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GEOLOGICAL SURVEY ADMINISTRATION

Mineral Status and Future Opportunity

CENTRAL JORDAN URANIUM DEPOSITS

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Uranium

1. Introduction

The main goal of this summary report is to focus on all of Jordanian uranium deposits, especially the surficial uranium deposits in Central Jordan that has been studied in detail and opened for investment.

Jordan had been covered by airborne radioactive survey in the year 1980 and indicated several radioactive anomalies. Regarding the area under study, the gamma radioactivity intensity ranges between 1000 and 2000 count per second (c/s), and related, mostly, to the phosphorite. The prevailing intensity is around 500c/s related to non-phosphatic rocks, river and mud-flat sediments.

The re-evaluation of airborne gamma anomalies and ground radiation studies carried out in 1991, 1992 resulted in the identification of a zone related to non-phosphatic formations (Table1). The results of both airborne and ground radiation surveys (gamma scintillometry and spectrometry, radon emanometry and radon (track-etch) measurements) indicated the following uranium deposits areas (Figure1).

Table (1): Location of Uranium Deposits (Utm Coordinate System).

Location	Area (Km^2)	Coordinates	
		Easting	Northing
Central Jordan	1118	227000-253000	3451000-3494000
Mafraq Area	156	222000-235000	3587000-3599000
Wadi Sahb Elabiadh	345	308000-331000	3331000-3346000
Wadi Al Bahiyya	77	223000-234000	3374000-3381000
Wadi Araba – Wadi Dana	-Not calculated		

All uranium deposits areas except Wadi Araba– Wadi Dana area are surficial occurrences and associated with Pleistocene sediments.

Wadi Araba– Wadi Dana uranium deposits are associated with apatite minerals (vein) in Cambrian sandstone.

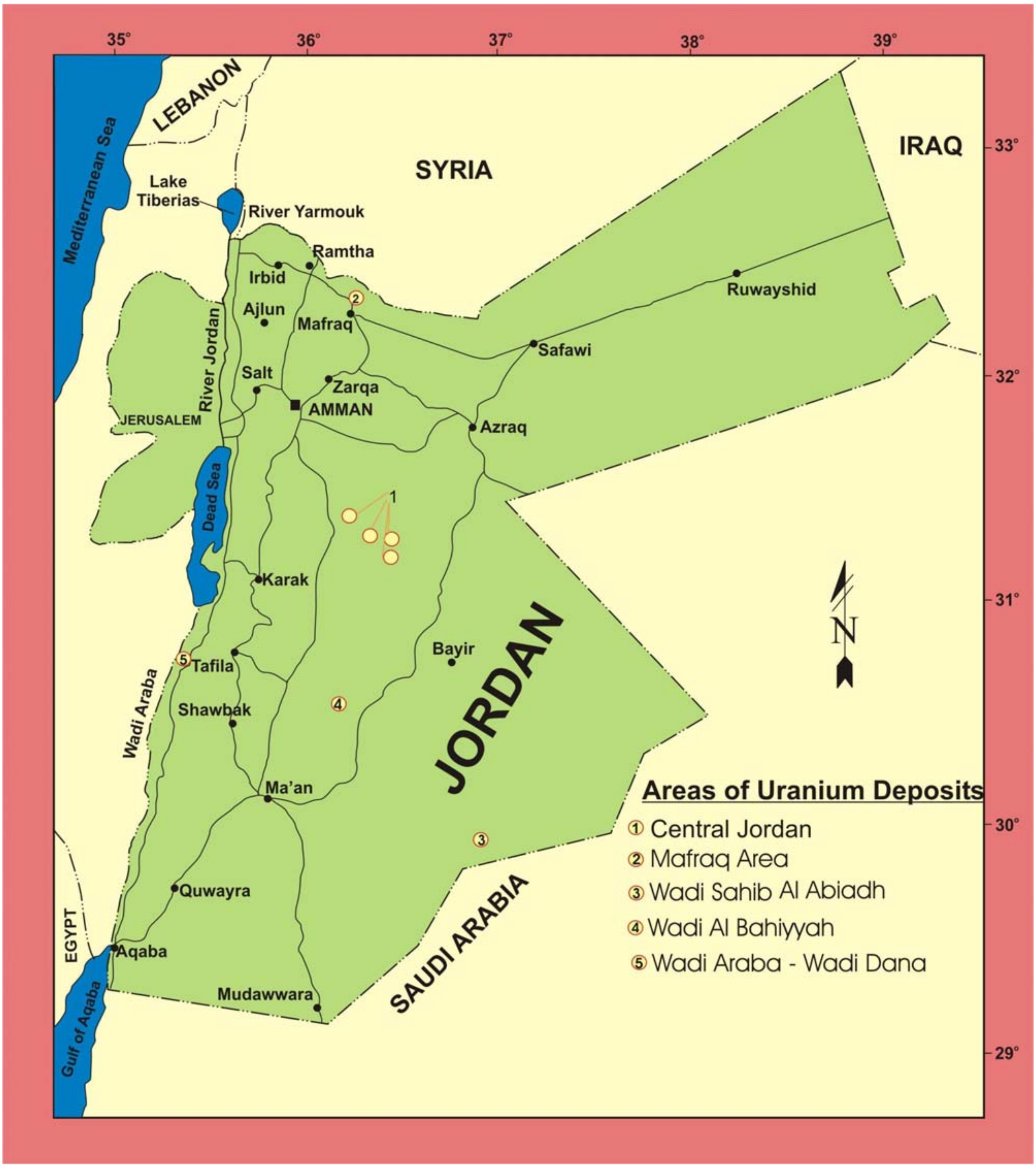


Figure (1): Location Map of Uranium Deposits.

2. Central Jordan Uranium Deposits

The largest clear radioactive anomaly that showed high radon gas concentrations and gamma ray intensity measurement readings and had been related to surficial uranium occurrences were identified in central Jordan in Pleistocene sediments and in highly fractured soft chalk marl of Paleocene age. Surficial uranium deposits were discovered for the first time in the central part of the Kingdom in the year 1992.

Evidences indicate that, the origin of uranium mineralization is from the marblization that was occurred in the vicinity rocks and produced Daba'a vary-colored marble.

Studies accomplished in uranium exploration project revealed that surficial uranium occurrences in central Jordan are strictly controlled by the occurrence of the vary-colored marble.

The exploration total area is located within 372km²; it has uranium shows and high radioactive measurements. The area of uranium is covered within sevrral topographic sheets; these are (Figure 5):

Siwaqa
Wadi Attarat Um Ghadran
Wadi Maghar
Khan Azzabib

Exploration measurements and investigations had guided to a total detail study area of 199km² that has higher readings for surface gamma ray intensity (< 150cps) and radon gas concentration (<100cpm) than the back ground (70cps for gamma and 50cpm for radon), a total number of 1682 trenches with an average depth of 2.5m were achieved in the study area, more than 3000 samples had been taken from the trenches were chemically analyzed (fluorimetric), results of analysis revealed that the total uranium distribution area is 115km² (Figure 2) and uranium concentrations ranged between 00 and 2220ppm, with an average uranium concentration of 522ppm including negative samples (00 ppm).

