Distribution and speciation of uranium in Jordan phosphate rocks and their phosphate fertilizer industry

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OUTLINE

1- Introduction

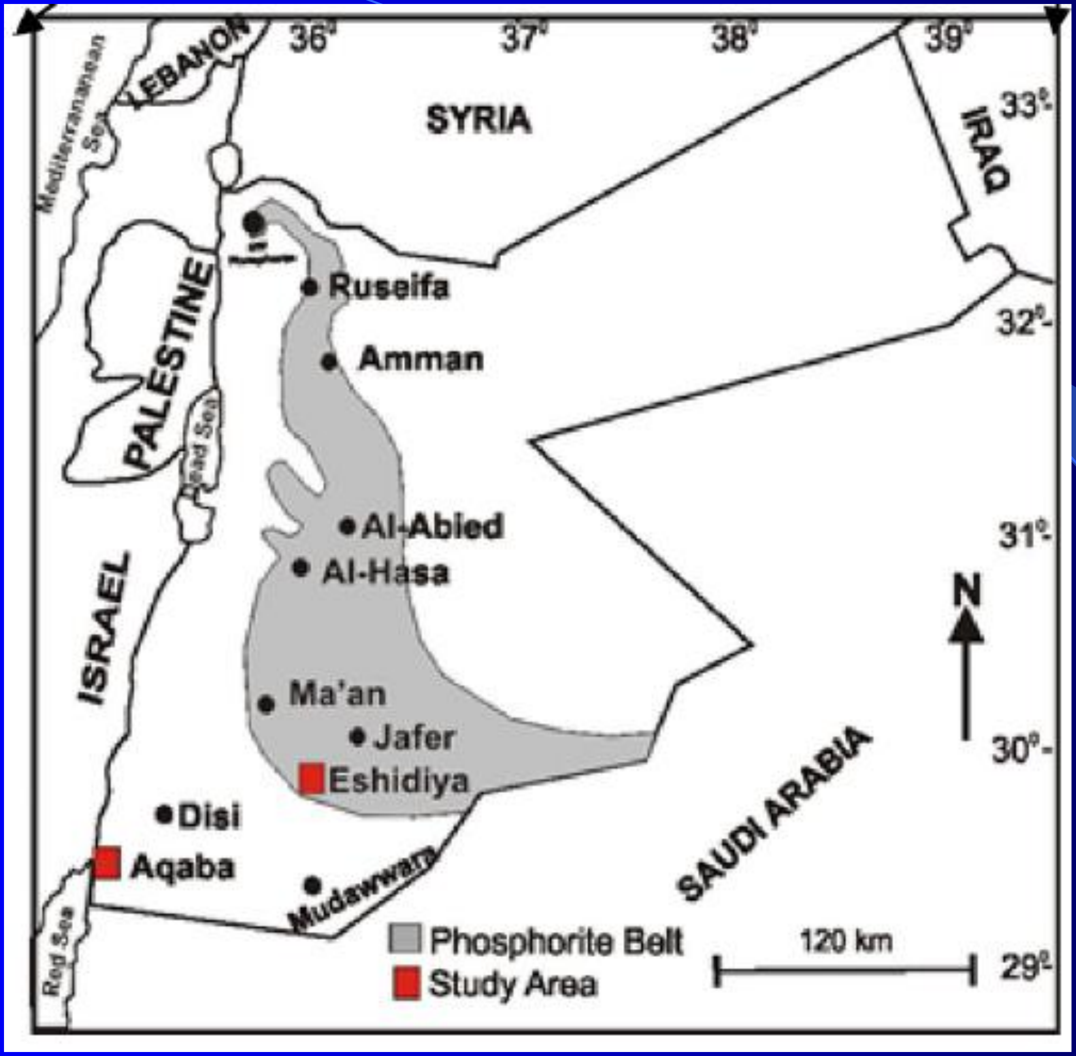
2- Objectives

3- Methods and Techniques

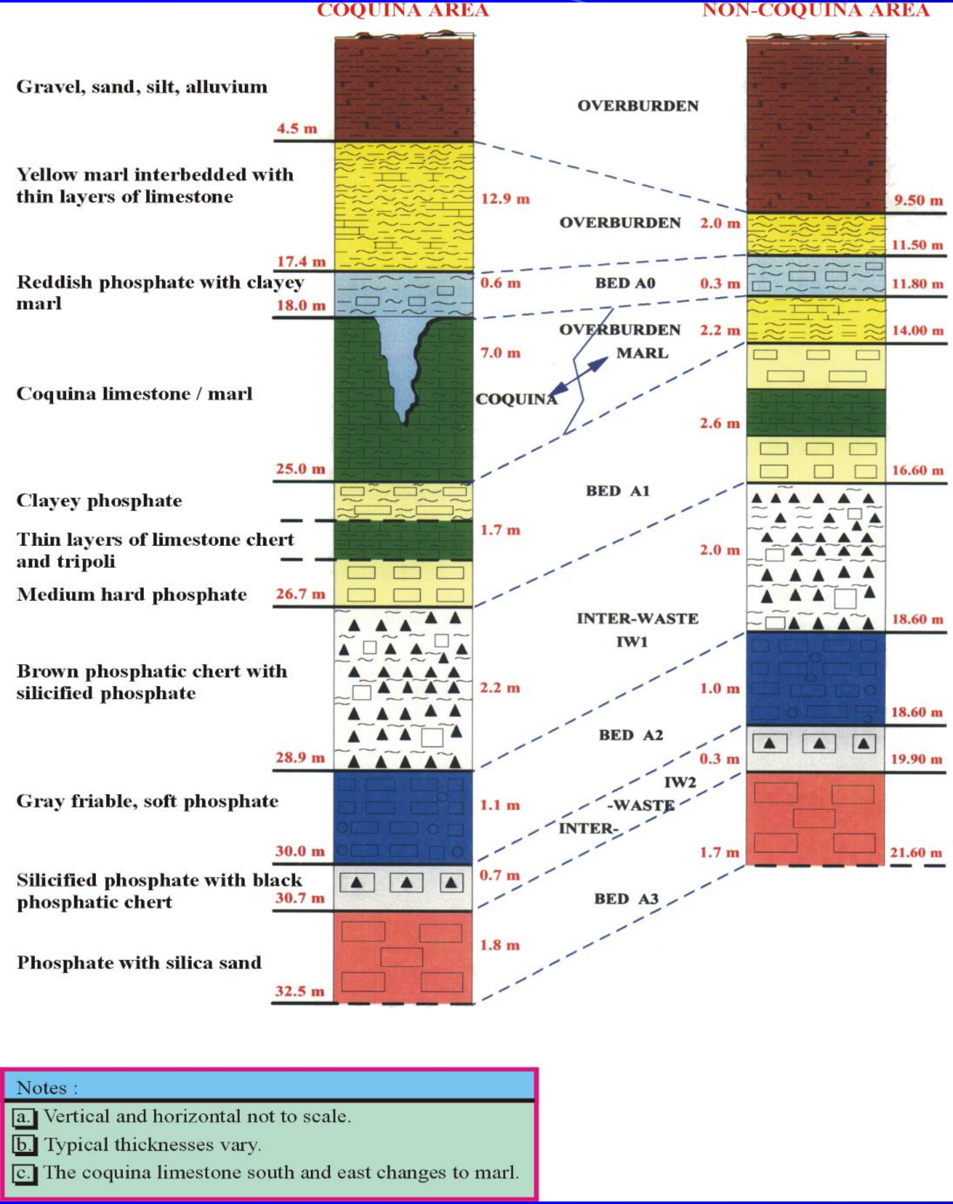
4- Uranium fate during different processing steps

