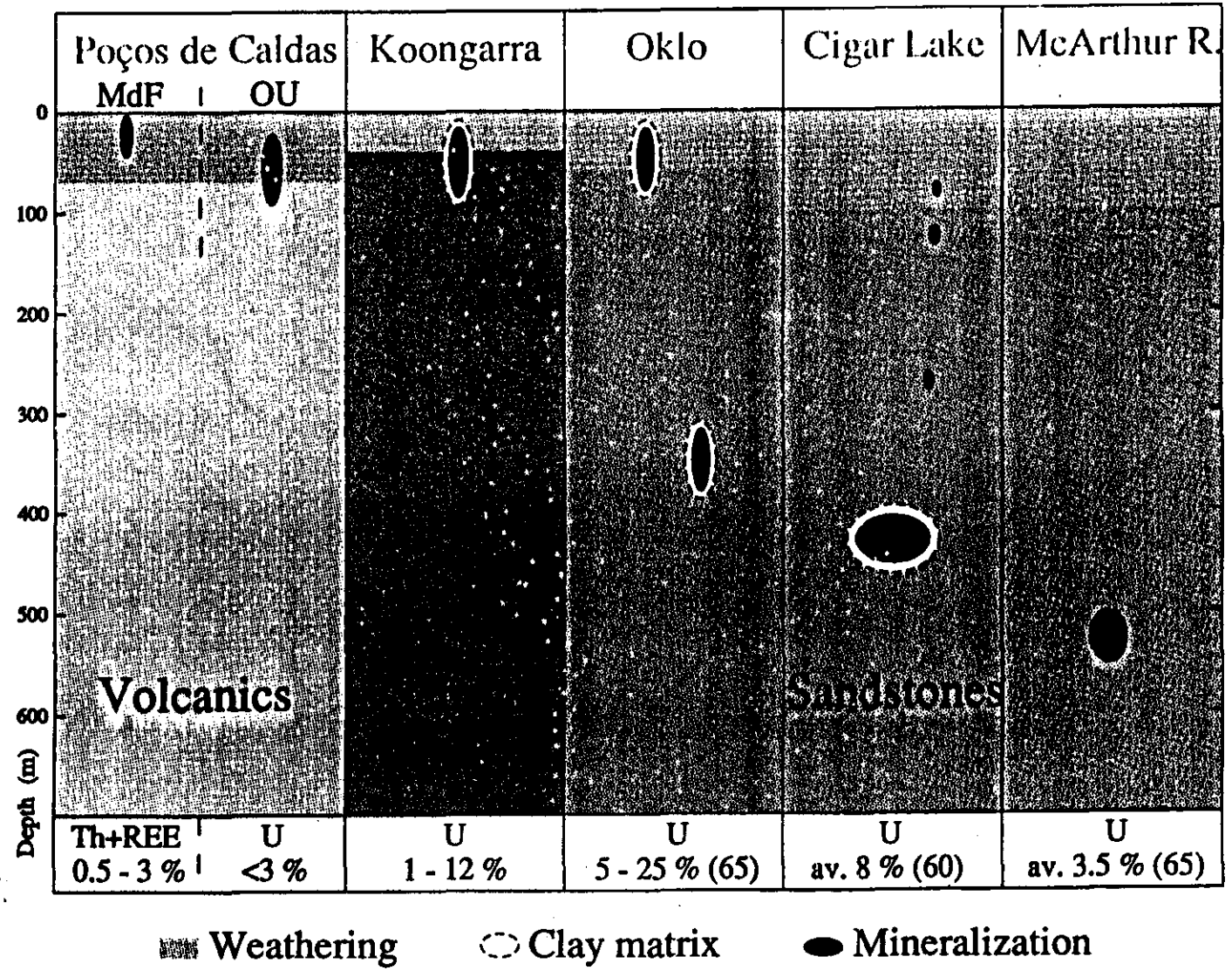