Upon the world uranium market status and IAEA standards in the year 1998, a uranium concentration cut off grade ranged between 140 and 600ppm were considered for estimating U3O8 (Yellow cake) reserves, and after excluding trenche areas that have uranium concentrations less than 140ppm, 37500 metric tonnes of U_3O_8 reserves were estimated in a total area of 38km² with 690ppm uranium concentration average, (Table-2 and Figure-2).

U_3O_8 (Yellow cake) reserves have been recently re-estimated according to the uranium ore classification systems utilized by IAEA and US DOE, and considering the uranium occurrences kind (Sedimentary surficial deposits) and sharpness distribution of uranium concentrations, in addition to the recent world uranium market status, especially demand and prices.

Both of 100 and 200ppm cut-off grades were used separately to re-estimate uranium reserves, 200ppm cut-off was found to be more reasonable and convenient due to several reasons (more details in Reserve Calculation). However, applying this cut-off grade had resulted higher reserve values than 100ppm cut-off grade because of:

- Areas of uranium concentration less than 200ppm occupy narrow zones (boundaries) around the considerable uranium blocks (Figure- 2). The total uranium ore area when cut-off 100ppm (61.7km^2) is not much larger than the total ore area when cut-off 200ppm (60km^2).

- The average thickness of ore in this zone 1s (0.8m) which is thin comparing with the average thickness of total ore area (1.3m).

- The average of U_3O_8 concentration when cut-off 100ppm is 591ppm, while it is 628ppm when cut-off 200ppm.

The recent reserve re-estimation had showed that the total uranium ore areas is 60km^2 with a reserve of 64880 metric tones and uranium concentration average of 628ppm (Table- 2 and Figure- 2).

An area of 1615km^2 has been considered as the first Jordanian uranium investment concession block after adding areas from both of Jebal Al Mutarammel and Qasr Al Kharranah topographic sheets.

Table (2): Areas of uranium locations/ 1998.

Area (Km^2)	**C. Jordan Concession Area (km^2)**	**Detail study Area (km^2)**	**Uranium Ore Distribution Area (km^2)**	**1998 Calculated Reserve (cut-off 140-600ppm) Area (km^2)**	**2007 Calculated Reserve(cut-off 200ppm) Area (km^2)**
Siwaqa		106	55	13	28.1
W.Maghar Attarat	1615	80	51	16	22.73
Khan Azzabib		**13**	**10**	**9**	**9.18**
Total	**1615**	**199**	**115**	**38**	**60**

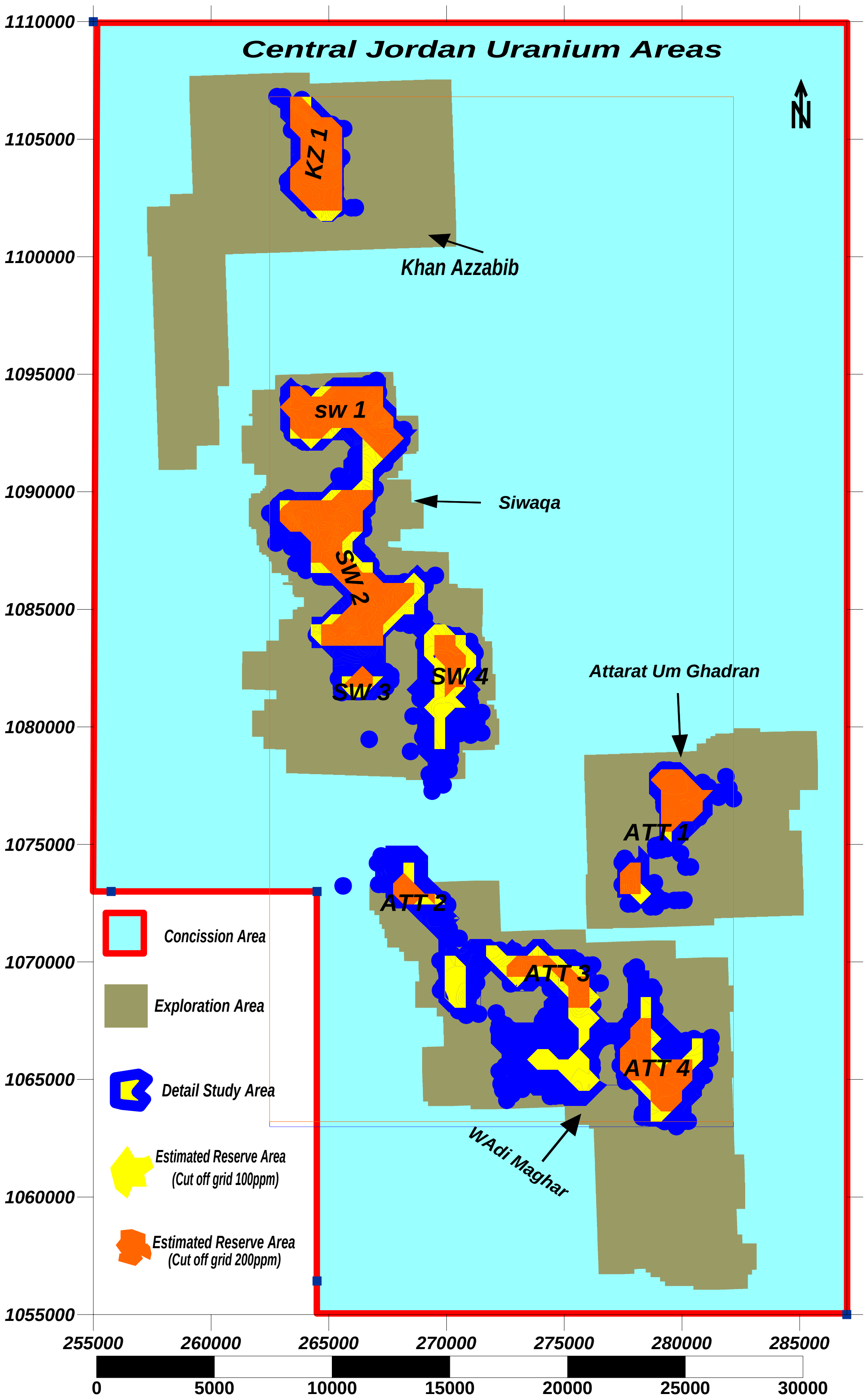


Figure (2): Central Jordan Uranium areas.

3. Study Area Location and Characterization

3.1. Study Area Location

Central Jordan uranium deposits area locates about 60kms south of Amman, and is bounded by Queen Aliaa' Airport from the north, Al Qatranah town from the south, Amman– Aqaba high way (desert road) from the west and by Aqaba– Azraq high way from the east.

Study area can be defined by the following coordinates (Figure 3):

E: 227000 – 253000 N: 3451000 – 3494000 (UTM).
E: 258284 – 282781 N: 1063681 – 1107537 (Pal. Belt).

