IAEA CLASSIFICATION OF URANIUM DEPOSITS

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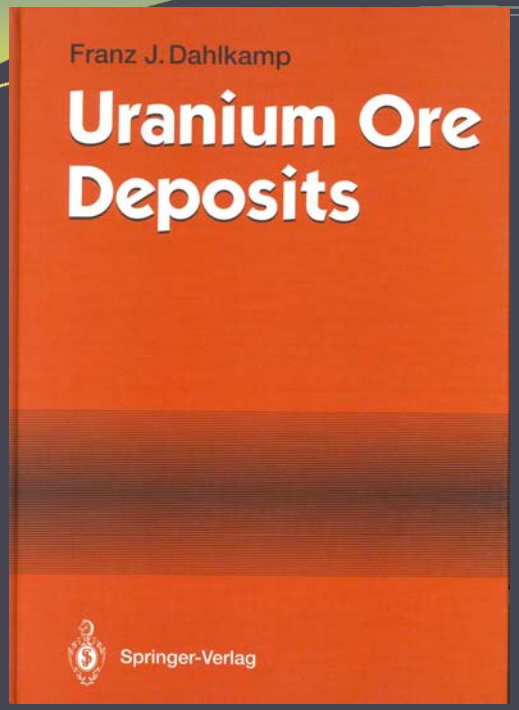
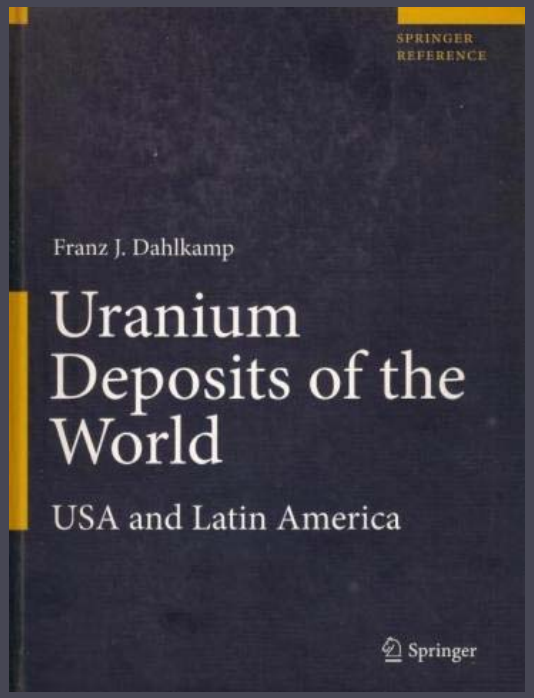
IAEA Vienna – URAM 2014

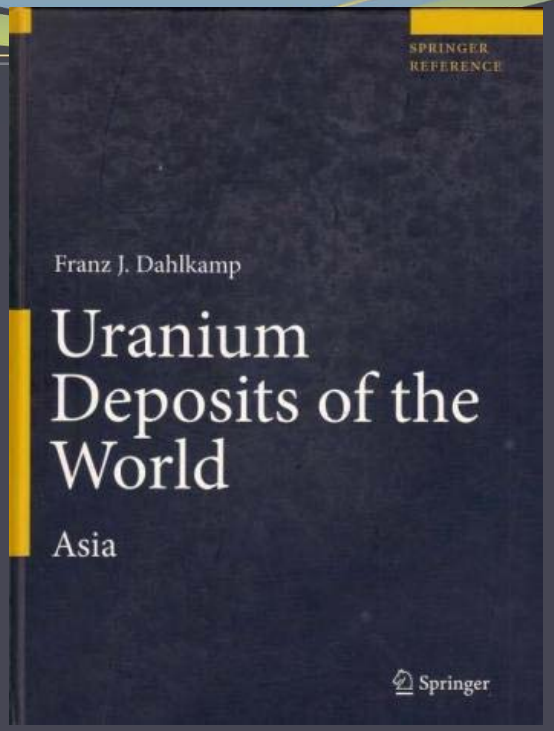
Franz DAHLKAMP



1993

2. 2010





1. 2009

3. Europe (2014 ?)

4. Africa-Australia ??

- Classifications of uranium deposits follow two general approaches, focusing on:
  - descriptive features such as the geotectonic position, the host rock type, the orebody morphology, ... : « geologic classification »
  - or on genetic aspects : « genetic classification »

1991 IAEA uranium deposits classification

1) Unconformity-related	23	
2) Sandstones	250	
3) Quartz-pebble conglomerates	22	
4) Veins	128	
5) Breccia complexes	1	
6) Intrusive	13	
7) Phosphorites	10	
8) Collapse breccia pipes	10	
9) Volcanic	43	
10) Surficial	16	
11) Metasomatites	12	
12) Metamorphic	10	
13) Lignite-coal	22	
14) Black shales	9	
15) Other types (carbonates)	13	(582)

Deposits were conventionally listed in order of economic ranking

2012 « Red Book » classification

- 1) Unconformity-related (McArthur, Ranger)
- 2) Sandstones (Mynkuduk, Arlit)
- 3) Hematite breccia complexes (Olympic Dam)
- 4) Quartz-pebble conglomerates (Witwatersrand)
- 5) Veins (Limousin, Czech Republic)
- 6) Intrusive (Rossing, Ilimaussaq)
- 7) Volcanic and caldera-related (Streltsovska)
- 8) Metasomatites (Michurinskoye, Lago Real)
- 9) Surficial (Yeelirrie, Langer Heinrich)
- 10) Collapse breccia pipes (Arizona Strip)
- 11) Phosphorites (Uncle Sam, Gantour)
- 12) Other types (metamorphic, limestones, coal)
- 13) Rock types with elevated U content (pegmatites, granites, black shales)

IAEA 2013 classification of uranium deposits

- The 2013 IAEA classification is a combination between the IAEA classification used in the Red Book since 1991 and the Dahlkamp (1993, 2009) classifications:

