2 and 3 for Zawita, Tikrit and Tar Al-Najaf sections, respectively. The assemblages of heavy minerals have been recognized (according to the classification of Folk, 1974). They divided into opaque and transparent minerals as below:

Opaque minerals

They represent the higher percentage of heavy minerals with ranges of (51.79-62.5) % and an average of 55.84% at Zawita sands, (43.97-62.5)% and an average of 50.82 at Tikrit sands and (36.33-52.35)% and an average of 43.93 at Tar Al-Najaf Sands. Their grains have sub-angular to sub-rounded shapes (Plate 1-A), the high specific of Opaque minerals relates with the iron content (Folk, 1974). The abundance in Zawita is more than that inTikrit and the later is more than that in Tar Al-Najaf sands. Their existence indicates to acidic and basic igneous rocks as well as metamorphic rocks.

Transparant minerals

***Mica group*:** the minerals of mica group in the studied samples include:

Biotite content fluctuates from (0-3.06) % with an average of 1.47% at Zawita, (0-2.17)% with an average of 1.27% at Tikrit and (0-3.43)% with an average of 0.85% at Tar Al-Najaf. This mineral occur as angular to sub-angular at Zawita area , graduates to subangular to subrounded in the samples of Tikrite area; to be semi-rounded at Tar Al-Najaf area (Plate 1-B, C, D). It appears as brown and/or yellow flakes, which are strongly pleochroic, the cleavage is distinct.

Chlorite ranges between (2.53-21.94)% with an average of 10.17% at Zawita, (0.54-13.57)% with an average of 7.35% at Tikrit and (1.42-23.43)% with an average of 7.38% at Tar Al-Najaf sands . Mineral Chlorite exhibits shades of green in color. It has angular shape of grains in the samples of Zawita section and subangular shape at Tikrit area and graduates to be semi-rounded shape at Tar Al-Najaf area. Chlorite mineral is also found as platy in habit (Plate 1-E and F). It is mostly secondary in origin formed from alteration of ferromagnesian silicate minerals. Also, chlorite is derived from metamorphic rocks (Hibbard, 2002).

Muscovite is colorless. Obvious cleavage traces run along the length of the grain, but because the rock is deformed, they have a bent or wavy appearance (Plate 2- A, B and C). Muscovite ranges(0-2.55)% and average of 1.02% at Zawita, where ranges from(0-4.91)% with an average of 1.72% in Tar Al-Najaf sediments.The presence of mica (biotite and muscovite) as well as quartz and feldspar is clear supplied from the granitic rocks which considered as of one source supplied clasts. Biotite and muscovite are also derived from acidic igneous and metamorphic rocks (Dana, 1982, Hibbard, 2002 and Boggs, 1995).

Ultrastable heavy minerals: These minerals in Injana Formation in the studied sections include rutile, tourmaline and zircon.

Rutile participates in investigated sections with a range of (0-1.23). average of 0.47% at Zawita; (0-0.7) and an average of 0.20% at Tikrit and 0-1.14% with an average of o.46% at Tar Al-Najaf sands. It is characterized by high relief, reddish color to deep yellow red with subrounded shape at Tar Al-Najaf (Plate 2- D). Rutile is widely distributed as accessory mineral in metamorphic and felsic igneous rocks (Boggs, 1995 and Tucker, 1991).

Tourmaline ranges from (0 -1.14%)% with an average of 0.55% at Zawita, (0.37-3.24)% with an average of 1.50 % at Tikrit and (0.71-19.02)% with an average of 7.09 % at Tar Al-Najaf sediments.. It has Subangular shape with hony color and tabular habit grains in Tikrit; where it appears as rounded –subrounded shape in Tar Al-Najaf (Plate 2-E and F). Its high abundance is clear at Tar Al-Najaf than the rest section.Tourmaline derived from felsic igneous rocks especially granite, metamorphic rocks. (Petijohn et al., 1972 and Tucker,1985).

Zircon is ranging from (0.1-2.47)% with an average of 1.14% at Zawita, (0.57-2.28)% with an average of 1.4 % at Tikrit and (1.11-6.78)% with an average of 3.6% at Tar Al-Najaf sands . It has prismatic habit in Tikrit and subrounded-rounded in Tar Al-Najaf with colorless or pale color (Plate 3- A and B) and very high relief without cleavage. Tar Al-Najaf, obviously, has abundance of zircon more than the other sections. Zircon is widely distributed in granites and syenites (Folk, 1974; Pettijohn, 1975). It is resistant to destruction during erosion and deposition.