The following coordinates (Pal. Belt) bound concession study area:
Coordinates of area corners:

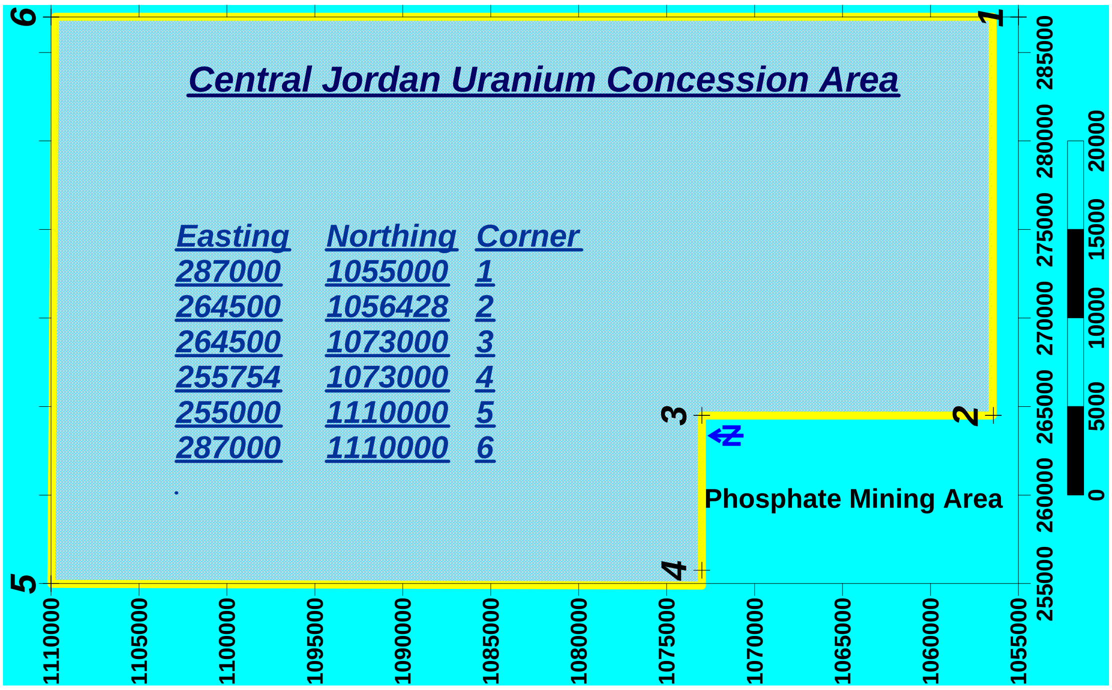


Figure (3): Central Jordan Uranium Concession Area.

3.2. Study Area Characterization

The study area is characterized by:

- Occurrences of varicolored marble, which is stratigraphically, equivalent to the chalk-marl of Maastrichtian-Paleocene age.

- Paleo-thermal phenomena such as travertine sediments and hot water holes.

- Desert weather (The summer is hot; while in winter there is a differences in temperature between day and night). Wind blows from the west all the year except some winter days that recorded dusty strong cold eastern wind.

- Low rainfall.

- As a part of the Jordanian Badia, the study area is considered as an arid area with scattered green spots of farms especially in Khan Azzabib area which is part of Jordanian Government greening blueprint.

- Water resources available from local water wells or Siwaqa Dam which is located at the western edge of the concession area.

- The Uranium concession area is very close to the Capital Amman and is served by three main high ways (Figure 5):

  A. Amman – Aqaba high way from the west.
  B. Azraq – Aqaba high way from the east.
  C. Siwaqa – Azraq new high way which crosses the center of the study area and ties the two mentioned high ways.

4. General Geology and Stratigraphy

4.1. Geology

The geology of central part of Jordan (Figure 4) comprises the following rock formations:

Table (3): Geological formations in central part of Jordan.

Formation	Age	Thickness (m)	Rock type	Remarks
Al-Hisa	Maastrichtian	30 - 60	Al Qatrana / Sultani Phosphorite.	Interlayer chert, marl and Coquina.
Muwaqqar	Maastrichtian Paleocene	25 - 75	Chalk-marl and chalky limestone.	Interlayer chert. Oil shale represents.
Um Rijam	Paleocene Eocene	20 - 50	Brecciate chert and Limestone.	
Surficial sediments	Pleistocene	0.0 – 2.5	Gravel, sand and mud.	Fine grained badly and unconsolidated carbonatic sediments are occurred. Travertine is found associated with fault systems.
Valley filling mud sediments	Holocene	0.0 - 1	gravel, river sand and mud flats	

From structural point of view, dipping in the area is gentle towards east, and north-east. The main structural feature that affected the area is Siwaqa fault, which extends from southeast of the Dead Sea to the Saudi Arabia border. There are also minor other faults affected the area, but of less importance.

4.2. Stratigraphy

The soil/sediment covers (Holocene-recent in ages); consists of soil cover, river and mud-flat sediments. These sediments are brown in color, brittle and fragmented (Figure- 4).

Other sediments in the area are of Pleistocene age, which consists of off-white carbonate, fine grained, brittle and partly medium hard material. In lower part this material intermixed with fragmented chalk-marl of the underlain beds. Therefore this zone is called the “reworked zone”.

5. Topography

The topography of the study area is generally flat, but it has gentle slopes and dipping towards the heights in the east and north–east regions (Figure 5). An East – West trending main wadi is crossing the study area along Siwaqa fault. The radioactive zone is horizontal in general.