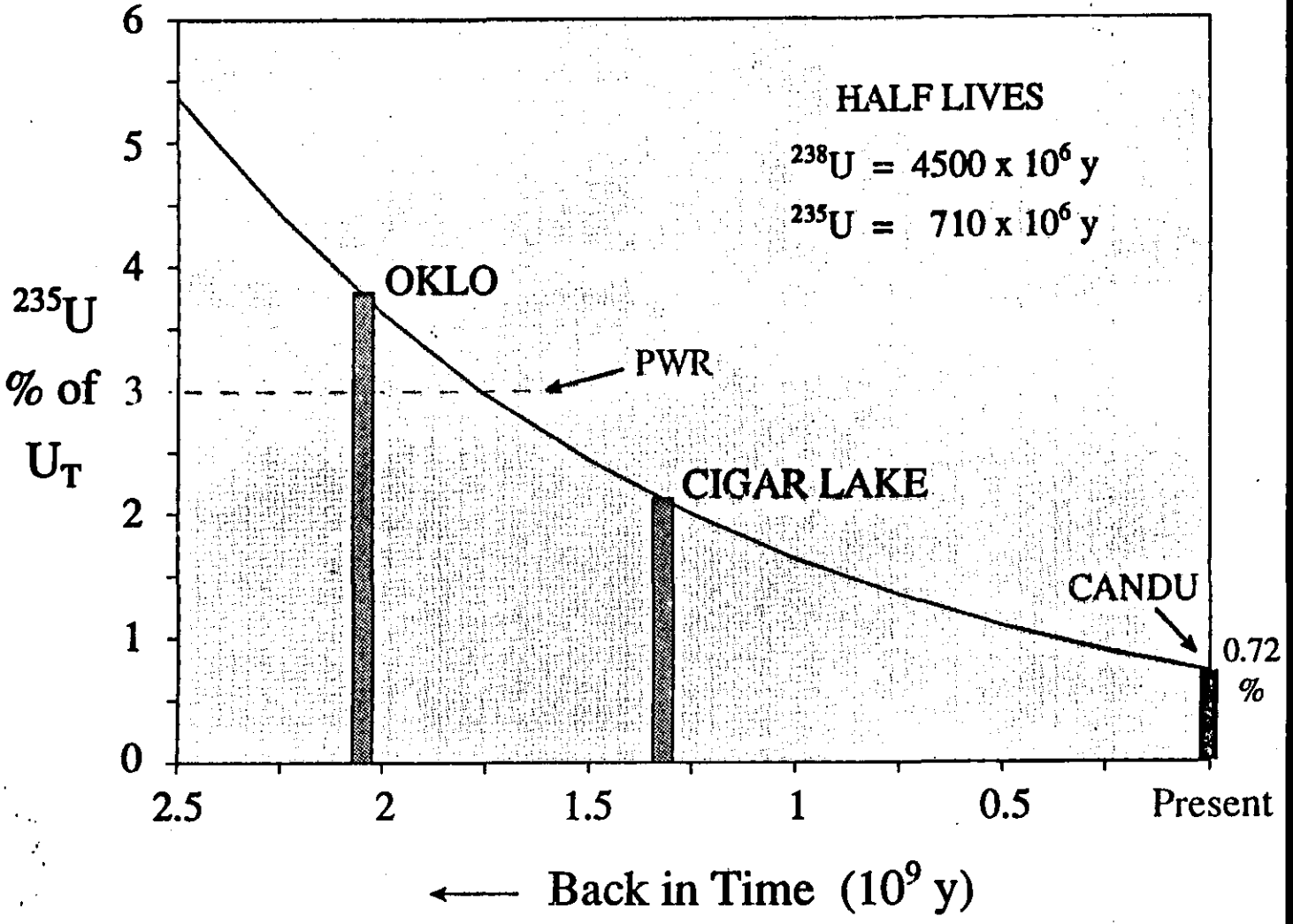
NATURAL NUCLEAR REACTOR