Metastable minerals

Metastable minerals include garnet, epidote and staurolite.

Garnet at Zawita ranges from (1.23-11.19)% with an average of 3.95 %, at Tirit from(3.86-15.14)% with an average of 7.30% and at Tar Al-Najaf ranges from(3.07-21.19)% with an average of 11.8 %. The amount of garnet is, clearly, greater at Tar Al-Najaf than those at Zawita and Tikrit sands.The garnet grains are isotropic and have high relief, pale brown color and hexagonal shape (plate 3-C). It is especially characteristic of metamorphic rocks (Kerr, 1959; Mason and Berry, 1968). Garnet is a relatively stable mineral under both weathering and burial diagenetic conditions (Morton and Hallsworth, 1999).

Epidote is a mineral index of several facies of regionally metamorphosed rocks (Boggs, 1995). The percentage of epidote ranges from (5.1-16.15 %, 9.95-18.38% and 8.57-20.56%)with an average of(11. 1% , 13.78% and 13.4 %) at Zawita, Tikrit and Tar Al-Najaf, respectively . Epidote grains have subangular to angular shape with light yellow to colorless; they are mostly non-pleochroic (Pate 3-D,E and F).

Staurolite is a regional metamorphic phase of intermediate to high grade. Staurolite is also one of the index minerals that are used to estimate the temperature, depth, and pressure at which a rock undergoes metamorphism (Mason and Berry, 1968). The percentage of staurolite ranges from(0-0.93 %, 0-0.7 % and 0-2.45%) with the averages of (0.28 %, 0.2 % and 1.02%) at Zawita,Tikrit and Tar Al-Najaf sands respectively. The content of this mineral in last section is more than other sections.

Unstable heavy minerals

***Amphiboles group*:** Amphibles group, typically, occur with plagioclase feldspar, quartz, and biotite, as well as with chlorite and oxide minerals. It consists from Tremolite, Hornblend and Glaucophane.

Tremolite ranges from (0-1.25% and 0-1.86%) with average of (0.36%, and 0.67%) at Zawita and Tikrit, respectively, and absent at Tar Al-Najaf sands . It has subangular shape with colorless in color at Tikrit (plate 4-A).Tremolite – Actinolite occurs in contact metamorphic deposits, in schist and gneisses and in metamorphic limestone (Kerr, 1959 and Boggs, 1995).

Hornblende is moderately stable and common in igneous and metamorphic rocks (Pettijohn *et al.,* 1972). Hornblende is characteristic of some medium-grade metamorphic rocks in which hornblende and plagioclase are the major constituents. The percentage of hornblende mineral ranges between(2.89-8.33)% with an average of 5.28% at Zawita, (10.8-8.47)% with an average of 4.84% at Tikrit and (0-2.86)% with an average of 0.86% at Tar Al-Najaf sands. It seems that Zawita section distigusheed with great abundance than Tar Al-Najaf. It has light-green color and rectangular shape at Tikrit (Plat 4-B).

Glaucophane can be found in studied Injana Formation as individual grains and violet in color (Plate 4-C). It ranges between (0-1.67%, 0-0.7% and 0-1.11%), and its average is (0.74 %, 0.3 % and 0.27%) at Zawita, Tikrit and Tar Al-Najaf, respectively. Usually, it is common in metamprphic rocks such as schist and gneiss (Boggs, 1995).

Pyroxene group: Pyroxene group is solid solutions of great complexity and two families, Ortho-pyroxenes (Orthorhombic) and Clino-pyroxenes (Monoclinic) that were recognized in (Plate 4-D and E,). The percentage of ortho-pyroxene ranges from(1.3-2.93%, 0.54-2.97% and 0-0.71%) with an average of (1.92, 1.4 and 0.39) at Zawita, , Tikrit and Tar Al-Najaf sediments, respectively. The percentage of clino-pyroxene ranges from (0.62-4.38%, 1.16-4.25% and 0.71-2.96%) with an average(2.69, 2.76 and 1.58) at Zawita, , Tikrit and Tar Al-Najaf sediments, respectively. The most amount of each pyroxene types is at Zawita, whereas the minor is at Tar Al-Najaf sands. Pyroxenes are yellowish green to colorless in color with no or weak pleochrism, partially to weakly corroded and parallel extinction. They are the most important group of ferromagnesian rock-forming minerals, , and crystallize under a range of different conditions (Mange and Morton, 2007) and also they are widely distributed in the basic igneous rocks (Tucker, 1991). Pyroxene and amphiboles tend to be unstable uder weathering circumstances.