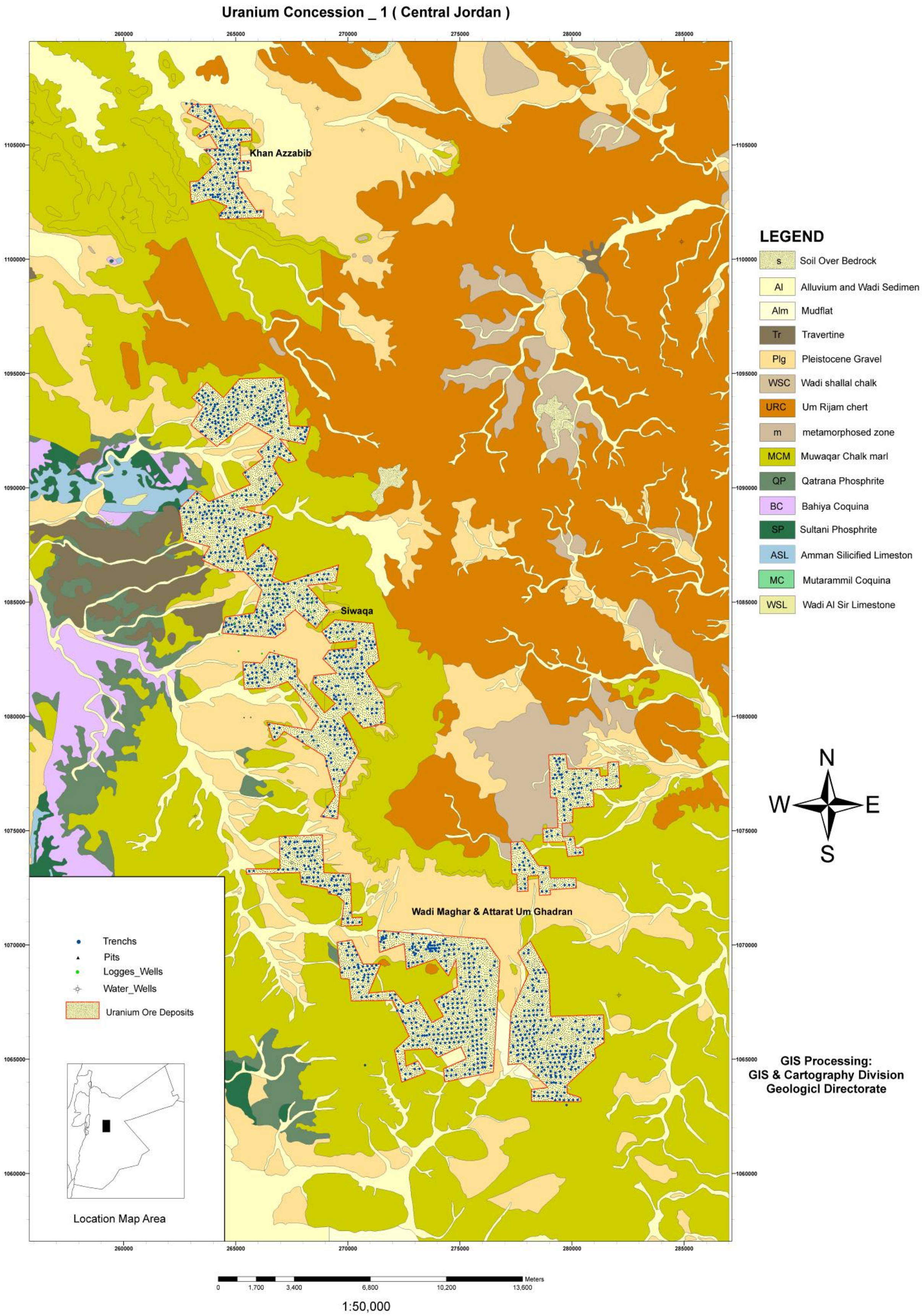


Figure (4): Lithological distribution map for the uranium concession area-1/ Central Jordan.

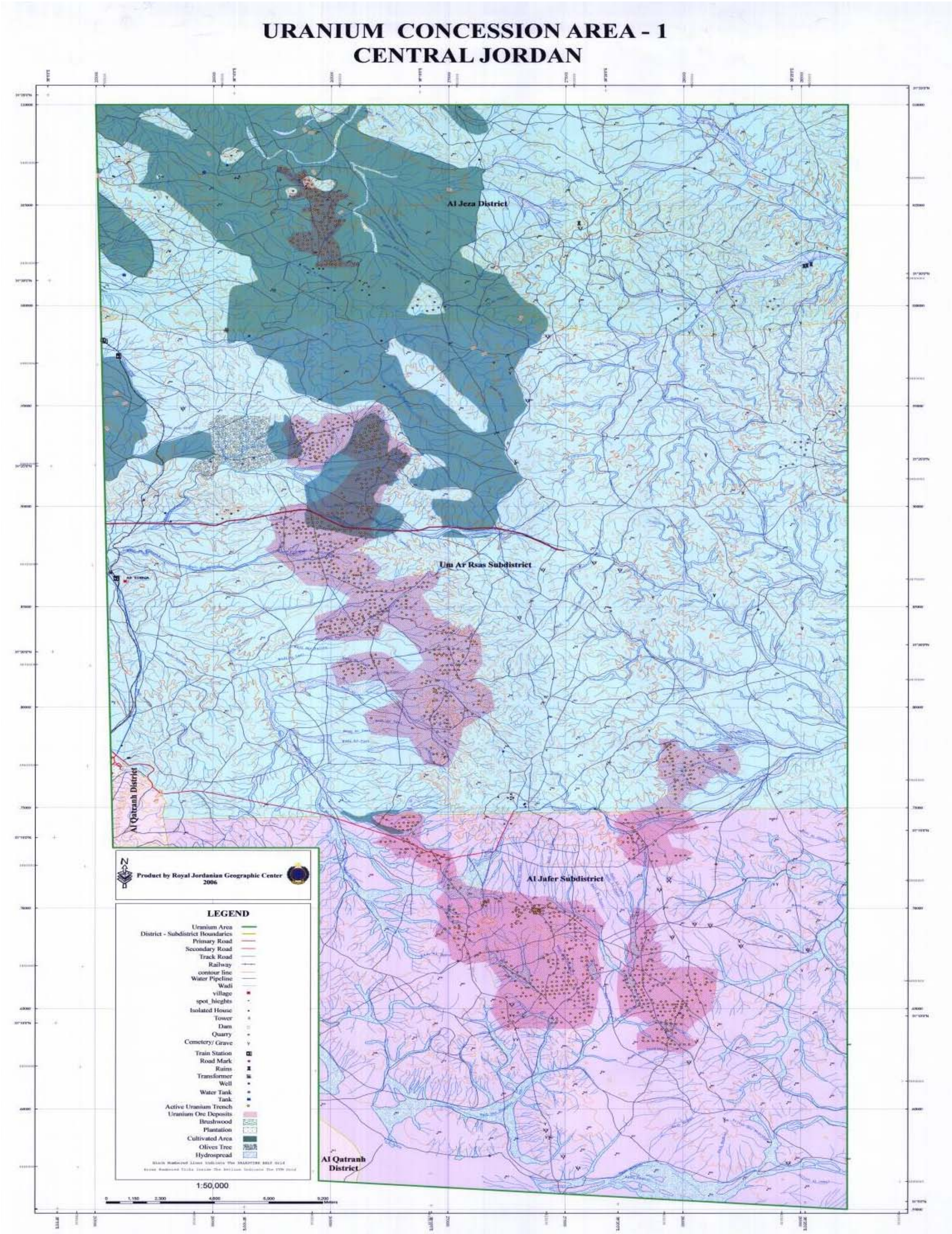


Figure (5): Topographic map for the uranium concession area-1/ Central Jordan.

6. Exploration Method

An airborne spectrometric survey covering the entire country was completed. Ground base radiometric surveys of anomalies identified in the airborne survey were carried out. Precambrian basement and Ordovician sandstone target areas were evaluated using geological, geochemical and radiometric mapping and/or surveys.

A regional geochemical sampling program involving stream sediments and rock samples was applied with geological and radiometric follow-up. An evaluation of the uranium potential of the Jordanian phosphate deposits was completed.

A comprehensive survey in central Jordan was carried out in the course of three exploration stages:

1. Reconnaissance stage: Random measurements of gamma and radon (alpha track-etch method) were performed.

2. Semi-detailed stage: In this stage such measurements were carried out on a grid system.

3. Detailed studies: Proposed areas were radiometrically surveyed on a grid system starting with radon measurements (emanometric method) in order to delineate the ore body, followed by trenching (on grid cells) and sampling.