  15 main types of deposits, 36 sub-types and 14 classes have been retained

« Uranium DEPOSITS »

- *IAEA-NEA Red Book (2012):* « Uranium deposit : a mass of naturally occurring mineral from which uranium could be exploited at present or in the future »

- *IAEA-UDEPO Database:*
  - geological database first
  - no economic connotation: geological resources
  - 300 t U minimum, no restrictions for the grade
  - 1532 deposits/districts in 74 countries listed end of 2013

IAEA 2013 classification

- 1. Intrusive
- 2. Granite-related
- 3. Polymetallic hematite breccia complex
- 4. Volcanic-related
- 5. Metasomatite
- 6. Metamorphite
- 7. Proterozoic unconformity
- 8. Collapse breccia pipe
- 9. Sandstone
- 10. Paleo quartz-pebble conglomerate
- 11. Surficial
- 12. Coal-lignite
- 13. Carbonate
- 14. Phosphate
- 15. Black shales

IAEA 2013 classification

- 1. Intrusive
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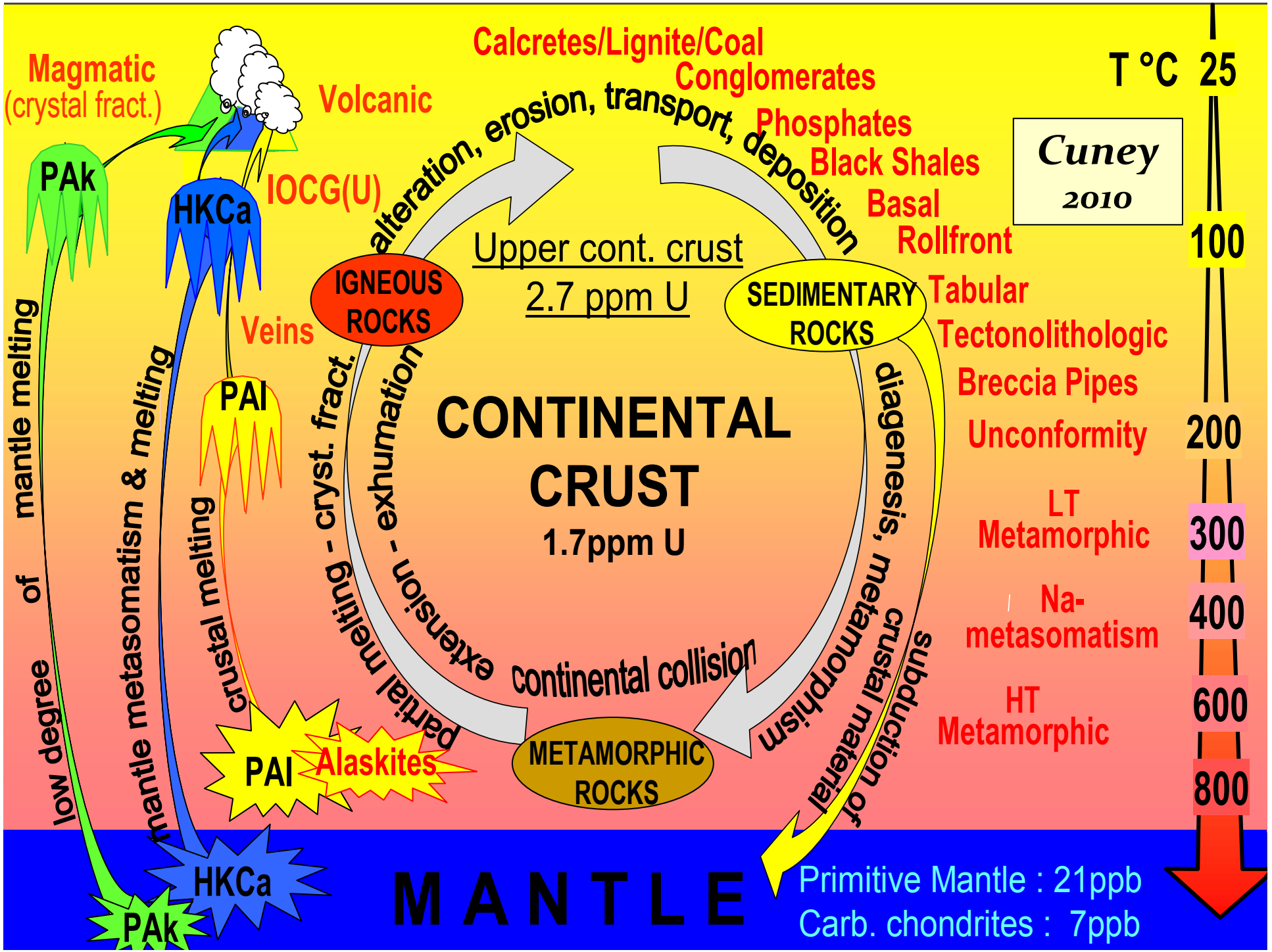
- 9. Sandstone
- 10. Paleo-quartz pebble conglomerate
- 11. Surficial
- 12. Coal-lignite
- 13. Carbonate
- 14. Phosphate
- 15. Black shales