5- Plant availability of U

6- Conclusions



Distribution of potential phosphate deposits



Lithostratigraphical sections of coquina and non-coquina areas (modified after Sofremines, 1984).

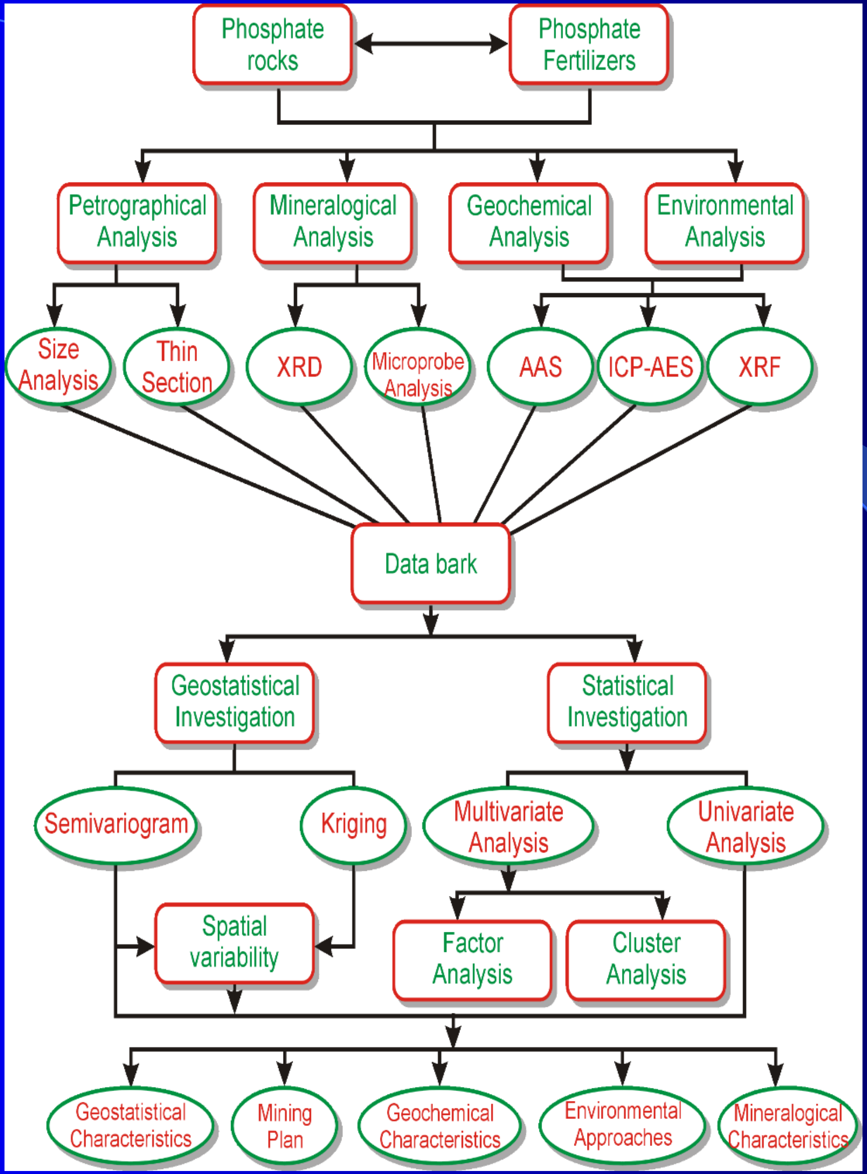
Aims of This Study

1- Determining the mode of occurrences of U in EShidiya phosphorites.