6.1. Exploration Activities

6.1.1. Field Work

1. Radon and gamma measurements on grid systems (Figures 6 & 7), more than 13000 car borne and foot gamma measuring stations and 11000 emanometry and track-etch radon gas points were performed in Central Jordan study area.

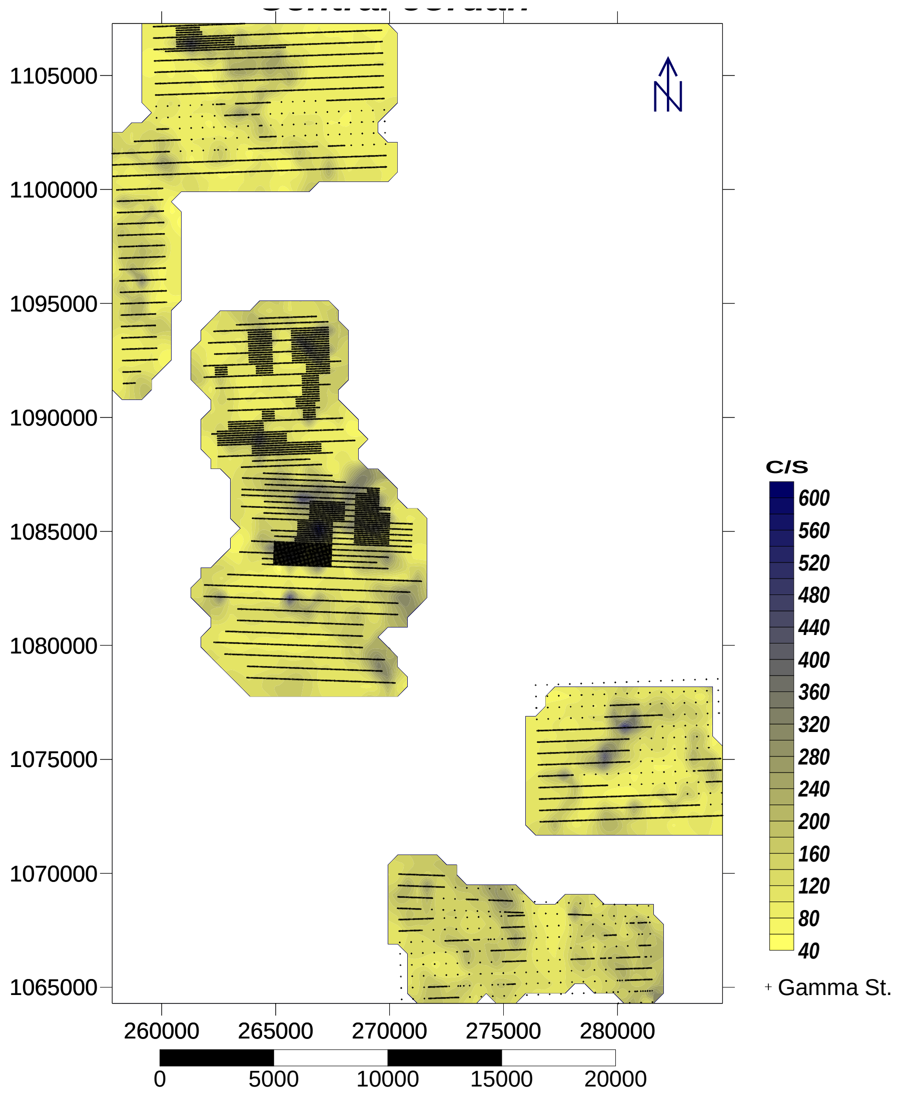
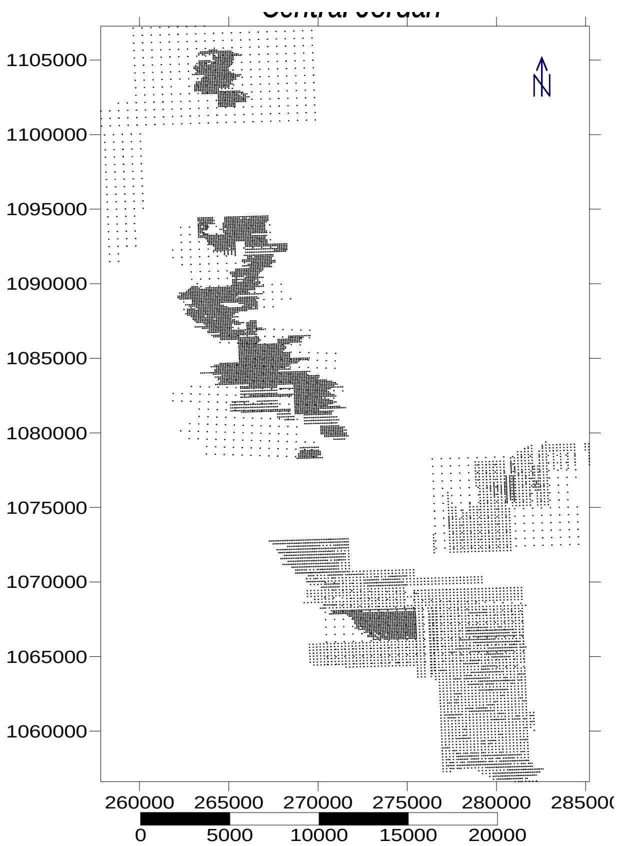
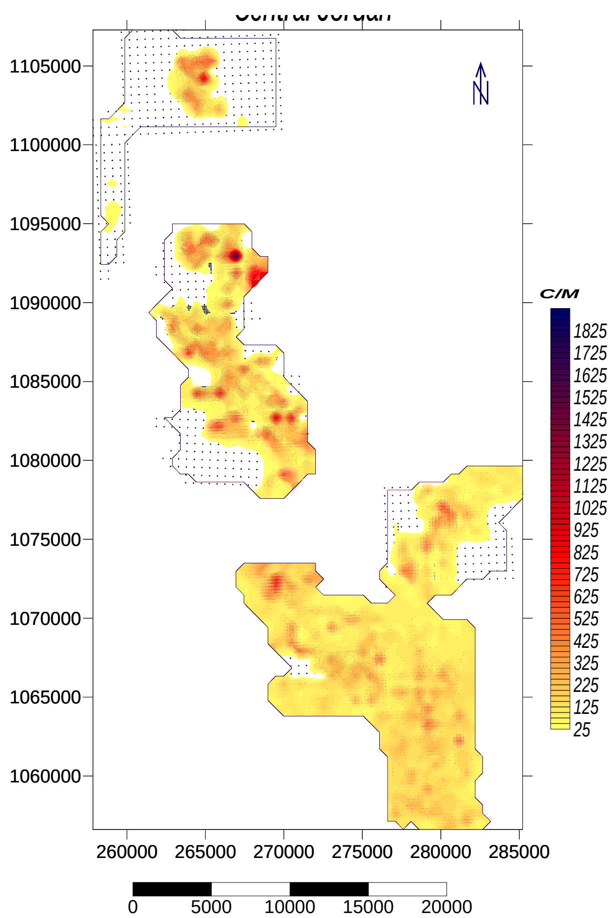


Figure (6): Gamma station locations and Gamma intensity map (Central Jordan).