Celestite : Celestite can precipitate directly from the sea water; sometimes found in evaporate deposits. In Injana Formation it is characterized by high transparency. It occurs as euhedral to subhedral crystals of columnar shape (plate 4-F). There are many generation of celestite in Najaf area. Celestite grows within exclusive zones tend to be exist filling fissures, fractures small cavities, cementing sand and in association with gypsum (AL-Ankaz, 2012). This mineral found in Tar Al- Najaf area ranging between(0-24.82)% with an average of 7 % , and it is absent in Zawita and very slightly in Tikrit areas. The irregularity distribution feature was the specific for celestite.

Others

There are very small quantity of other minerals found in investigated samples,such as titanite with an average of 0.5% at Zawita and 0.28% at Tikrit sands. Kyanite and anatase at Zawita sands only with an average of 0.1% for each of them. .

Discussion and conclusion

The effects of Zagros basic rocks on Injana sediments of Zawita area corroborated with pyroxene and amphibole content where the average of pyroxene content is about 4.61% in Zawita to be 1.97% at Tar Al-Najaf sections, whereas the amphibole content is about 6.38% at Zawita to be 1.13% at Tar Al-Najaf sections; as well as the pyroxene and amphibole content is about 4.16% and 5.82% at Tikrit area, respectively (Fig. 2).

In the other side, regarding the effects of the second provenance on Injana sediments in the studied areas which is Arabian shield rocks; it seems that the greater effect of this provenance is at Tar Al-Najaf sections, this conclusions is based on the heavy minerals study which showed unusual concentration of Zircon in the samples of Tar Al-Najaf sections where the average content of zircon is about 3.6% and graduate to be 1.38% at Tikrit and 1.14% at Zawita sections, respectively. Tourmaline mineral behaves the same trend of zircon in the studied samples where it shows higher content at Tar Al-Najaf section (Average=7.08%) and decrease to be 0.55% and 1.52% at Zawita and Tikrit sections, respectively. This unusual amont of zircon and tourmaline minerals(ultra stable minerals) in the studied samples of Injana sedments at Tar Al-Najaf section is as a result of the effect of acidic rocks of Arabian shield provenance, further than the longer distance of sediments transportation with the time which can be observed from the roundness of zircon and tourmaline shape.

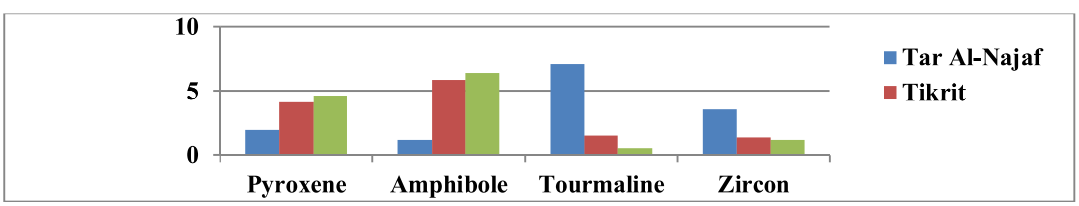

Fig. (2): Histogram shows the distribution styles of pyroxene, amphibole zircon and tourmaline minerals in Injana sediments at the three studied areas(Zawita, Tikrit and Tar Al-Najaf).