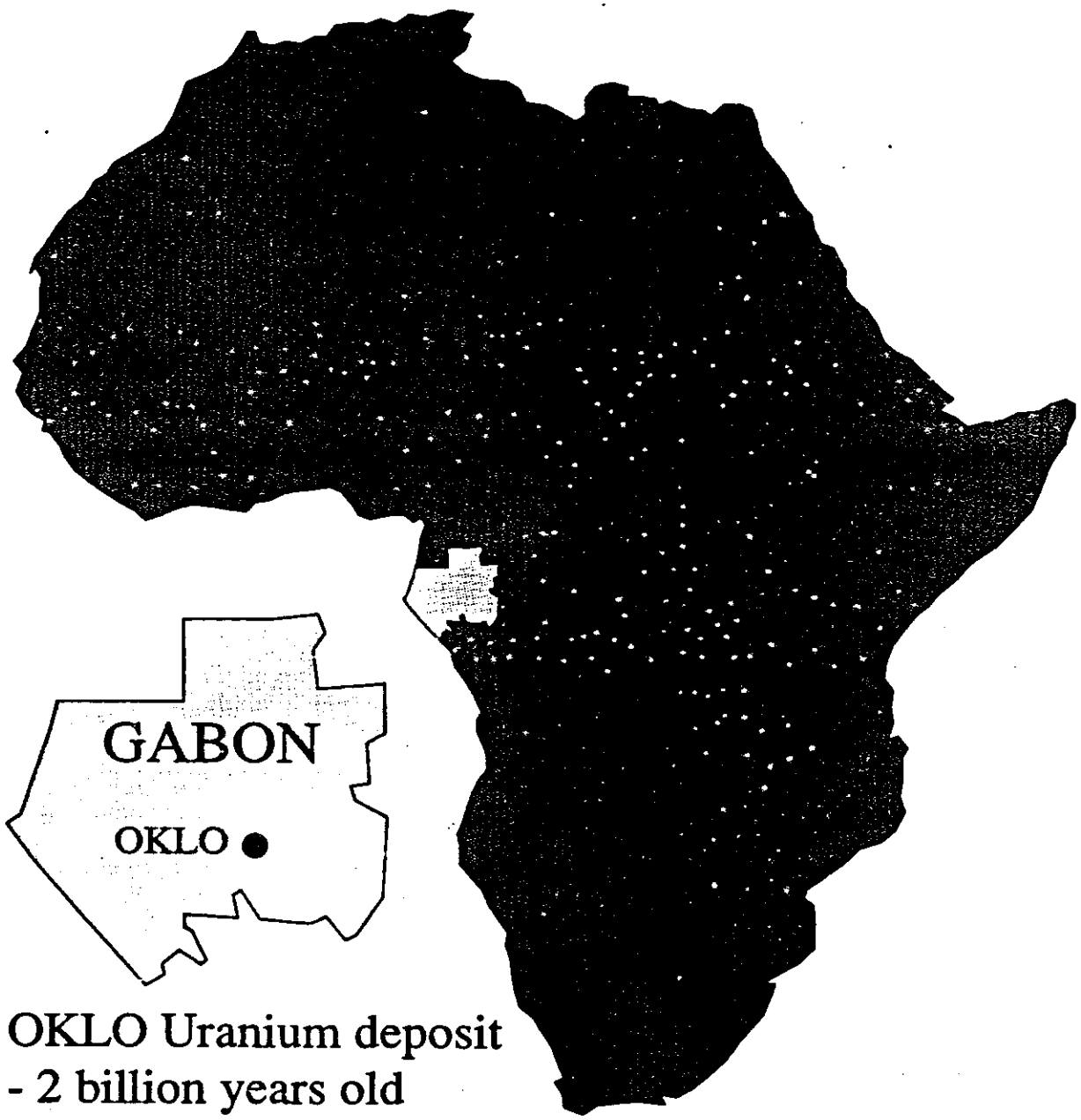
OKLO URANIUM DEPOSIT

URANIUM DEPOSITS



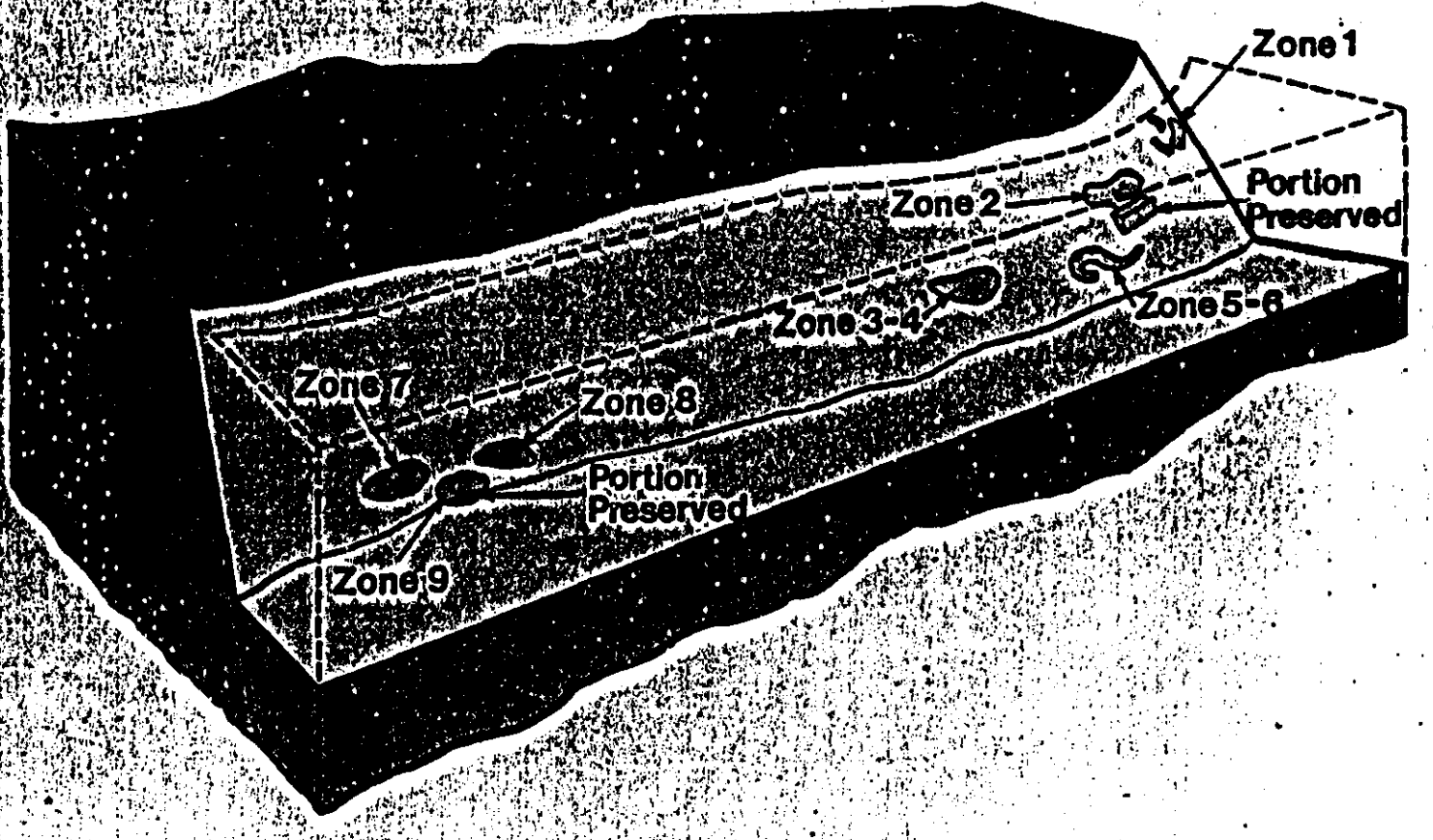