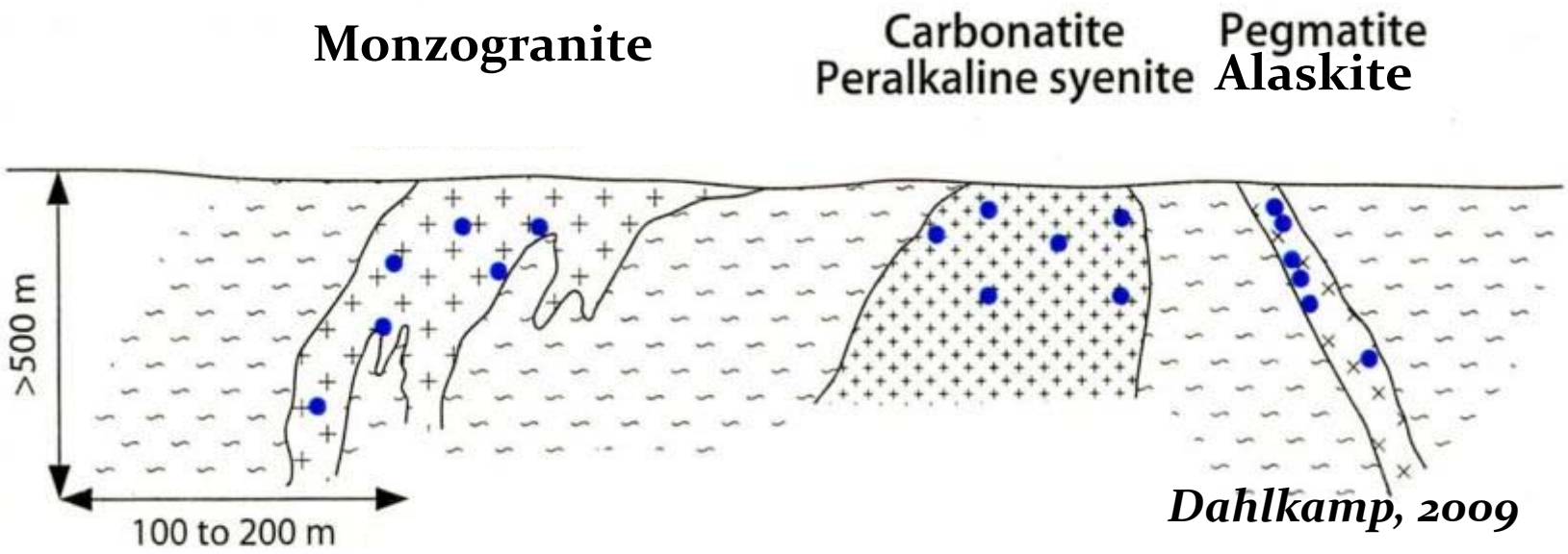
- **Sediment/sedimentary basins associations**
  - 11. Surficial
  - 9. Sandstone
  - 10. Paleo-quartz pebble conglomerate
  - 8. Collapse breccia pipe
  - 7. Proterozoic unconformity
  - 12. Coal-lignite
  - 13. Carbonate
  - 14. Phosphate
  - 15. Black shales
- **Metamorphic**
  - 1.1. Intrusive anatectic
  - 5. Metasomatite
  - 6. Metamorphite
- **Igneous plutonic and volcanic**
  - 2. Granite-related
  - 4. Volcanic-related
  - 1.2. Intrusive plutonic
  - 3. Polymetallic hematite breccia complex


Magmatic
(crystal fract.)
Volcanic
Calcretes/Lignite/Coal
Conglomerates
Phosphates
Black Shales
Basal
Rollfront
Tabular
Tectonolithologic
Breccia Pipes
Unconformity
LT
Metamorphic
Na-
metasomatism
HT
Metamorphic
T °C
25
100
200
300
400
600
800
Cuney
2010
PAk
HKCa
IOCG(U)
Veins
PAI
alteration, erosion, transport, deposition
Upper cont. crust
2.7 ppm U
IGNEOUS
ROCKS
SEDIMENTARY
ROCKS
CONTINENTAL
CRUST
1.7ppm U
low degree of mantle melting
mantle metasomatism & melting
crustal melting
partial melting - cryst. fract.
extension - exhumation
continental collision
diagenesis, metamorphism
subduction of crustal material
PAI
Alaskites
METAMORPHIC
ROCKS
HKCa
PAk
MANTLE
Primitive Mantle : 21ppb
Carb. chondrites : 7ppb

Number of deposits by type

- 9. Sandstone 627
- 2. Granite-related 129
- 4. Volcanic-related 124
- 6. Metamorphite 106
- 7. Proterozoic unconformity 85
- 1. Intrusive 83
- 5. Metasomatite 76
- 10. Paleo quartz-pebble conglomerate 69
- 11. Surficial 65
- 14. Phosphate 49
- 15. Black shales 45
- 12. Coal-lignite 33
- 8. Collapse breccia pipe 16
- 3. Polymetallic hematite breccia complex 15
- 13. Carbonate 10 (1532)