For delineating the ore body horizontally, radon value of 300c/m was considered through field tests as a border limit in order to delineate areas favorable for higher uranium concentrations.



(A)



(B)

Figure (7A): Radon measurements location map (Central Jordan).
Figure (7B): Radon concentration and measurements distribution map (Central Jordan).

2. Trenching and sampling within the area delineated by radon survey, spacing between the trenches range between 150– 300m. All trenches (1682 trenches) were lithologically described, radiometric measured, and determined both of its radioactive and overburden zones.

3. Samples collection and preparation.

6.1.2. Laboratory and Office Work

- Fluorimetric uranium analysis.
- Mineralogical examination.
- Autoradiographic examination.
- Geochemical study.
- All data and information were computed and stored in a data-base.

7. Instruments and Measuring Techniques

1. BGS-3, GIS-5, Centrex Company, Scintillation counters (Scintillometers).
2. GRS 500 Portable field Scintello- Spectrometers.
3. Office Spectrometer.
4. RD-200, Centrex Company, field Radon gas detector (Emanometer).
5. Alpha (Radon) track-etch counting tools.
6. GPS and Theodolite survey equipments.
7. Gamma logging vehicle.
8. Fluorimetric analysis instrument and tools.
9. D4E Excavator.

All radiation instruments were systematically calibrated and synchronized in NRA by project stuff using instruments radioactive sources and standers that had been provided by IAEA and Centrex Company.

8. Reserve Calculation

The general outline method of uranium reserve calculation was found to be most convenient for Central Jordan ore for the following reasons:

- **I.** The radioactive zone is horizontal in general.
- **II.** Lithology, and to some extent, radioactivity distribution is homogeneous.
- **III.** The trenches spacing ranges between 150- 300m (mostly 200m). This range seems, to a certain degree, reasonable.
- **IV.** Thickness of the radioactive zone does not differ too much from one trench to another.
- **V.** The thickness of the overburden is also not widely variable.

Regarding reserve calculations the following points were strictly taken into consideration:

- **a.** Depending on radon measurements (Figure 7) and concentrations of uranium (Figure 10), Siwaqa ore was sub divided into 4 blocks (Figure 2), both of Wadi Maghar and Wadi Attarat Um Ghadran areas were studied as one area and also sub divided into 4 blocks (Figure- 2). As a high concentrated and almost has no geological losses Khan Azzabib area was sub divided and taken as one individual block. Blocks have a cut-off grade (200ppm) which represents the minimum level of uranium concentration. The highest concentration grade was found in Khan Azzabib individual block, uranium ore zone average thickness has reached 1.5m in block (4) of Siwaqa area, while Attarat and Wadi Maghar study area hugged blocks of low concentration grade and reserve tonnage. (Table- 4).

- **b.** The average grade of Central Jordan ore is high (Siwaqa 592ppm, Attarat/ Wadi Maghar 345ppm and Khan Azzabib 948 ppm) comparing with producing uranium mines (i.e. Rossing under ground uranium mine in Namibia which has an average grade of 300ppm and cut-off grade 100ppm).

- **c.** Open pits grades are lower than the underground grades.

- **d.** Cost of Sedimentary surficial uranium mining recovery and tailings rehabilitation is much lower than the under ground ones.

- **e.** Central Jordan uranium mineralization distribution I mostly sharp at the boundaries of the ore.

- **f.** Trenches comprising original and fine material samples which give uranium concentration equal to or higher than the cut-off grade, were included in the blocks. However, only uranium concentration values of the original samples were considered by the calculation of the ore reserve.

- **g.** Trenches indicate, instead of the radioactive zone, other lithologies like oil shale, whitish limestone, greenish marl, river and mud-flat-sediments were excluded.

- **h.** Dry ore density of 1.4 g/cm3 was utilized in the reserve calculation. This value is virtually low because the ore consists of badly consolidated, friable and highly fractured carbonate material.

The reserve was calculated according to the following formula:

T = A X t X d X U3O8 %100

Where:

T	=	U3O8 tonnage (mt)
A	=	Block area (m^2)
t	=	ore thickness (m)
d	=	ore density (g/cm^3)

*According to the uranium ore classification systems utilized by IAEA and US Department of Energy (DOE), Central Jordan Uranium ore is classified under an early phase of "Reasonably Assured" category. This may equal to a semi-assured category.

Table (4): Estimated Uranium Ore (U3O8) Deposit (Reserve).

Central Jordan Uranium Areas	Block	Area (km^2)	Total Area (km^2)	Average Conc.(ppm)	Total Average Conc.(ppm)	Average Ore Thick. (m)	Estimated Uranium Ore (U_3O_8) Inventory (tones)	Total Estimated Uranium Ore (U_3O_8) (tones)
Siwaqa	1	7.1	28.1	688	592	1.25	8548	34320
	2	14.9		778		1.27	20400	
	3	0.82		488		1.42	0.8	
	4	5.26		415		1.49	4570	
Attarat and Maghar	1	7.56	22.73	405	345	1.34	5740	14965
	2	3.5		342		1.23	2060	
	3	4.8		263		1.31	2315	
	4	6.87		371		1.36	4850	
Khan Azzabib	KZ	9.18	9.18	946	948	1.28	15595	15595
Total		**60**	**60**			**1.32**	**64880**	**64880**

However, uranium ore reserve in central Jordan is more than the calculated amount (64880 tones) for reasons because Studies in Khan Azzabib area had not finished yet.

In fact it is expected that uranium oxide (U_3O_8) reserve tonnage in Central Jordan is higher than the estimated one and may reach more than 70,000 tones when considering:

- Studying and estimating reserves in the unstudied part of Khan Azzabib area.
- Assuming no geological losses.
- Following the hall vertical radioactive zone of all trenches.

9. General Results and Properties of Central Jordan Uranium Deposits

Soft carbonate rocks in central Jordan contain high uranium concentrations, these rocks formed a radioactive zone (uranium host rock) which is composed of carbonatic materials.

Mineralogical, lithological and geochemical examinations had been applied on the surficial uranium deposits and indicated the following results that reflect the uranium ore properties:

1. Central Jordan ore is located near to the surface,
   Consequences:
   - Open-cast mining operations.
   - Easy and not costly mining operations.
   - Mitigation of hazardous radon risks.

2. High uranium concentrations associated with carbonate rocks,
   Consequence:
   - Utilization of alkaline method for uranium leaching is known to be easy and not costly.

3. High uranium concentrations are found as minute unrecognizable mineralization disseminated within fine grained sediment, and as yellowish stains of secondary uranium mineralizations coating fractures and fragmented chalk marls,
   Consequences:
   - Advantages in mining operations and ore dressing.
   - Stains are beneficiated through brushing technique.

4. Mineralogical examinations indicate lack of sulfates and low contents of clay minerals,
   Consequence:
   - Highly appraised, otherwise, they act negatively upon leaching and precipitation of uranium.