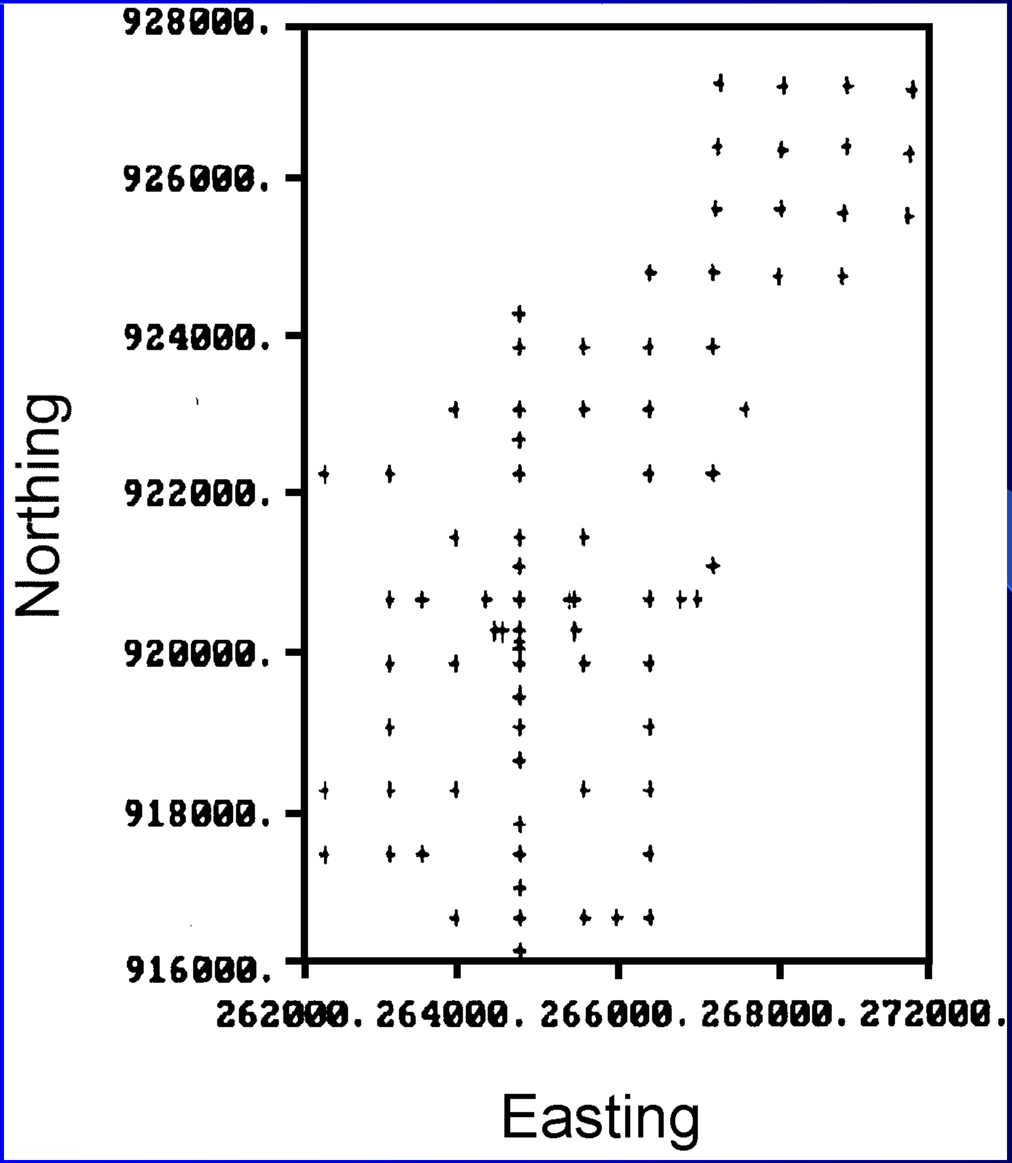
2- Determining the redistribution pathway of U during different processing steps (e.g. Crushing and Screening Processes) the beneficiation processes (e.g. Washing and Flotation) the drying processes in all beds A1, A2 and A3 and the fertilizer processes (e.g. DAP).

Aims of This Study

3- Determining the plant available toxic heavy metals like U the might be enter the soil through fertilizers produced from these phosphates.



Flow chart showing the systematic methods of Uranium investigation.



Plot of the samples locations.