Type 1 - Intrusive deposits



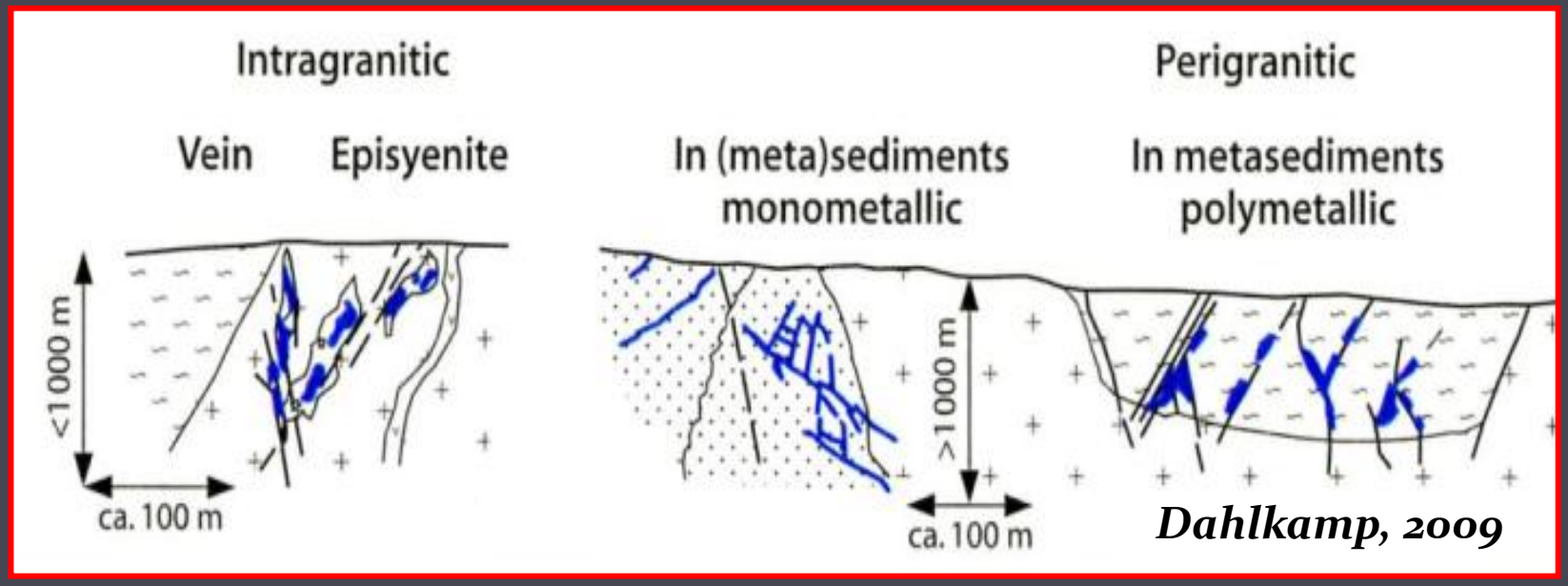
Two sub-types:

-1.1. Intrusive anatectic (pegmatites-alaskites) (Rossing, Namibia)

-1.2. Intrusive magmatic

- *granite-monzonites (Bingham Canyon, USA)*
- *peralcaline complexes (Kvanefjeld, Greenland)*
- *carbonatites (Catalao, Brazil)*

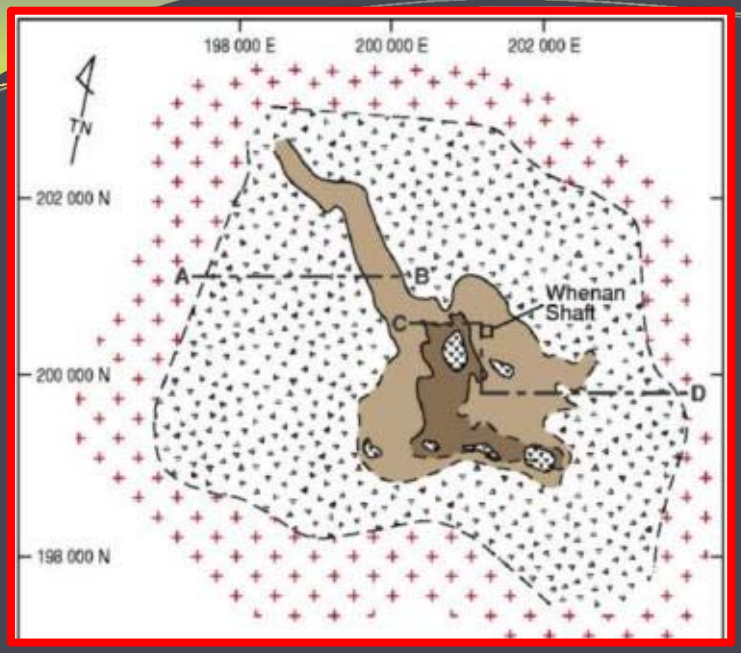
Type 2 - Granite-related deposits

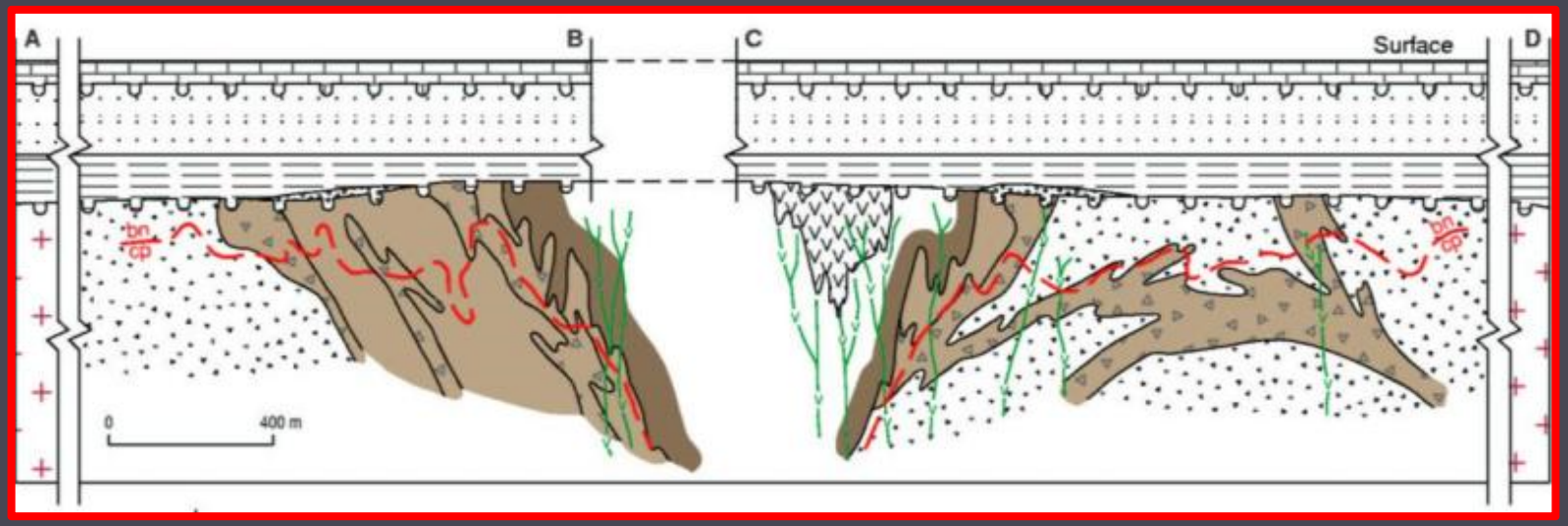


2 sub-types :

