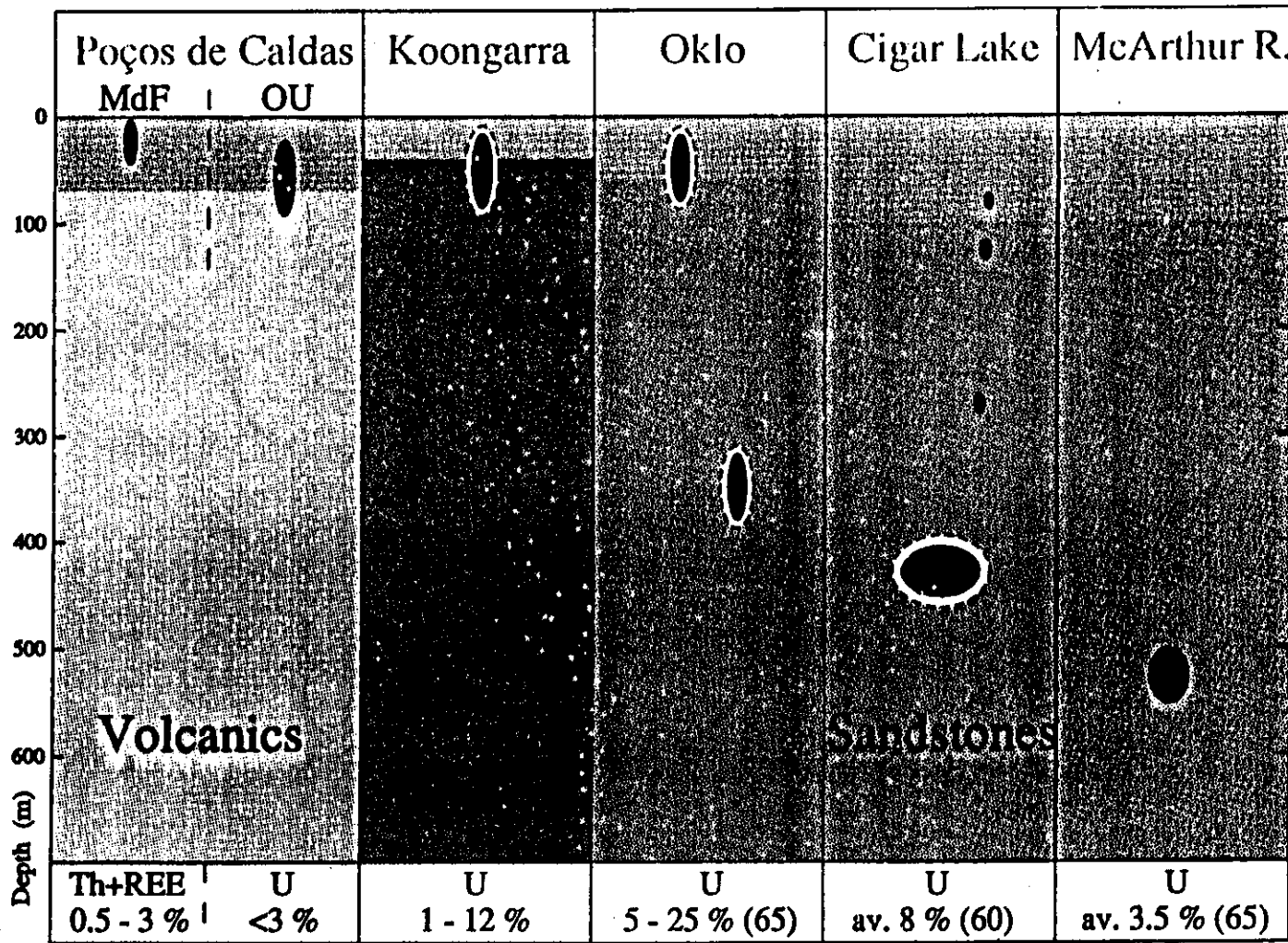




# NATURAL NUCLEAR REACTOR

OKLO URANIUM  
DEPOSIT



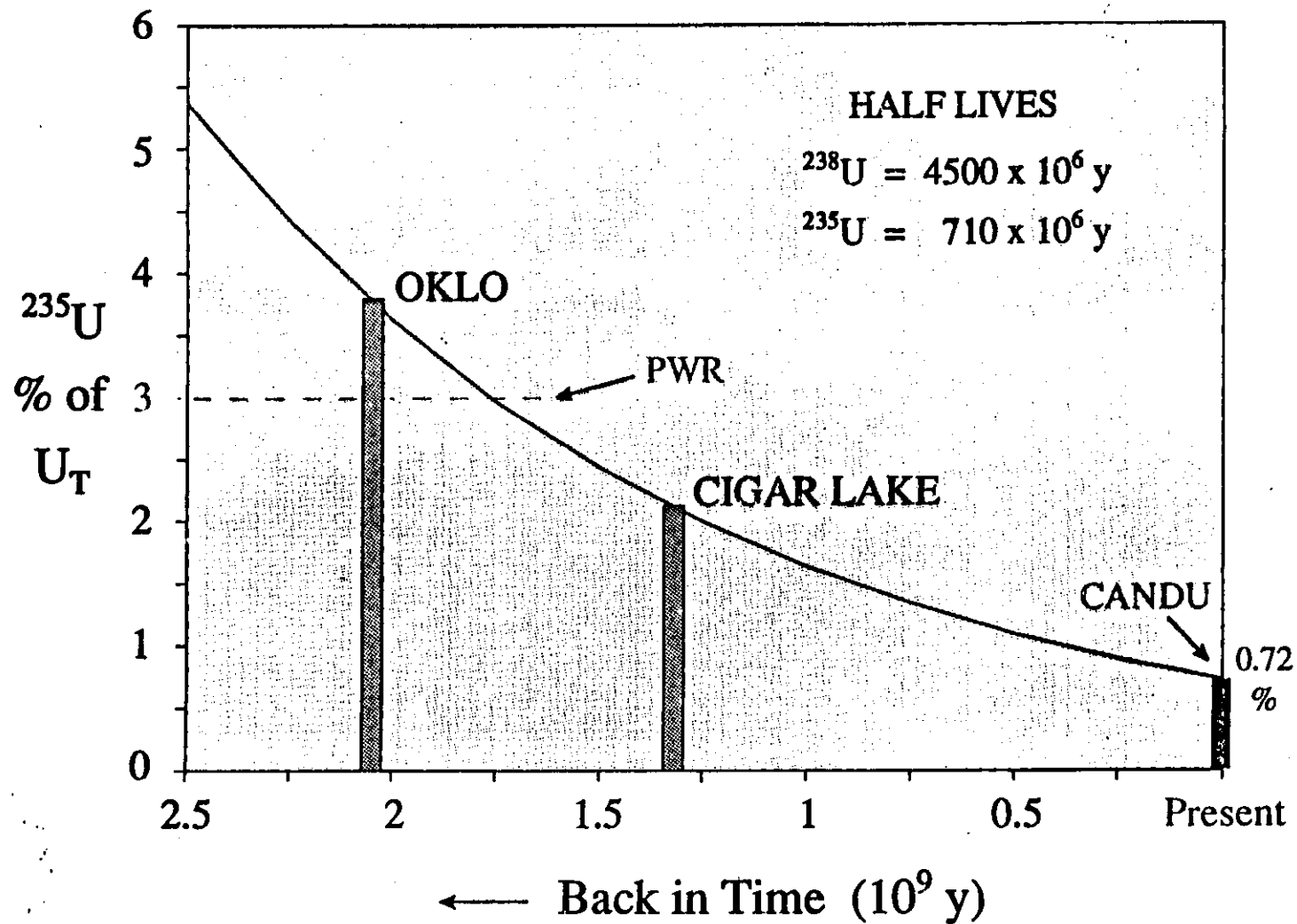
# URANIUM DEPOSITS

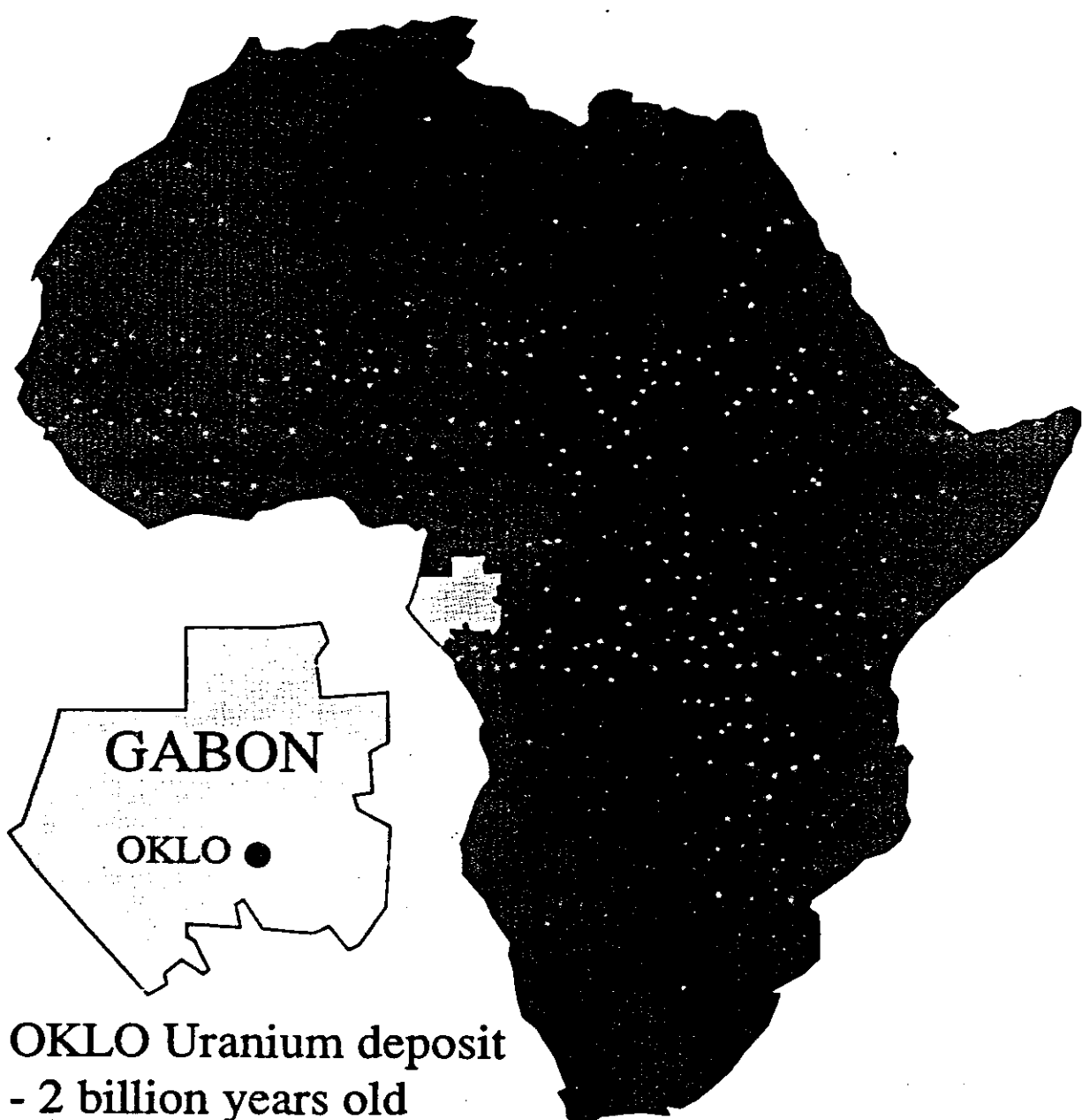


 Weathering     
  Clay matrix     
  Mineralization



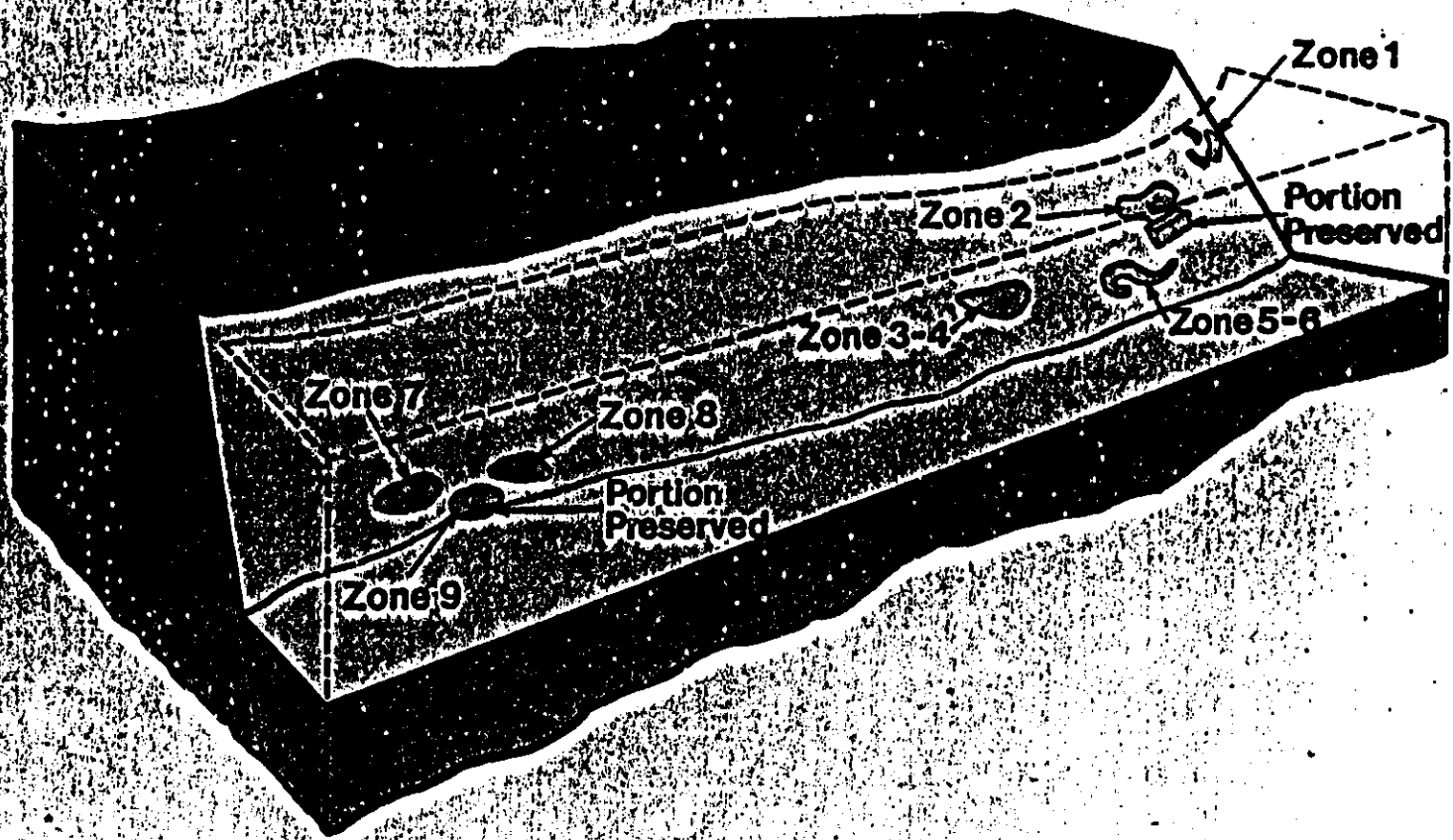
# CHANGE IN $^{235}\text{U}$ ABUNDANCE



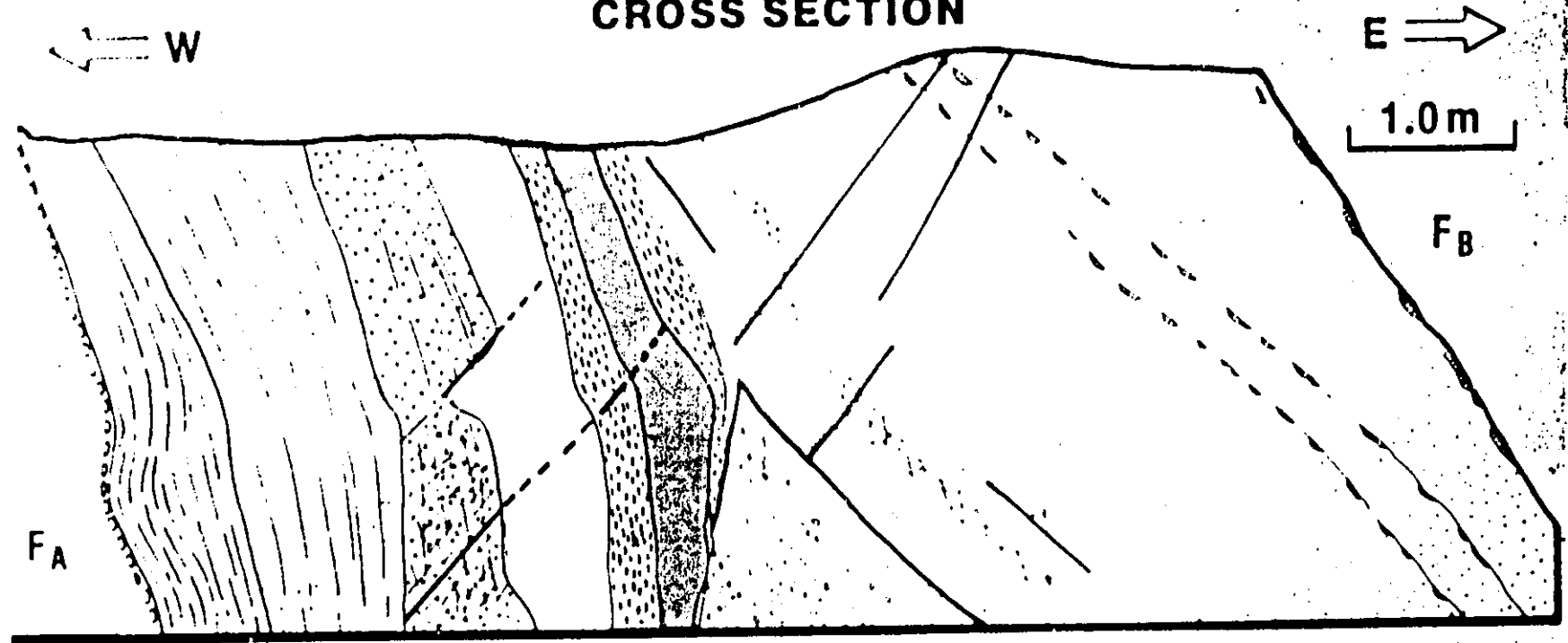


OKLO Uranium deposit  
- 2 billion years old  