Mean concentrations of major oxides (%) of phosphate from Eshidiya Mine

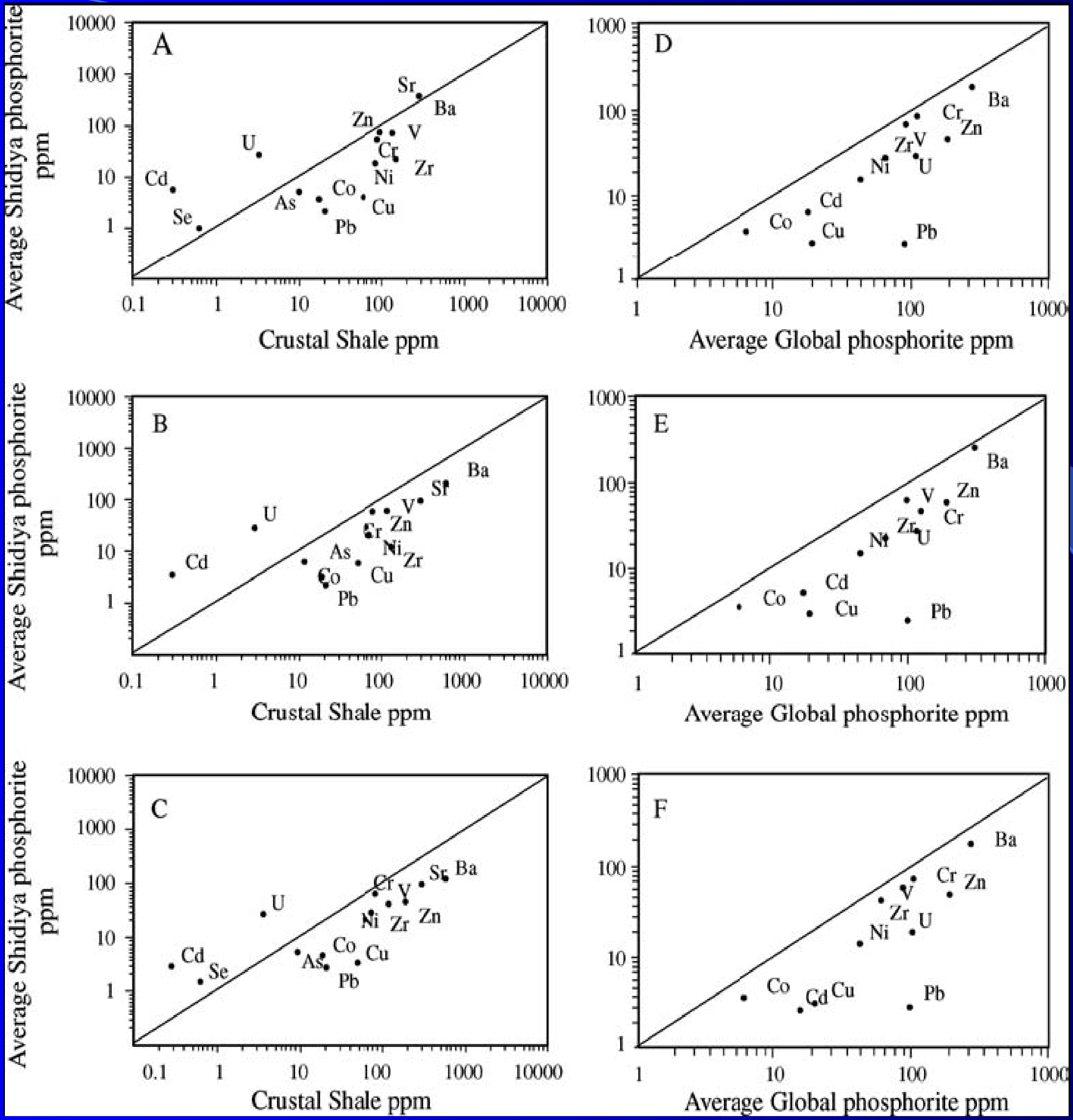
Variable	Bed-A1	Bed-A2	Bed-A3
P_2O_5	21.09	30.43	11.67
CaO	32.06	42.28	17.61
SiO_2	29.95	12.11	57.40
$Al2O_3$	2.40	1.81	1.37
Fe_2O_3	1.77	1.44	1.32
MgO	0.31	0.19	0.20
Na_2O	0.34	0.34	0.33
K_2O	0.10	0.07	0.06
TiO_2	0.11	0.08	0.07

Mean concentrations of trace metals (ppm) of phosphate from Eshidiya Mine

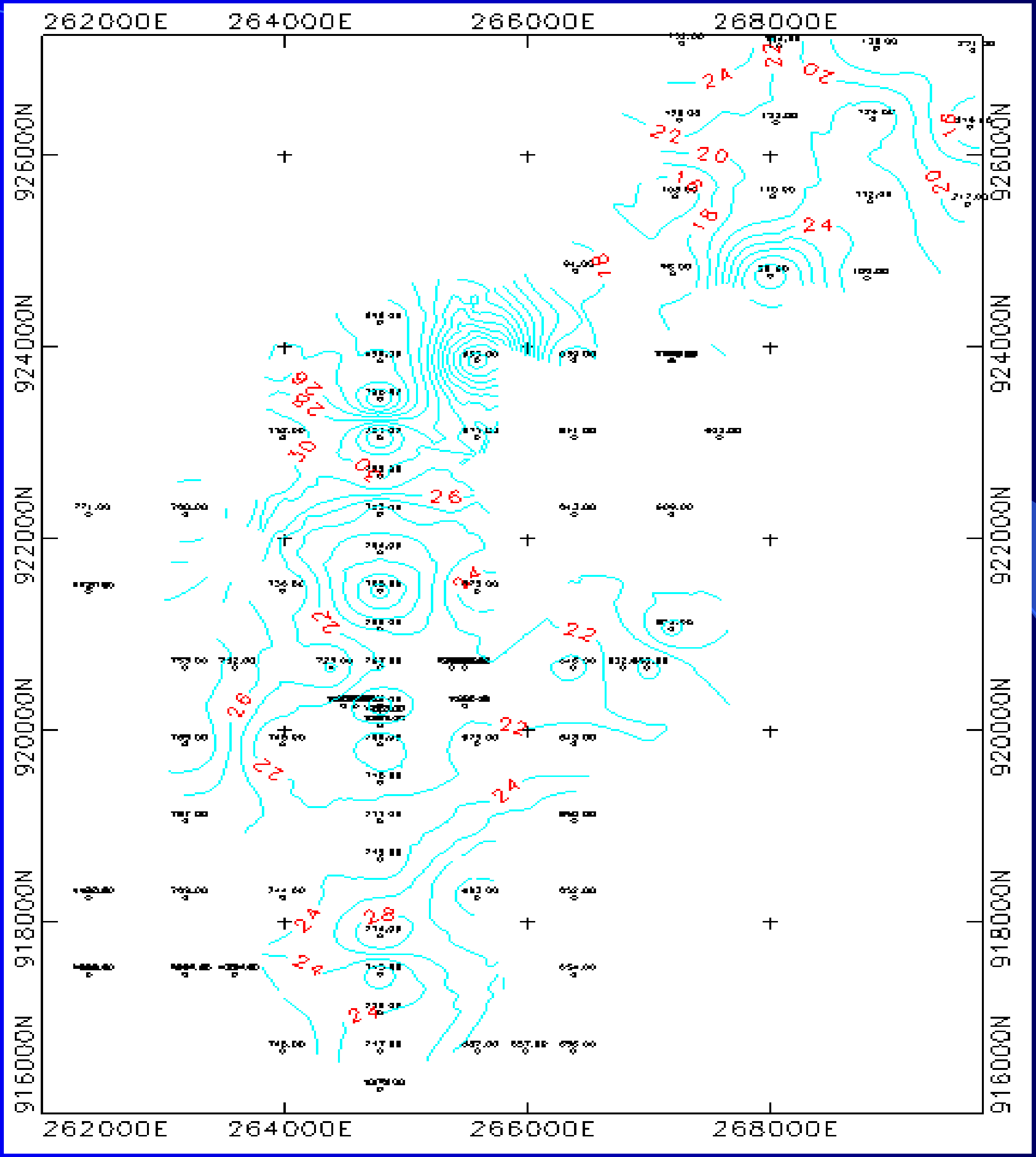
Variable	Bed-A1	Bed-A2	Bed-A3
As	7	9	7
Cd	6	5	3
Co	4	4	3
Cu	4	5	3
Cr	91	57	81
Mn	572	662	524
Ni	22	20	17
Th	3	3	4
U	33	42	23
V	87	87	63
Zn	52	61	48

Average chemical analysis of U abundance in Worldwide sedimentary phosphate rocks.