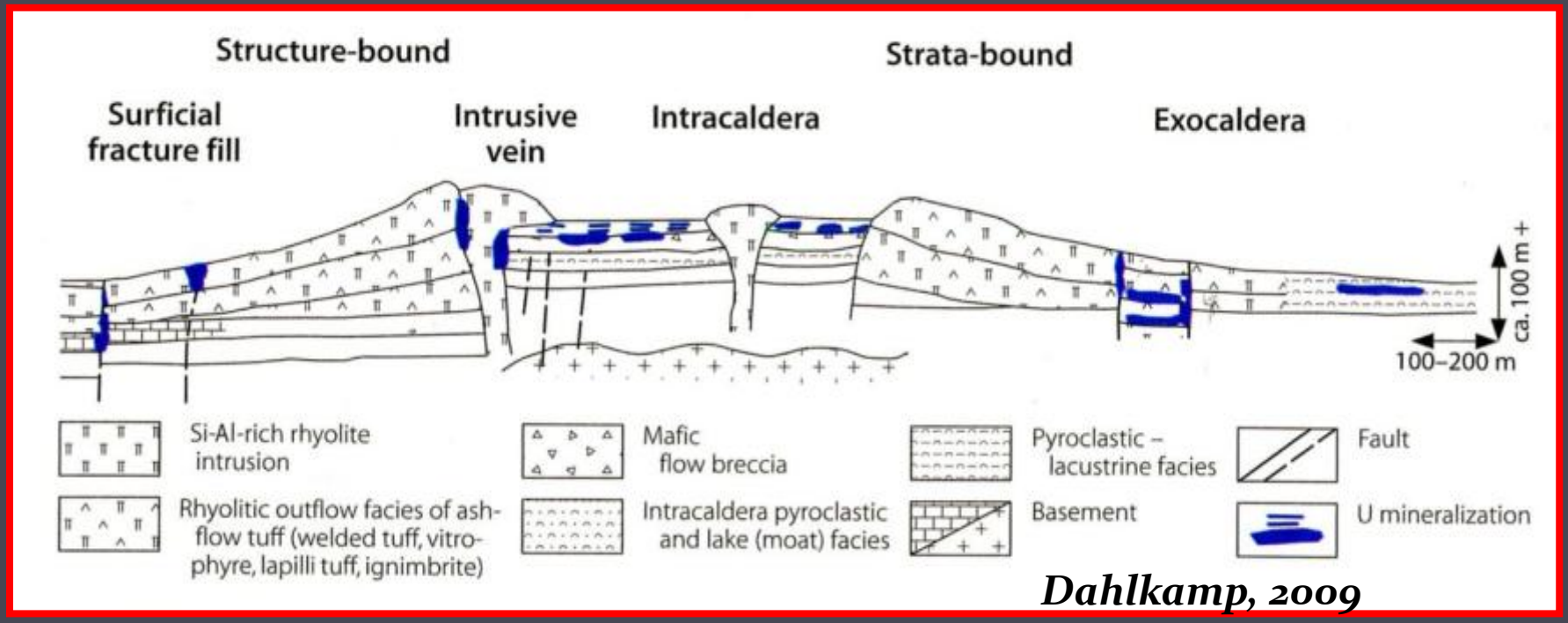
- *2.1. Intragranitic (La Crouzille District, France)*
- *2.2. Perigranitic (Pribram District, Czech Republic)*

Type 3- Polymetallic iron-oxide breccia complex (Olympic Dam)