Petrography analysis had showed that Pleistocene deposits contain cryptocrystalline texture, crystalline quarts, gypsum, clay, iron oxides and opaque minerals.

10. Conclusions

The following points are some conclusions which may act positively on the techno-economics of the ore.

The ore is near or almost near the surface; the average overburden thickness is 0.5m. This may ease an open cast mine operation.

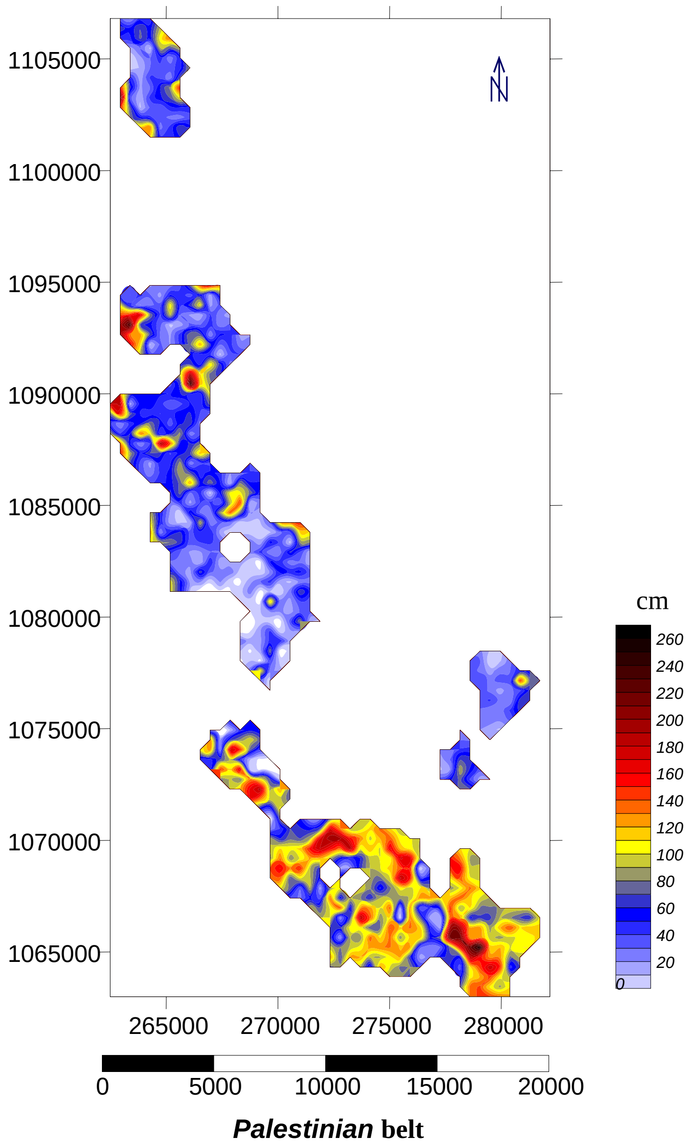


Figure (8): Overburden thickness distribution over Uranium ore/ Central Jordan.

The total thickness of the radioactive zone ranges between 0.4- 5m (average 1.3m). This zone is covered by a soil/sediment overburden of an average thickness of 0.5m. Moreover, the radioactive zone is characterized by a fluidal appearance of pink, brown and green color, which is identical with the adjacent varicolored marble.

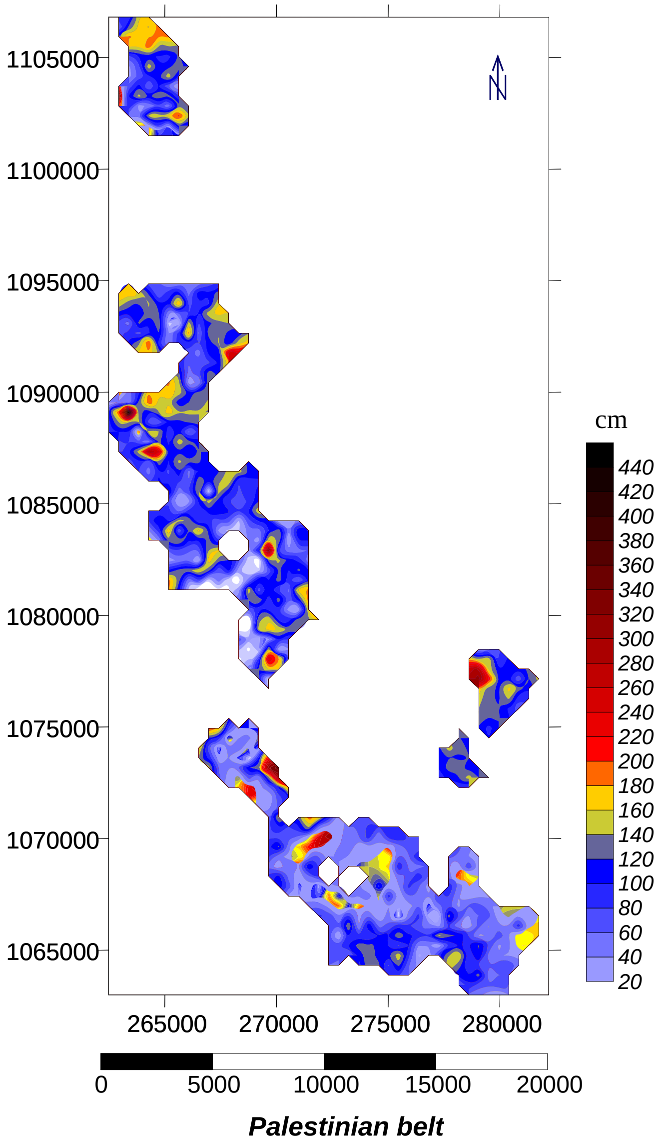


Figure (9): Active zone/ Uranium ore thicknesses distribution/ Central Jordan.

The mineralization occurs as either minutely disseminated grains within the sediments or as yellowish secondary uranium minerals filling fractures and small pockets in the radioactive zone is composed of carbonatic materials.