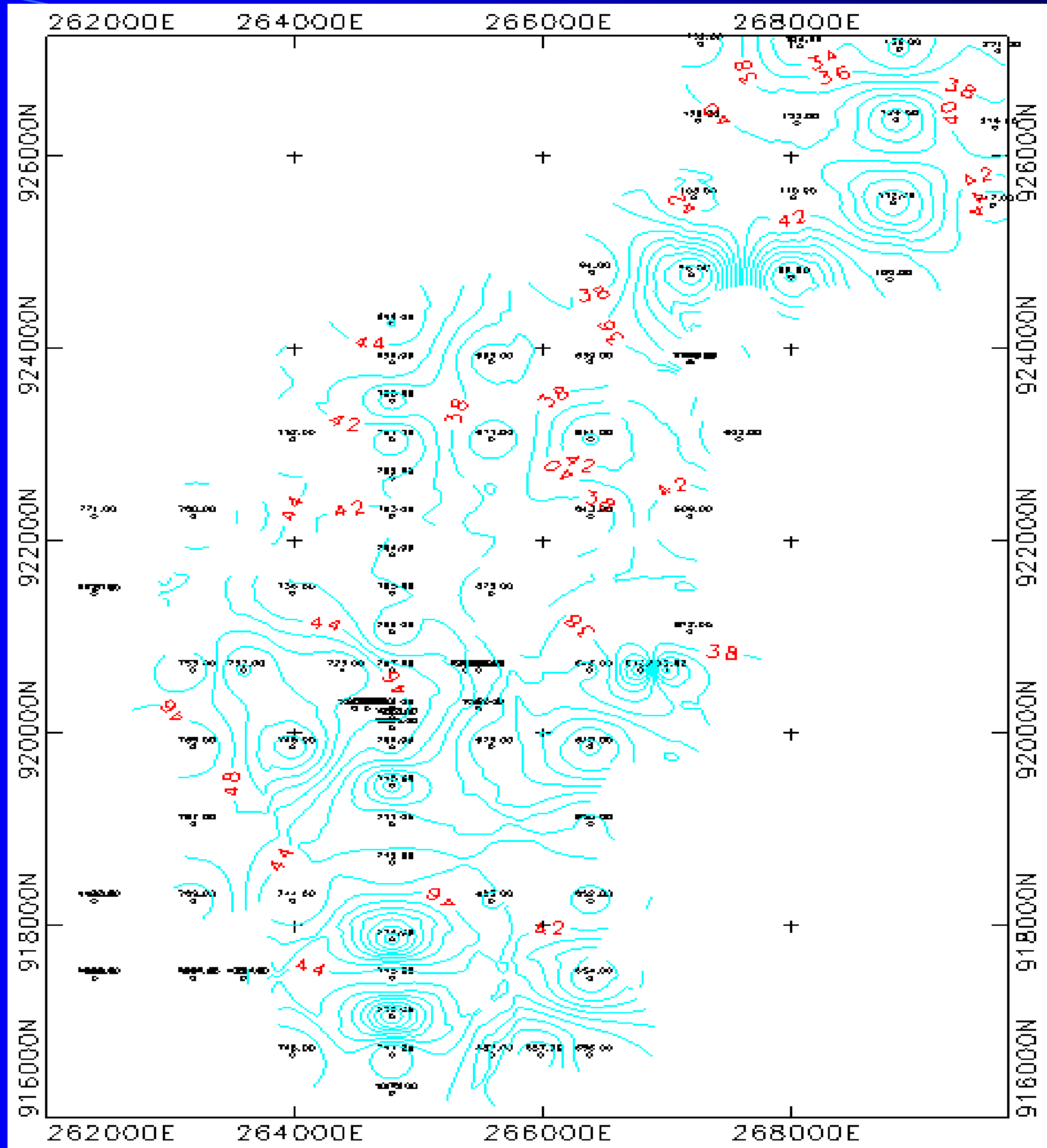
Country	Deposits	U	Refernces
Algeria	Djebel Onk	25	IFDC (1997)
Australia	Duchess	92	IFDC (1997)
China	Kaiyang	31	IFDC (1997)
Egypt	Abu Tartur	80	IFDC; TVA
Israel	Arad	150	IFDC (1997) ; TVA
Jordan	Central Jordan	65	Abed et al. (2008)
	Shidiya	46	IFDC (1997)
Eshidiya	A_1	33	This study
	A_2	42	This study
	A_3	23	This study
Morocco	Khouribga	88	Baechle and Wolsteen (1984)
Peru	Sechura	72	IFDC; TVA
Senegal	Taiba	64	IFDC
Syria	Khneifiss	75	IFDC (1997)
Togo		94	IFDC (1997)
Tunisia		44	IFDC; TVA,; Altschuler (1980)
United State	Central Florida	141	IFDC;TVA
	North Florida	81	IFDC;TVA; Wakefield (1980)
	Idaho	107	IFDC; TVA; Altschuler (1980)
	North Carolina	65	IFDC; TVA