Type 4 - Volcanic-related deposits

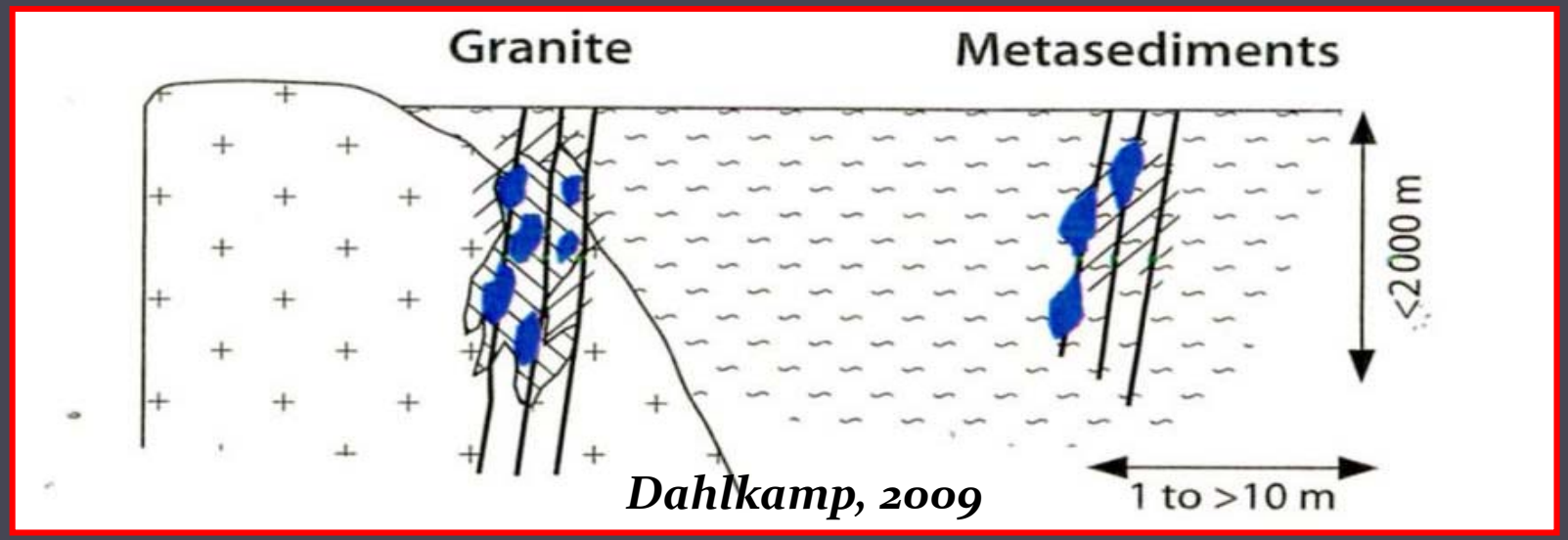


Dahlkamp, 2009

3 sub-types:

- *3.1. Structure-bound (Streltsov, Russia)*
- *3.2. Stratabound (Maureen, Australia)*
- *3.3. Volcano-sedimentary (Anderson Mine, USA)*

Type 5 - Metasomatite

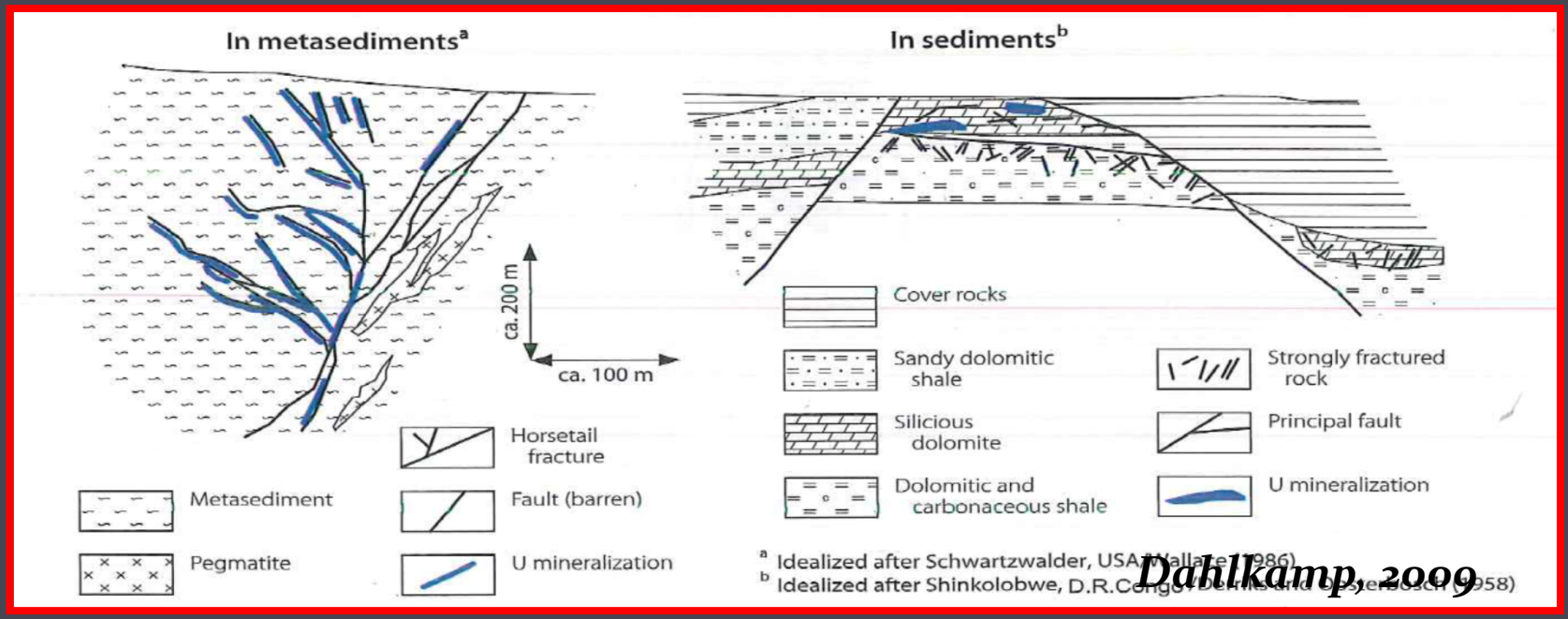


Dahlkamp, 2009

3 sub-types:

- *5.1. Na-metasomatite (Kirovograd District, Ukraine)*
- *5.2. K-metasomatite (Elkon District, Russia)*
- *5.3. Skarn (Mary Kathleen, Australia)*