Table (1) shows heavy minerals of Zawita section

Mineral stability	Mineral group	Location	Zawita section									
		Sample number / %	IZ1	IZ3	IZ5	IZ6	IZ8	IZ9b	IZ10	IZ14b	IZ18	Average
		Opaque	57.76	52.17	53.31	58.1	56.25	55.41	52.71	62.5	51.79	55.84
		Alterites	1.18	3.7	1.53	4.55	1.88	2.31	2.7	4.17	4.97	3.0
		Rock fragments	0.36	1.23	0.51	1.14	0.63	0	0.77	0	0.62	0.5
Ultra stable		Rutile	1.08	1.23	0	0	0	0.46	0.39	0.83	0	0.47
		Zircon	2.17	2.47	0.1	1.14	1.25	0.46	0.39	0.83	1.24	1.14
		Tourmaline	0.72	0.62	0	1.14	0.63	0.93	0.77	0.1	0	0.55
Meta stable		Garnet	11.19	1.23	4.59	2.27	1.25	3.24	1.93	1.67	3.73	3.95
		Stuarolite	0	0	0	0	0	0.93	0.39	0.83	0	0.28
		Zoisite-Epidote	12.27	6.79	5.1	10.2	12.5	11.1	15.05	11.67	16.15	11.1
Unstable	Amphible group	Tremolite-Actinolite	0	0.62	0	0	1.25	0.93	0	0	0	0.36
		Hornblende	2.89	6.17	3.57	4.55	6.88	6.48	4.25	8.33	3.73	5.28
		Glaucophane	0.72	0.62	0.51	0	0.63	1.39	0.77	1.67	0.1	0.74
	Pyroxene group	Ortho pyroxene	1.81	2.62	1.3	2.4	2.5	2.93	2.39	0.83	1.62	1.92
		Clino pyroxene	2.17	3.85	2.02	4.27	4.38	2.31	3.21	2.5	0.62	2.69
		Titanite	1.08	0.62	0	0	0	0.46	0.77	0	1.24	0.49
	Mica group	Chlorite	2.53	14.81	21.94	7.95	6.88	7.41	10.81	3.33	11.8	10.17
		Biotite	1.08	1.23	3.06	0	1.25	2.31	2.32	0	1.86	1.47
		Muscovite	0.2	0	2.55	2.27	1.88	0.93	0	0.83	0	1.02
		Anatase	0.36	0	0	0	0	0	0.39	0	0	0.1
		Kyanite	0	0	0	0	0	0	0	0	0.62	0.1

Table (2) shows heavy minerals of Tikrit section

Mineral stability	Mineral group	Tikrit section								
		Sample number / %	IK1	IK3	IK5	IK7	IK9	IK11	IK15	IK16	Aver.
		Opaque	43.97	48.64	49.37	48.86	51.33	47.41	62.50	49.73	50.82
		Alterites	4.56	5.53	4.21	4.52	5.20	7.57	8.75	7.39	6.07
		Rock fragment	0.98	1.58	1.05	1.81	1.12	1.08	1.25	1.14	1.3
Ultra stable		Rutile	0.65	0.1	0.7	0.45	0	0	0	0	0.21
		Zircon	2.28	0.79	1.4	1.81	0.74	2.16	1.25	0.57	1.4
		Tourmaline	1.63	1.58	0.7	0.45	0.37	3.24	2.5	1.14	1.52
		Celestite	0	0	0.7	0	0	0	0	0	0.14
Meta stable		Garnet	7.82	5.14	3.86	4.52	4.09	15.14	6.25	7.39	7.3
		Stuarolite	0	0	0.7	0.1	0	0.1	0	0.57	0.2
		Zoisite-Epidote	15.31	16.99	17.89	9.95	10.78	18.38	10.0	10.23	13.78
Unstable		Hornblende	8.47	1.98	4.56	6.33	7.81	1.08	1.25	7.39	4.84
		Tremolite-Actinolite	0.65	0.39	0.35	0.45	1.86	0	0	1.14	0.67
		Glaucophane	0.65	0	0.7	0	0	0.54	0	0.57	0.3
	Pyroxene group	Orth pyroxene	0.98	0.79	0.7	2.26	2.97	0.54	1.25	1.14	1.4
		Clino pyroxene	3.26	1.16	2.56	1.81	3.69	1.78	3.75	4.25	2.76
		Titanite	0.98	0	0	0.45	0.37	0	0	0	0.28
	Mica group	Chlorite	6.84	13.04	8.07	13.57	9.29	0.54	1.25	6.82	7.35
		Biotite	0.98	2.37	2.46	2.71	0.37	0.54	0	0.57	1.27