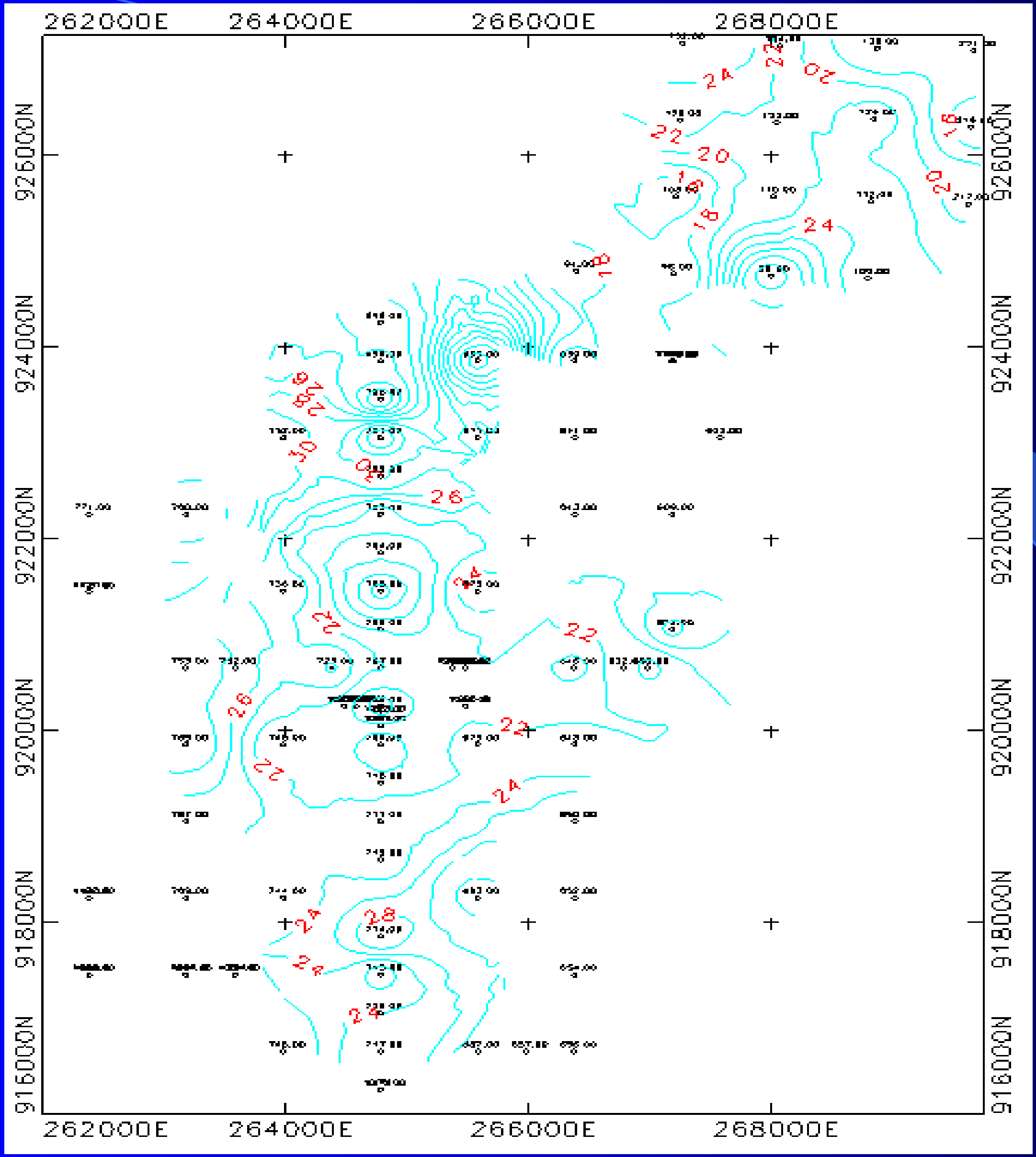
A, B, C Trace element composition of Eshidiya phosphorites beds A1,A2, And A3 respectively compared with shale (after Turekian and Wedepohl 1961). D, E, and F Trace element composition of Eshidiya phosphorites beds A1,A2, and A3 respectively, compared with average global phosphorites (after Altschuler 1980)



Contour maps showing dispersion patterns of U in bed A1



Contour maps showing dispersion patterns of U in bed A2



Contour maps showing dispersion patterns of U in bed A3

Sampling Scheme and Results for Bed A1

Matrix weighs 1000 tons

Crushing and Screening

-12.5 mm (Product)

+12.5 mm (Reject)

Soft Ph. Weighs (502.4 tons)

Element	in ppm	in tons
U	59	0.03

Hard Ph. weighs (497.6 tons)

Element	in ppm	in tons
U	45	0.02

Beneficiation (Washing)

-5+1 mm reject weighs (27.7 tons)

Element	in ppm	in tons
U	61	0.002

-12.5+5 reject weighs (107.5 tons)

Element	in ppm	in tons
U	19	0.002

-1+53µ final product weighs (139 tons)

Element	in ppm	in tons
U	80	0.01

-53µ slime weighs (147.4 tons)

Element	in ppm	in tons
U	38	0.006

Sampling Scheme and Results for Bed A2

Matrix weighs 1000 tons

Crushing and Screening

-12.5 mm (Product)

+12.5 mm (Reject)

Soft Ph. Weighs 985.4 tons

Element	in ppm	in tons
U	54	0.05

Hard Ph. weighs 41.6 tons

Element	in ppm	in tons
U	42.5	1.02

Ph. chert weighs 41.6 tons

Element	in ppm	in tons
U	23.6	0.57

+200 # coarse 881.7 tons

Element	in ppm	in tons
U	45	0.05

-200 # fine (dust) weighs 76.7 tons

Element	in ppm	in tons
U	50	0.65

-4mm product weighs 844.4 tons

Element	in ppm	in tons
U	47	0.06

+4mm (reject) weighs 37.2 tons

Element	in ppm	in tons
U	13.5	0.37

Sampling Scheme and Results for Bed A3

Matrix weighs 1000 tons

Crushing and Screening

-12.5 mm (Product)

+12.5 mm (Reject)

Soft Ph. weighs (615.3 tons)