Type 6 - Metamorphite



Dahlkamp, 2009

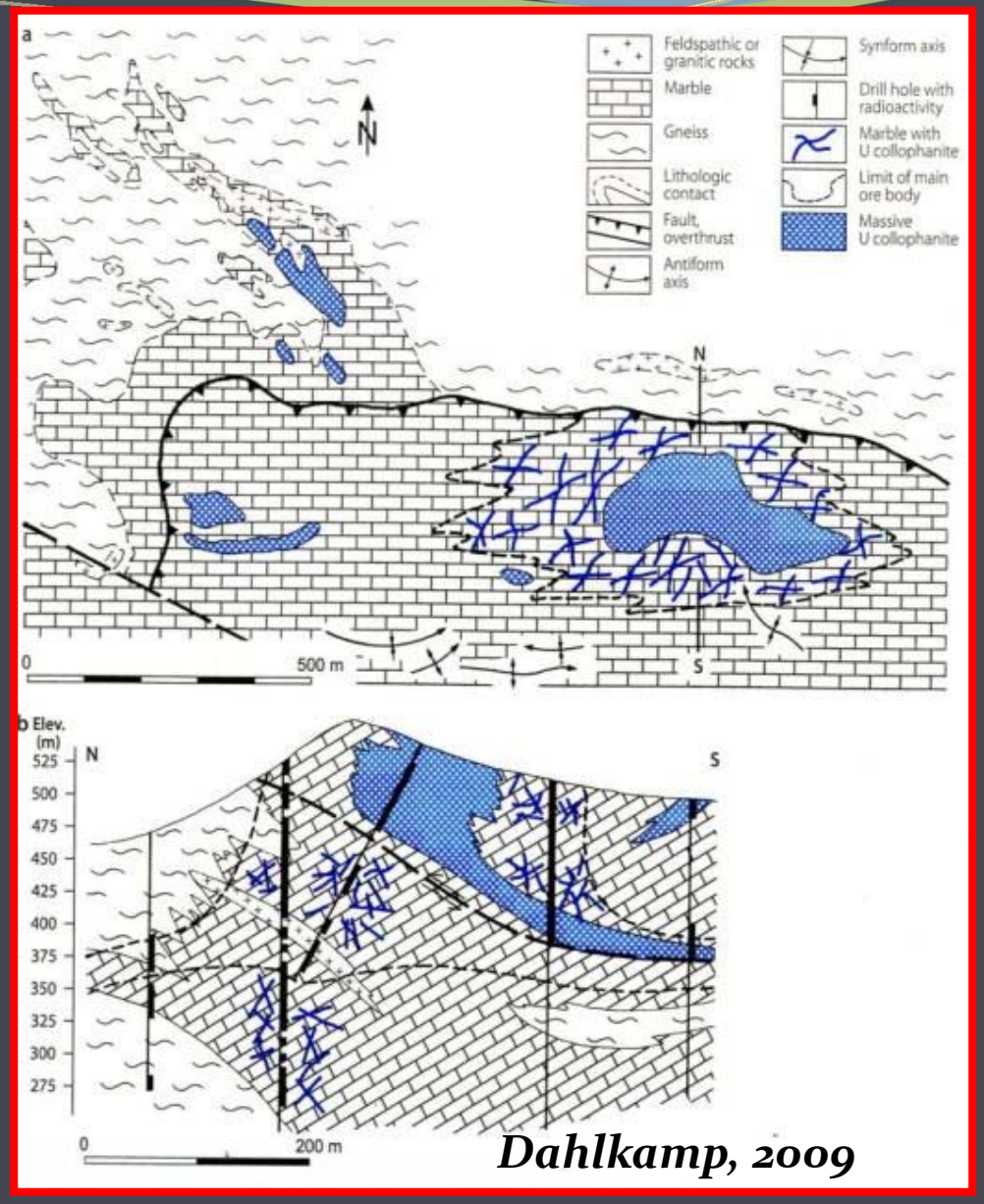
3 sub-types:

- *6.1. Stratabound (Forstau, Austria)*
- *6.2. Structure-bound*
  - *Monometallic veins (Schwartzwalder, USA)*
  - *Polymetallic veins (Shinkolobwe, Democratic Rep of the Congo)*
- *6.3. Marble-hosted phosphates (Itataia, Brazil)*

Itataia-Santa Quiteria deposit

6.3. marble-hosted phosphate

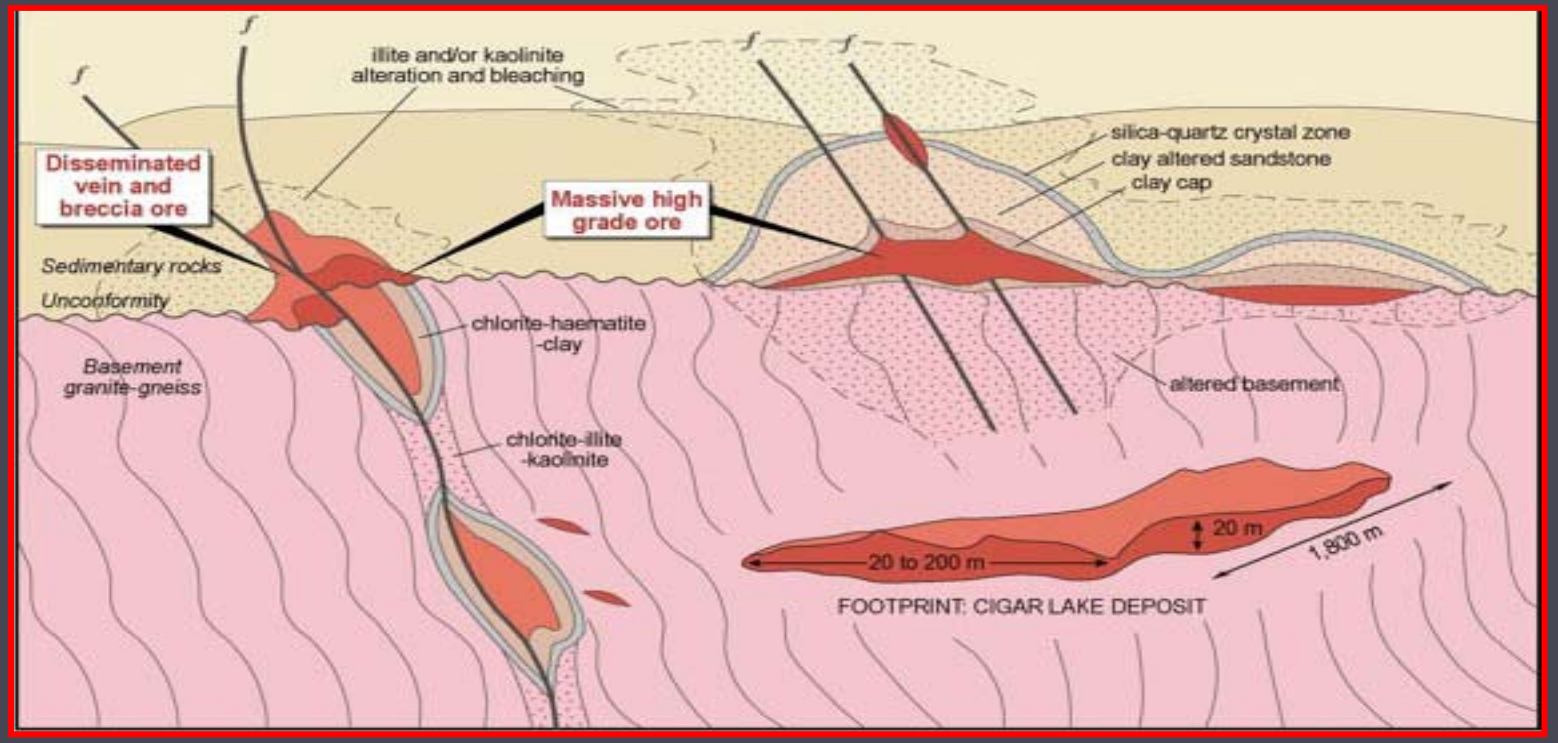
Complex hydrothermal metasomatic Cambrian-Ordovician uraniferous collophane deposit, hosted by Precambrian metamorphic marls