Table(3) shows heavy minerals of Tar Al- Najaf sections

Mineral stability	Mineral group	Location	Tar Al- Najaf sections					
		Sample number / %	IMT6	IMT9	IMT10	IMT11	IT15	IT17	Aver.
		Opaque	36.33	42.14	52.35	42.1	42.55	49.73	43.93
		Alterites	3.89	2.86	6.38	2.45	3.55	3.39	3.92
		Rock fragment	0.56	0.57	1.42	0	0.71	0	0.58
Ultra stable		Rutile	0.56	1.14	0	0	0	0.85	0.46
		Zircon	1.11	1.71	2.84	4.91	3.55	6.78	3.60
		Tourmaline	2.78	1.71	10.64	19.02	0.71	2.12	7.09
		Celestite	6.11	0	0	0.1	24.82	0.1	7.0
Meta stable		Garnet	18.33	6.86	11.35	3.07	9.22	21.19	11.8
		Stuarolite	0.56	0	0.71	2.45	0.71	1.27	1.02
		Zoisite-Epidote	20.56	8.57	9.93	16.56	11.35	11.44	13.4
Unstable	Amphible group	Tremolite-Actinolite	0	0	0	0	0	0	0
		Hornblende	0.56	2.86	0	0.61	0	0	0.86
		Glaucophane	1.11	0	0	0	0	0	0.27
	Pyroxene group	Ortho-pyroxene	0.56	0.57	0	0.61	0.71	0	0.39
		Clino-pyroxene	2.56	0.71	2.96	1.45	0.71	1.12	1.58
		Titanite	0	0	0	0	0	0	0
	Mica group	Chlorite	4.44	23.43	1.42	1.84	1.42	1.69	7.38
		Biotite	0	3.43	0	0	0	0	o.85
		Muscovite	0.1	3.43	0	4.91	0	0.42	1.72

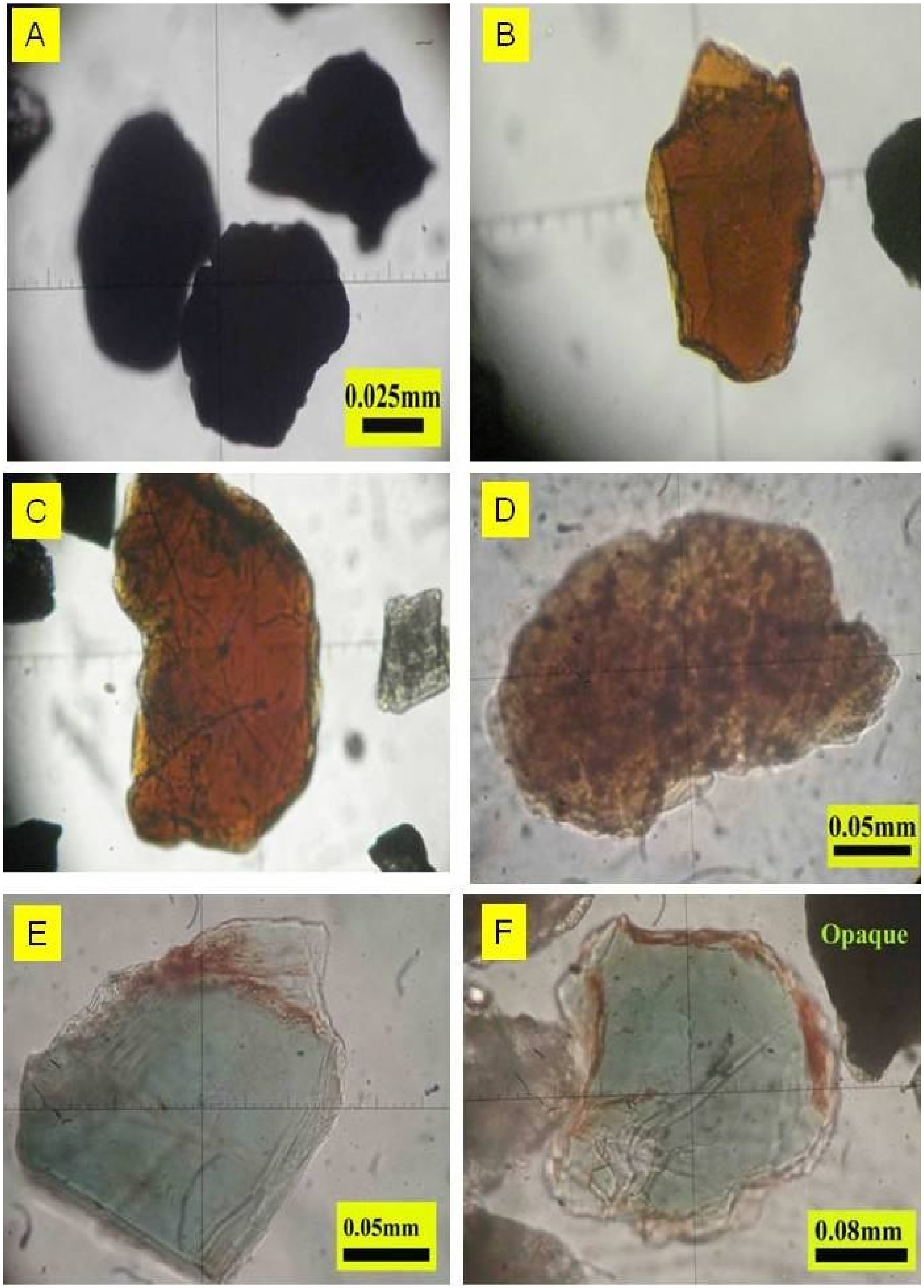

Plate (1):A: Opaque mineral, PPL , Zawita area. B, C and D: Biotie, PPL, at Zawita, Tikrit&Tar Al-Najaf areas, respectively. E and F: Chlorite minerals , PPL, at Tikrit and Tar Al-Najaf areas, respectively.