Element	in ppm	in tons
U	50	0.08

H. Ph. weighs (234.4 tons)

Element	in ppm	in tons
U	41	0.17

Ph. Chert weighs (41.6 tons)

Element	in ppm	in tons
U	24	0.58

Beneficiation (washing and Flotation)

-12.5+2 mm reject weighs (253 tons)

Element	in ppm	in tons
U	35	0.14

-53# slime weighs (42.3 tons)

Element	in ppm	in tons
U	28	0.66

-1+0.053mm product (320 tons)

Element	in ppm	in tons
U	32	0.10

-2+1mm reject weighs(48.6 tons)

Element	in ppm	in tons
U	35	0.72

-1+0.50 mm coarse weighs (200 tons)

Element	in ppm	in tons
U	35	0.18

-0.5+0.053 µ fine weighs (120tons)

Element	in ppm	in tons
U	30	0.25

Final Product

Element	in ppm	in tons
U	44	0.14

Sampling Scheme and Results for phosphate fertilizer

Matrix weighs 1000 tons

Feed

Element	in ppm	in tons
U	57.5	0.058

Grinding

Element	in ppm	in tons
U	57.5	0.058

React with sulphuric acid

Phosphoric acid 30% weighs (950 tons)

Element	in ppm	in tons
U	44	0.05

Phosphogypsum weighs (3800 tons)

Element	in ppm	in tons
U	2	0.0005

Phosphoric acid 54% weighs (560 tons)

Element	in ppm	in tons
U	109	0.19

React with Ammonia (HNO3)

DAP Fertilizer weighs (560 tons)

Element	in ppm	in tons
U	126	0.23

Elements fate in bed A_1.

Crushing and Screening		Beneficiation (Washing)	
Element	**Fate**	**Element**	**Fate**
As	Feed	As	Reject
Cd	Reject	Cd	Reject
Cr	Even	Cr	Reject
Cu	Feed	Cu	Reject
Mn	Feed	Mn	Reject
Ni	~ Feed	Ni	Reject
Pb	Feed	Pb	Reject
U	**~ Feed**	**U**	**Final product**
V	Even	V	Reject
Zn	~ Feed	Zn	Reject

Elements fate in bed A_2.

Crushing and Screening		Drying	
Element	**Fate**	**Element**	**Fate**
As	Reject	**As**	Final product
Cd	Reject	**Cd**	Final product
Cr	Even	**Cr**	Final product
Cu	Feed	**Cu**	Final product
Mn	Feed	**Mn**	Final product
Ni	Feed	**Ni**	Even
Pb	Reject	**Pb**	Even
U	**Reject**	**U**	**Final product**
V	Even	**V**	Final product
Zn	Even	**Zn**	Final product

Elements fate in bed A_3.

Crushing and Screening		Beneficiation (Washing and Flotation)	
Element	**Fate**	**Element**	**Fate**
As	Even	**As**	Reject
Cd	Reject	**Cd**	Reject
Cr	Feed	**Cr**	Reject
Cu	Feed	**Cu**	Reject
Mn	Feed	**Mn**	Reject
Ni	Feed	**Ni**	Reject
Pb	Reject	**Pb**	Reject
U	**Feed**	**U**	**Final product**
V	Feed	**V**	Reject
Zn	Feed	**Zn**	Final product