CHANGE IN ^{235}U ABUNDANCE





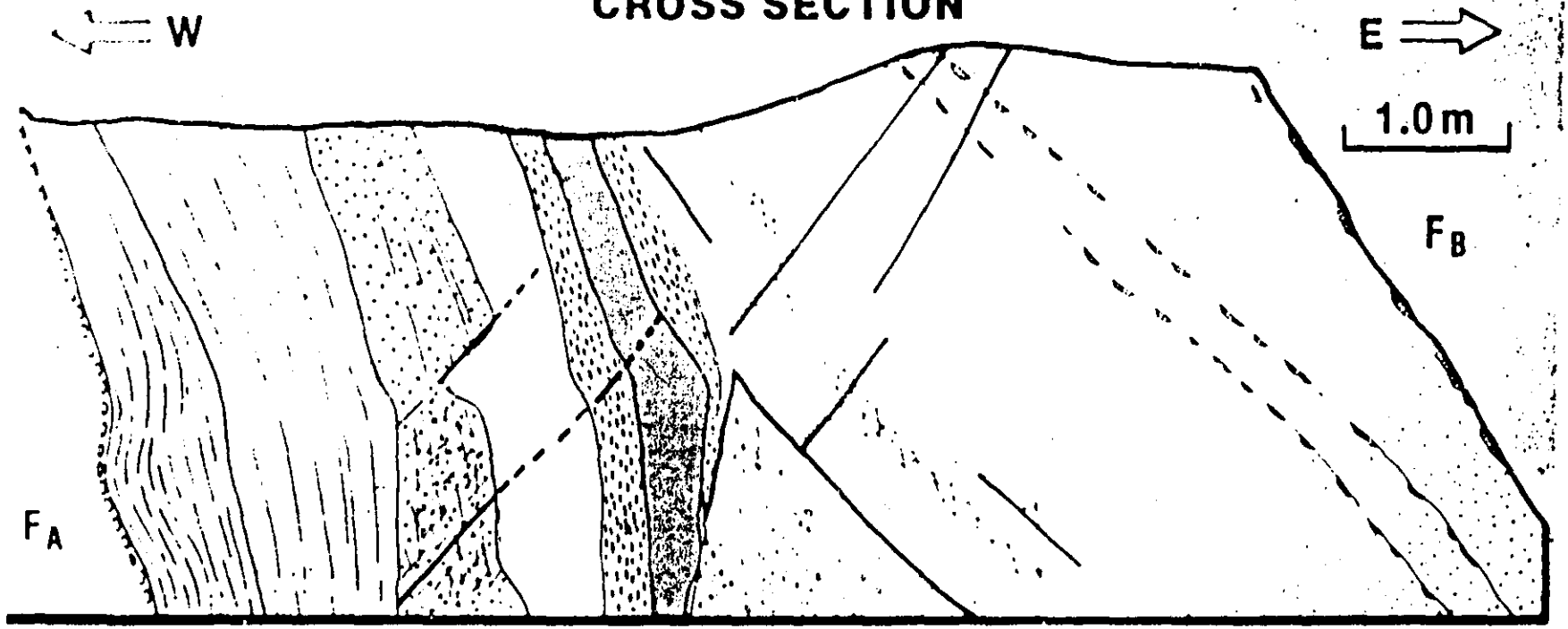
OKLO Uranium deposit
- 2 billion years old
- natural nuclear reactor