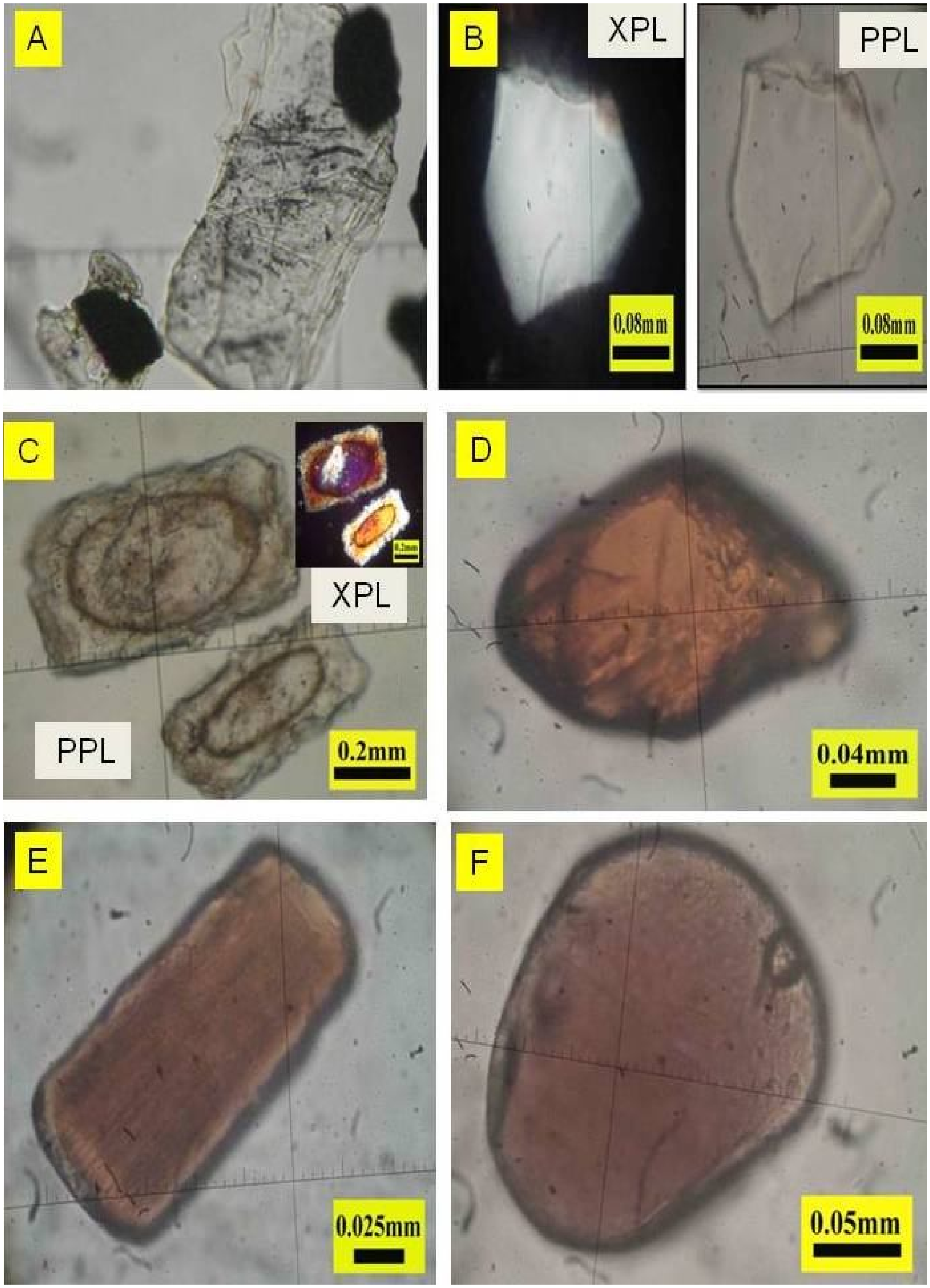

Plate (2):A: Muscovite, PPL, Zawita area. B:Muscovite, XPL and PPL at Tikrit area. C: Muscovite, PPL, Tar Al-Najaf area. D: rutile, PPL, at Tar Al-Najaf area. E&F:Tourmaline at Tikrit and Tar Al-Najaf areas, respectively.