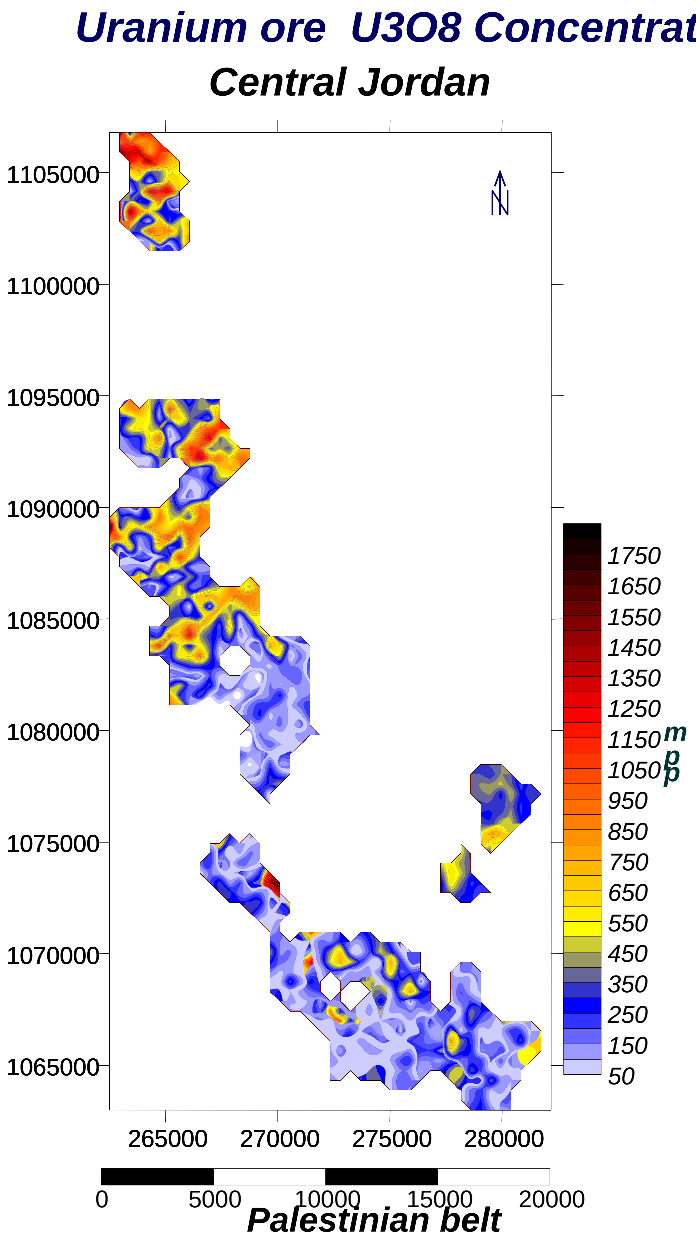


Figure (10): Uranium ore U_3O_8 concentration? Central Jordan.

Uranium deposits occur in the flat and the gentle slope of surface and near surface chalk marl areas.

Table (5): Areas of central Jordan uranium locations and data averages.

Area (Km^2)	Siwaqa	W.Maghar and Attarat	*Khan Azzabib	Average	TOTAL
Central Jordan. suggested Uranium Concession Area	1615 (includes Mutarammel &Q. Alkharranah)				**1615**
Exploration Area	162	190	20		**372**
Detail Study Area	106	80	13		**199**
Ur. Ore Dist. Area	55	51	10		**116**
Total average uranium concentration (all trenches) ppm	475	211	880	**522 ppm**	
1998 Calculated Reserve Area	13	16	9		**38**
1998 Reserve average uranium concentration ppm	765	425	880	**690 ppm**	
1998 U_3O_8 reserves Metric/tones	18000	9500	10000		**37500**
1998 Average ore thickness (m)	1.3	1.3	1.2	**1.3 m**	
2007 Re-estimated Reserve Area (Km^2)	28.1	22.7	9.2		**60**
2007 Average uranium concentration (cut-off 200ppm) ppm	592	345	948	**628 ppm**	
2007 Re-estimated U_3O_8 reserves Metric/tones	34320	15595	14965		**64880**
2007 (cut-off 200ppm) average ore thickness (m)	1.36	1.31	1.28	**1.32m**	
Average over- burden (m)	0.5	0.5	0.3	**0.4m**	

*The 20 Km2 exploration area of Khan Azzabib is the explored area. However, the active (anomalous) area in Khan Azzabib is about 40 Km2. Exploration activities were stopped in that area because uranium exploration project was frozen due to NRA priorities

11. World Uranium Mining, Production, Market, Demand and Prices

The known world estimated recoverable resources of uranium are 4,743,000 tones and more than 50% of it is located in Australia (24%), Kazakhstan (17%) and North America (Canada and U.S.A) (16%).

IAEA (International Atomic Energy Agency) reported in the Red Book 2005 that Jordan has 2% of world uranium resources, 79000 tones (proved and inferred uranium resources).

Nuclear power produces around 16% of the world's energy needs, and produces huge amounts of energy from small amounts of fuel, without the pollution that would be caused from burning fossil fuels.

World uranium usage in 2005 was about 68,000 tU. There was very little uranium exploration between 1985 and 2005, so a significant increase in exploration effort could readily double the known economic resources, and a doubling of price from present levels could be expected to create about a tenfold increase in measured resources, over time.

Total world production of yellow cake (U_3O_8) in 2005 was 49052 tones (41595 tones of Uranium). Over half of the world's production of uranium from mines is in Canada and Australia. An increasing proportion is produced by in situ leaching.

Jordan is expecting to produce 2000t/year (4% of world production) of U_3O_8 from Central Jordan uranium deposits due to investing uranium companies' proposals and NRA estimates.

World Uranium Demand is sharply increasing and the inventories are larger than originally believed for reasons:

- The world energy supply need will greatly increased in the next 20 years, especially cleanly-generated electricity.

- Nuclear power provides over 16% of the world's electricity, its use is increasing.

- Nuclear power is the most environmentally benign way of producing electricity on a large scale. Without it most of the world would have to rely almost entirely on fossil fuels for base-load electricity production.

- Renewable energy sources other than hydro have high generating costs but are helpful at the margin in providing clean power.

Uranium supply – demand imbalance has led to high and unpredictable prices. Due to world uranium quick increasing demands and concerns, uranium oxide U3O8 spot price jumped to reach the value $72/ lb, ($158/ kg) in very limited period (Weekly Spot Ux U3O8 Prices of December 19, 2006) and it is expected to reach higher levels.

Uranium prices heading towards $US100/lb will have no effect on demand, according to the head of new uranium float Epsilon Energy. Uranium was trading at $US36.25/lb at the beginning of the year. The rapid surge in prices has led some analysts to predict uranium will soon be trading at more than $US100/lb.

IEA believes proven uranium resources are sufficient to meet world requirements for all nuclear power reactors expected to be operational by 2030.

Coasts of uranium ores have been categorized into three categories by IAEA (U$48, U$84 and U$184), Jordanian surficial uranium ores had been classified within the first category.

12. Investment Opportunities of Central Jordan Uranium Deposits

Uranium deposits in Jordan, especially in central territories are considerable and economic reserves for many reasons (see study area characteristics, reserve calculation and properties of uranium deposits):

1. According to the uranium ore classification systems utilized by IAEA and US.DOE, Central Jordan ore production cost is classified under the first category (U$48). However, the cost is much less than U$48; it is almost U$25.

2. All uranium ores exploitation requirements (water, power, transportation roads and railways, infrastructure, etc...) are easily available and in hand in the ore site.

3. Central Jordan uranium deposits are surficial which can be mined by shallow open - pit techniques, easy and not costly mining operations, this means that the ore has no hazards of radon risk due to open- cast mining.

4. High possibilities of discovering other uranium ores in several areas in Jordan that will enrich Jordanian uranium ores.

Uranium deposits are open for investments and mining companies are invited on the basis of evaluation and exploration.

Many uranium exploration and mining companies showed it's interest in central Jordan uranium investment.

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