OKLO


Zone 1
Zone 2
Portion Preserved
Zone 3-4
Zone 5-6
Zone 7
Zone 8
Portion Preserved
Zone 9

OKLO REACTOR ZONE 9

CROSS SECTION



CONGLOMERATE
COARSE SANDSTONE
MED. SANDSTONE
FINE SANDSTONE
PELITE
BLACK ARGILLITE
GREEN ARGILLITE
REACTOR ZONE
ORGANIC MATERIAL
SHEAR ZONE
BRECCIA ZONE
FRACTURE

OKLO Natural Reactors

Nuclear fission

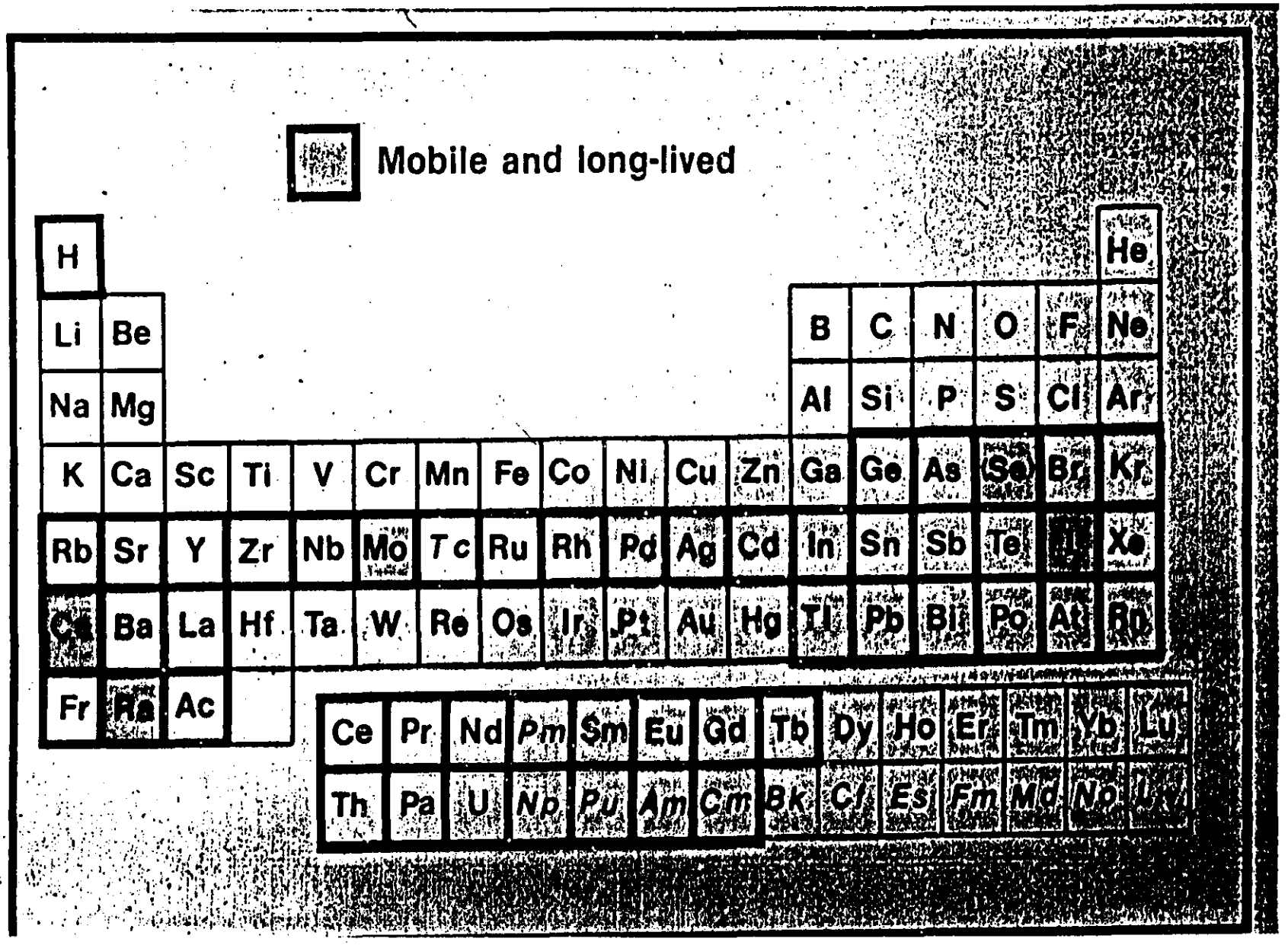