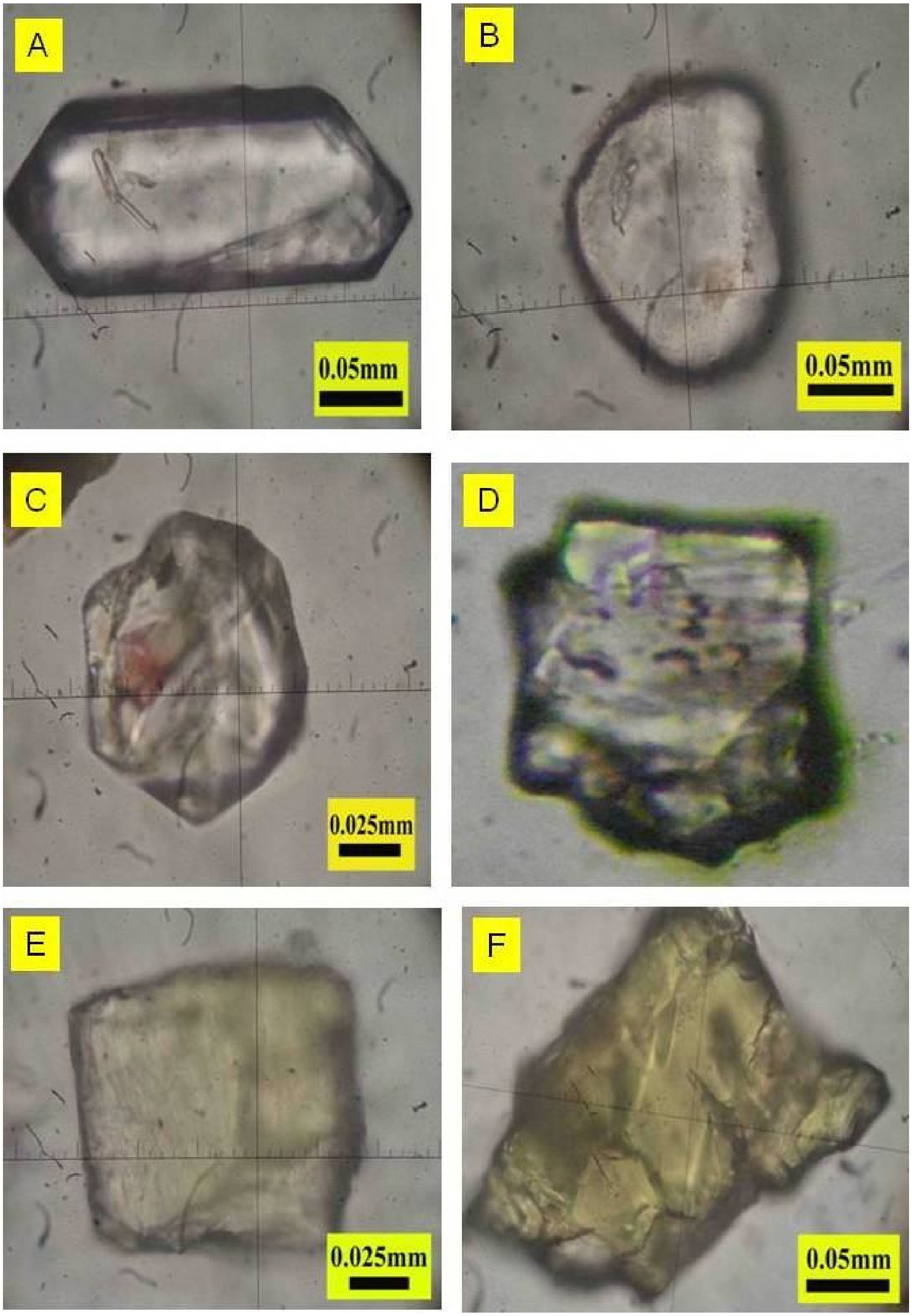

Plate (3): A&B: Zircon, PPL,at Tikrit and Tar Al-Najaf areas, respectively. C: Garnet, PPL, at Tikrit area. D, E and F: epidote, PPL, at Zawita, Tikrit and Tar Al-Najaf areas, respectively.