- natural nuclear reactor

# OKLO



# OKLO REACTOR ZONE 9 CROSS SECTION



- |   |   |   |
|---|---|---|
| <p> CONGLOMERATE</p> <p> COARSE SANDSTONE</p> <p> MED. SANDSTONE</p> <p> FINE SANDSTONE</p> | <p> PELITE</p> <p> BLACK ARGILLITE</p> <p> GREEN ARGILLITE</p> <p> REACTOR ZONE</p> | <p> ORGANIC MATERIAL</p> <p> SHEAR ZONE</p> <p> BRECCIA ZONE</p> <p> FRACTURE</p> |
|---|---|---|



# OKLO Natural Reactors

Nuclear fission

16 zones operated for ~600,000 years

Energy output


16,000 Megawatt-years = 1 CANDU for 10 years

Waste products

800,000 kg Used Fuel

2000 kg Plutonium

6000 kg Fission Products

 Mobile and long-lived

H																	He	
Li	Be											B	C	N	O	F	Ne	
Na	Mg											Al	Si	P	S	Cl	Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra	Ac																
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		





Stable or short half-lives

Long half-lives (> 100 a)

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te		Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw





Partly retained and long-lived

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	



## OKLO Natural Reactors

Radionuclide	Where found now
Short-lived	<50 m from reactor zones
Plutonium-239	within reactor zones
Cesium-135	within reactor zones
Technetium-99	within a few metres from reactor zones
Iodine-129	not found in reactor zones or surrounding rock



## CONCLUSIONS

### OKLO REACTORS

-   $\text{UO}_2$  matrix of reactor zones is stable for 2 Ga, surviving major geological processes including erosion of ~3 km of host rock.
-  Reactor zones and their host rocks have contained most of the nuclear reaction products ('waste products') in a relatively open, non-engineered system.