16 zones operated for ~600,000 years

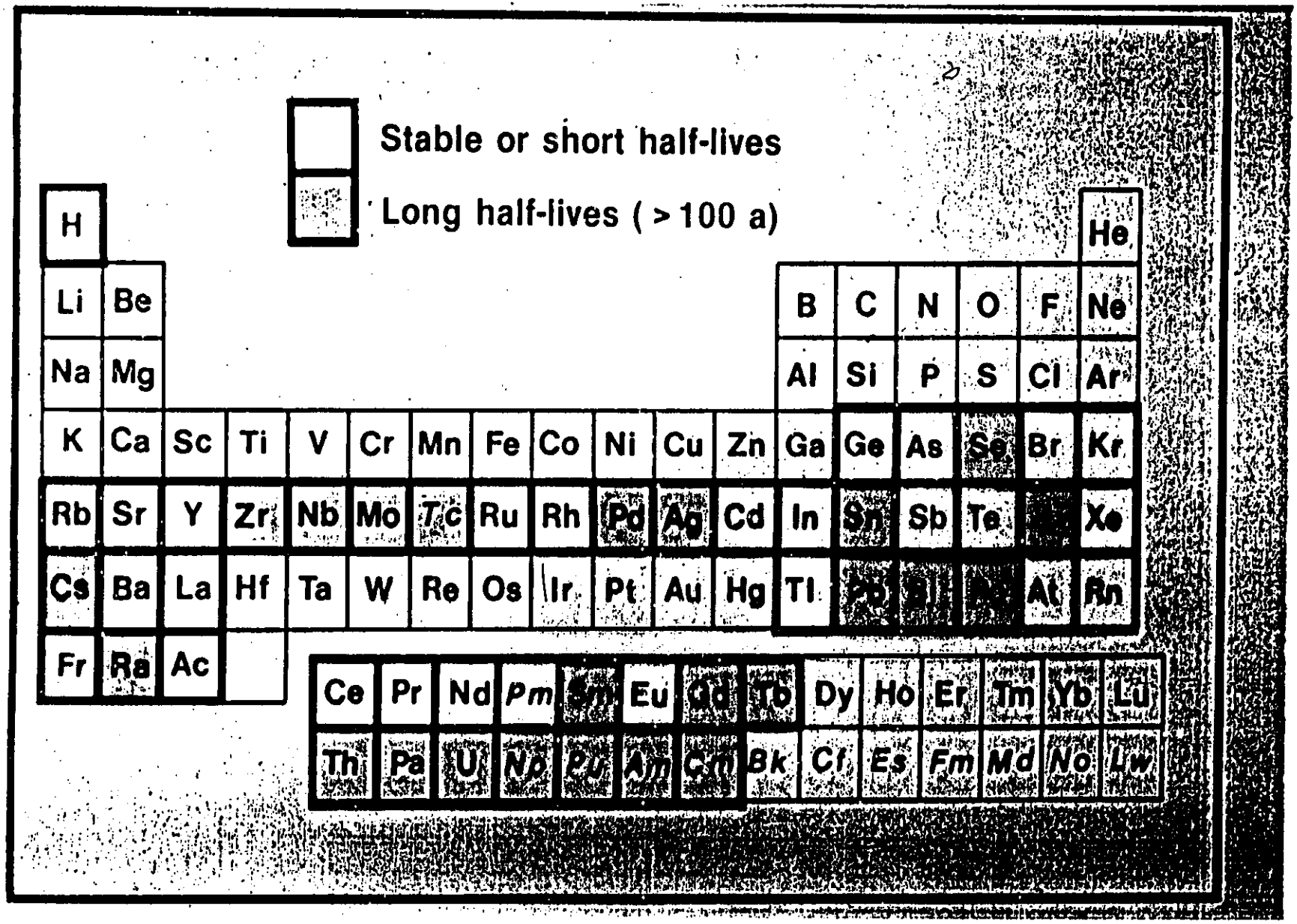
Energy output

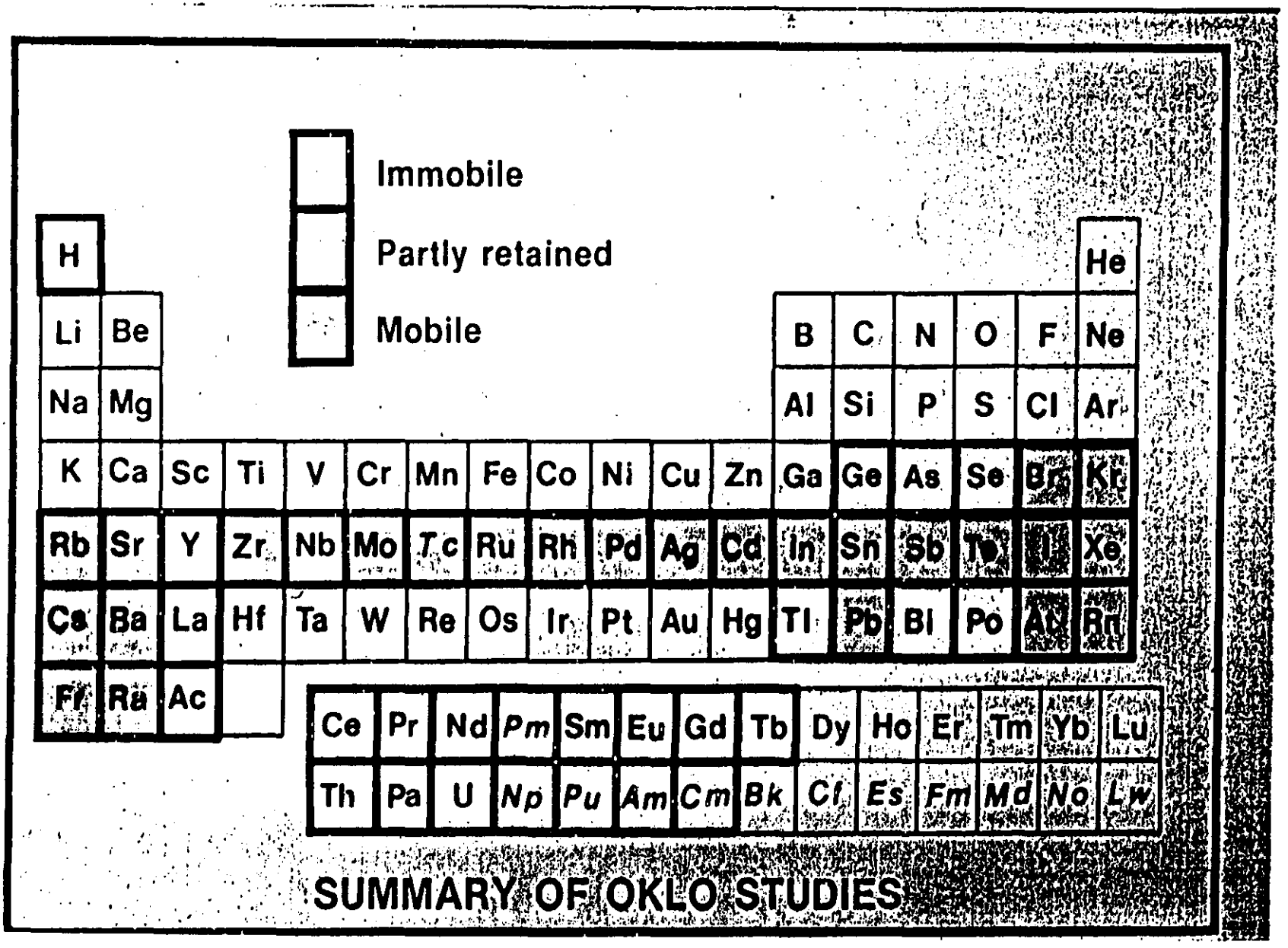
16,000 Megawatt-years = 1 CANDU for 10 years