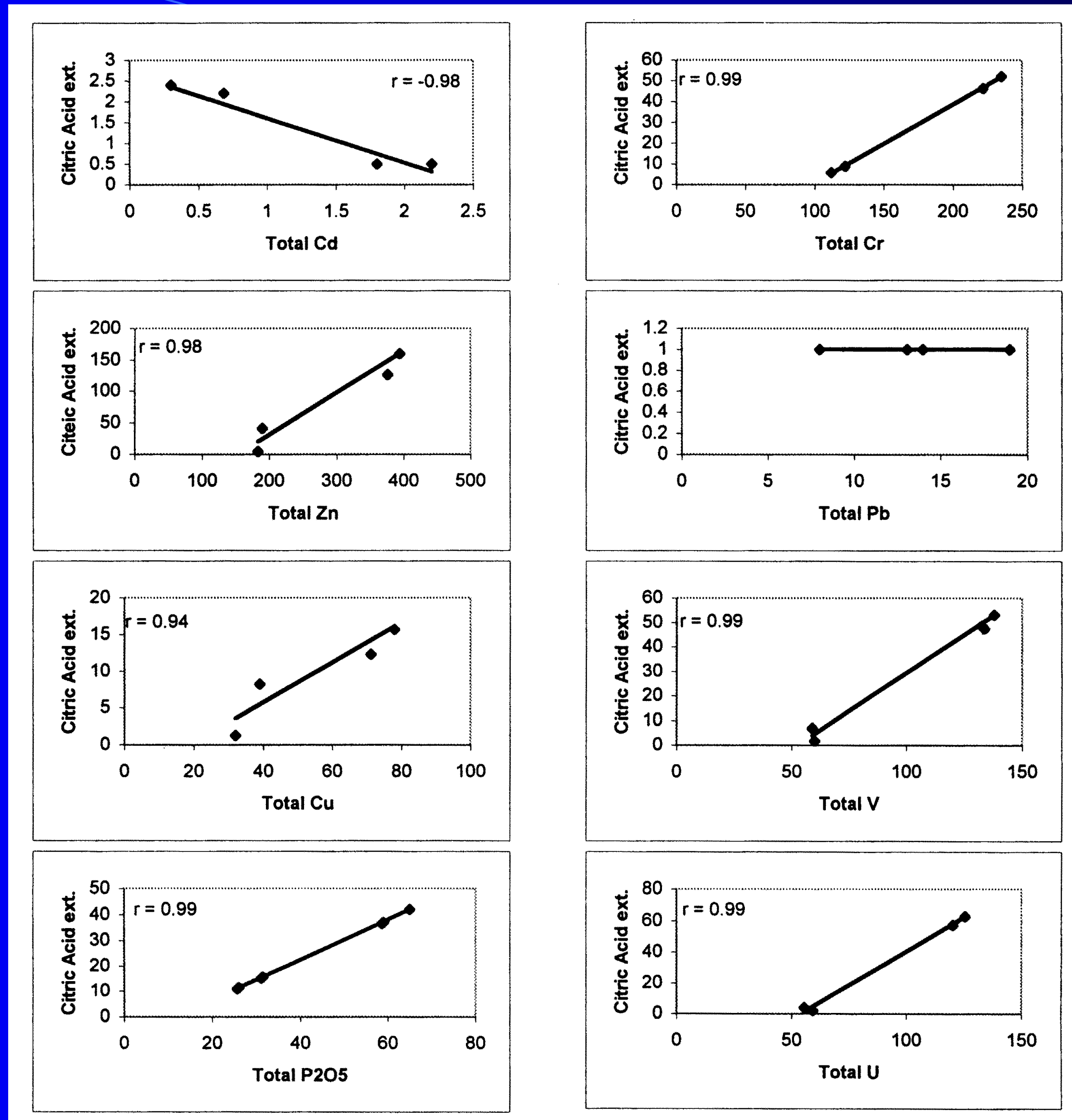
Elements fate in phosphate fertilizer

Phosphoric Acid 30% and Gypsum		Phosphoric Acid 54% and DAP	
Element	Fate	Element	Fate
As	Gypsum	As	DAP
Cd	Acid	Cd	Acid
Cu	Acid	Cr	DAP
Cr	Acid	Cu	DAP
Ni	Acid	Ni	Even
U	Acid	U	DAP
V	Acid	V	Even
Zn	Acid	Zn	DAP

Leaching experiments from raw phosphate to DAP

Leaching agent	Material	P_2O_5			U		
		T %	cx %	% T	T %	cx %	% T
0,1m EDTA pH = 4.5 0,1m EDTA pH = 4.5	Raw ph.	25.4	11.5	45	53	-	-
	DAP	63.2	36.5	58	128	-	-
	DAP/Raw ph.	2.5	3.2	1.3	2.4	-	-

Leaching agent	Material	P_2O_5			U		
		T %	cx %	% T	T %	cx %	% T
1 % Citric acid pH = 2.4	Raw ph.	25.4	11.0	43	53	17	32
	DAP	63.2	40.3	64	128	96	75
	DAP/Raw ph.	2.5	3.2	1.5	2.4	5.6	2.3



Relationship between the total of heavy metals content and their metal extracted using citric acid from phosphate fertilizers.

Correlation coefficients as a measure of the degree of mobility

Ranges (r)	Degree of Mobility
0.01-0.30	low mobility (L. M)
0.30-0.59	Intermediate (I. M)
0.60-1.00	high mobility (H. M)

Degree of elements mobility from fertilizer basd on EDTA and Citric acid extraction

Element	Techniques	(r) Values	Degree of Mobility	Overall assessment
P_2O_5	EDTA	-	-	
	Citric acid	0.99	H. M.	H. M.
Cd	EDTA	0.29	L. M.	
	Citric acid	0.98	Immobile	L. M.
Zn	EDTA	0.95	H. M.	
	Citric acid	0.98	H. M.	H. M.
Cu	EDTA	0.96	H. M.	
	Citric acid	0.94	H. M.	H. M.
Cr	EDTA	0.80	H. M.	
	Citric acid	0.99	H. M.	H. M.
Pb	EDTA	0.07	L. M.	
	Citric acid	0.00	Immobile	L. M.
V	EDTA	0.90	H. M.	
	Citric acid	0.99	H. M.	H. M.
U	EDTA	-	-	
	Citric acid	0.99	H. M.	H. M.

Abbreviation: L.M.= low mobility, H.M.= high mobility and I.M.= intermediate mobility

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

I

Geochemical findings

III Geochemical findings:

1- Based on the P_2O_5, CaO and fluorine contents the dominant Eshidiya phosphorite mineral phase is francolite.

CONCLUSIONS

III Geochemical findings:

2- U is accommodated in the francolite mineral phase

3- U is enriched in the raw phosphates when compared with their abundances in shale, while they depleted when compared with average global phosphorites.

CONCLUSIONS

II

Redistribution and mobility findings

1. Uranium fates during crushing and screening process of the three phosphatic beds are variable, whereas during benificiation and drying they exhibit some consistency.

2. U redistribution pathways during the phosphate processing steps were determined in the feed and in the final product. During crushing and screening process, U measured elements got enriched in the feed bed A1 and A3, whereas U got enriched in the reject bed A2. During beneficiation process, most U elements got enriched in the final product of three beds A1, A2 and A3

3- Uranium (ppm) fate during crushing and screening and beneficiation processes allow drawing the following conclusions:

	Final product	Hard Phosphate
A1	80	45
A2	47	43
A3	44	41

4. Uranium redistribution pathways during the phosphate fertilizer processing steps were determined in the feed and in the final product. U measured elements got enriched in the phosphoric acid (30%), phosphoric acid (54%) and DAP product. It was found that 93% of the U is partitioned in the phosphoric acid while the reminder is precipitated with PG waste materials.

5- Uranium (ppm) fate during phosphate fertilizer allow drawing the following conclusions:

	U (ppm)
Phosphoric acid (30%)	44
Phosphoric acid (54%)	109
DAP	126
Phosphogypsum	2

6. The assessment of the availability (mobility) of U elements from DAP to plant through soil using Citric Acid techniques allow drawing the following conclusions:

a- Based on citric acid, U elements with exhibit high mobility in acidic soils (pH $\geq$ 2.4)

b- The mobility of U elements will decrease strongly in alkaline soils (pH $\geq$ 7).

7. The assessment of the variability of toxic elements to plants using Citric Acid leaching techniques allowed to show the following conclusion: U is going to be available for plants even in acidic soils, and will be available upon direct application of phosphate to soils as well.

Thank You for Your Attention