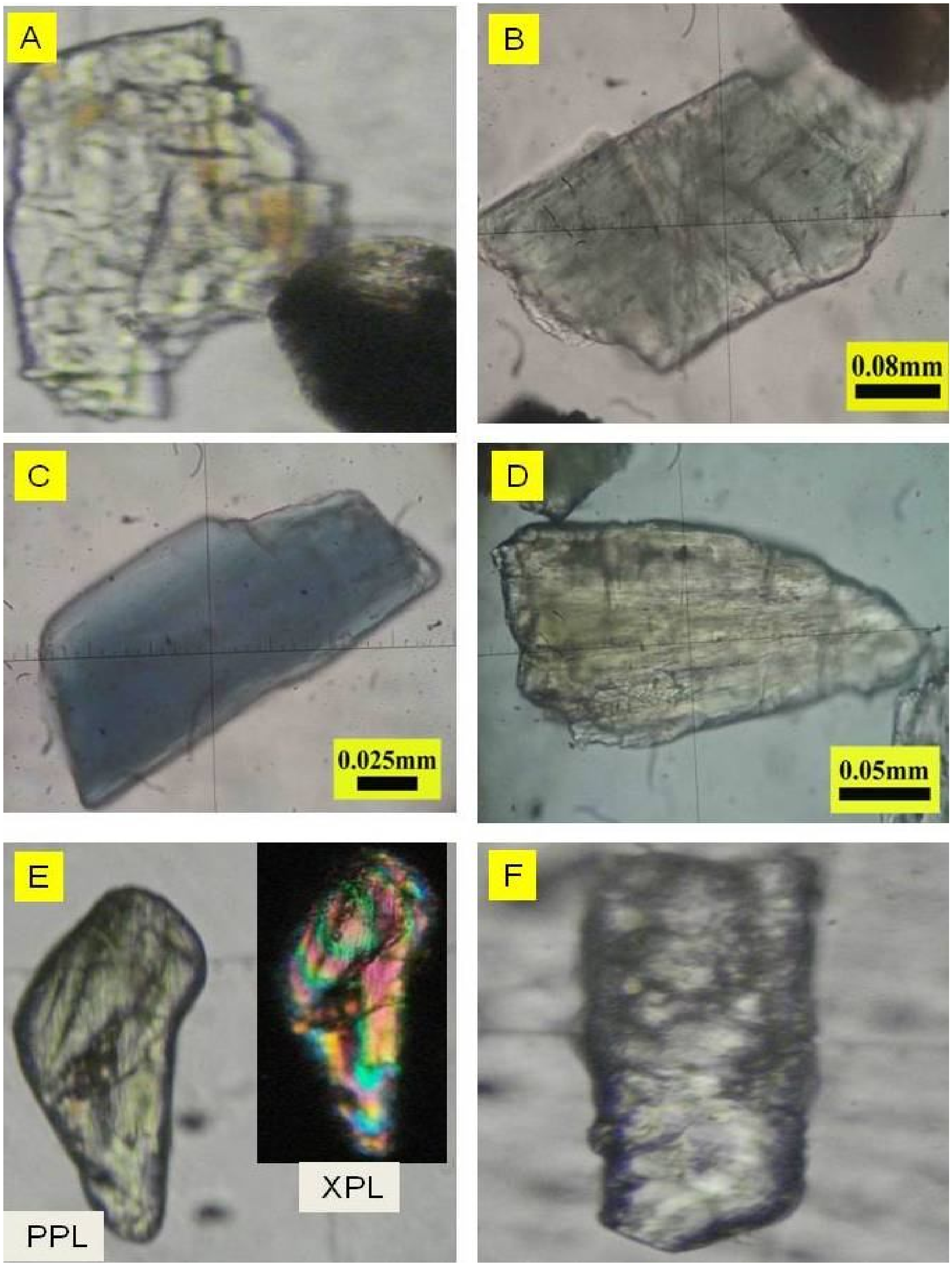

Plate (4):A:Tremolite, PPL,at Tikrit area. B: Hornblend,PPL, at Tikrit area. C: Glaucophane,PPL, at Tikrit area. D: Orthopyroxene, PPL, at Tikrit area. E. Clinopyroxene, PPL at Zawita area. F: Celestite, PPL, at Tar Al-Najaf area.

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