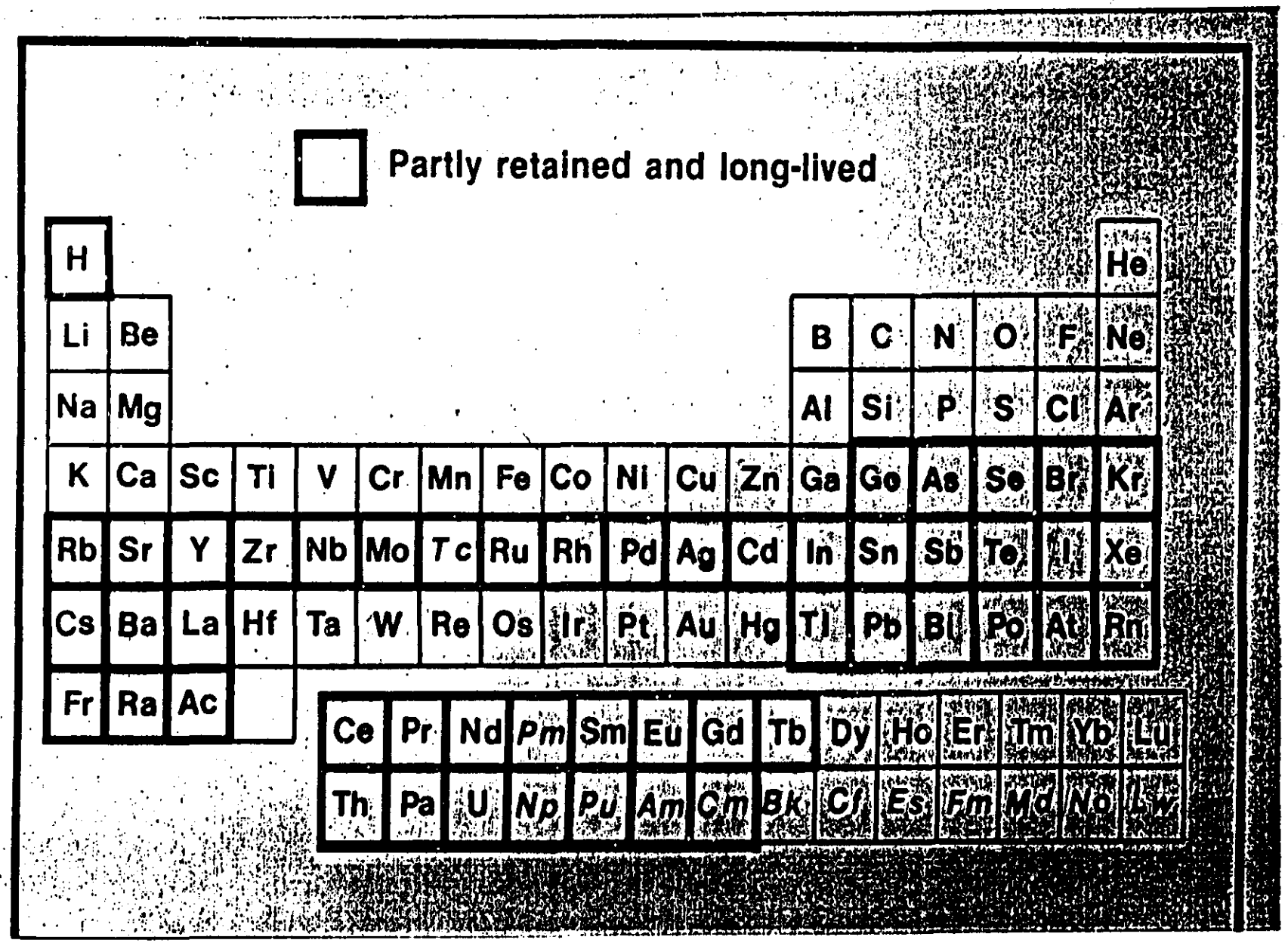
Waste products

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


Immobile
Partly retained
Mobile
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 Lw
SUMMARY OF OKLO STUDIES


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 Lw

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

- 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.