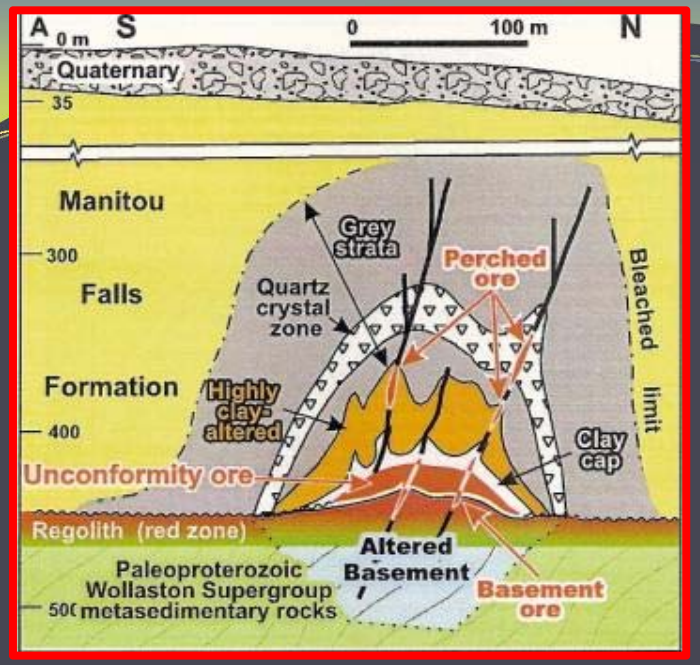


Dahlkamp, 2009

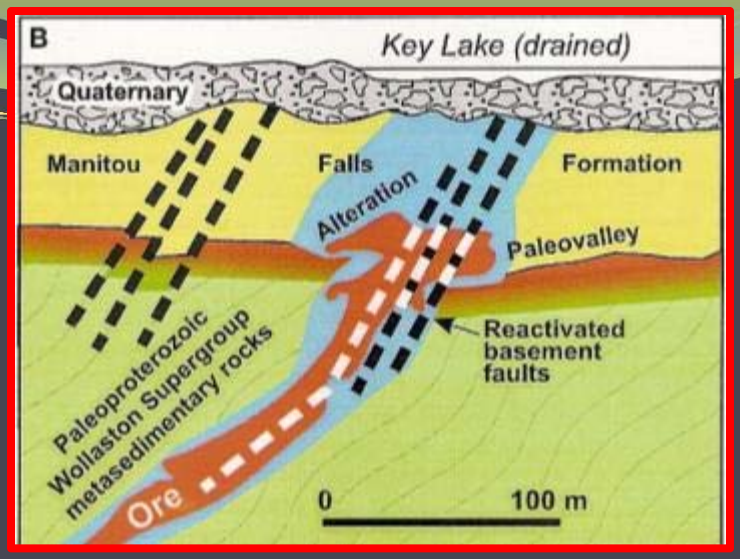
Type 7 - Proterozoic unconformity

- *3 sub-types :*
  - *7.1. basement-hosted (Jabiluka, Australia; Millenium, Canada)*
  - *7.2. unconformity-contact (Cigar Lake, Key Lake, Canada)*
  - *7.3. stratiform fractured-controlled (Lambapur, India)*

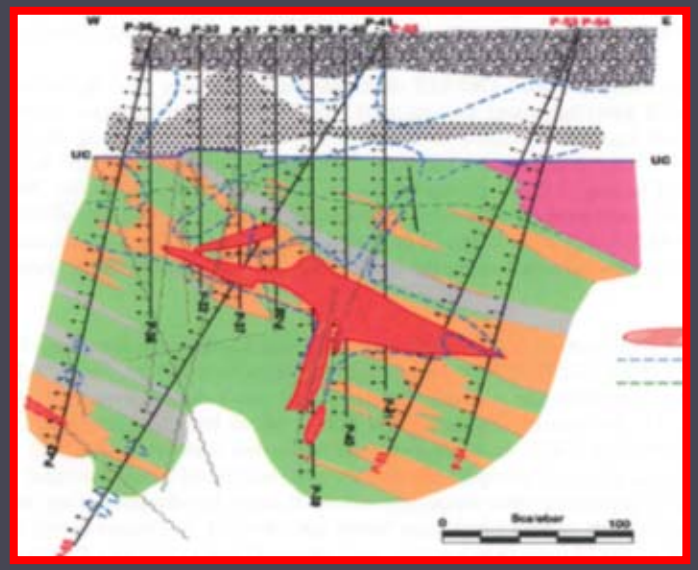




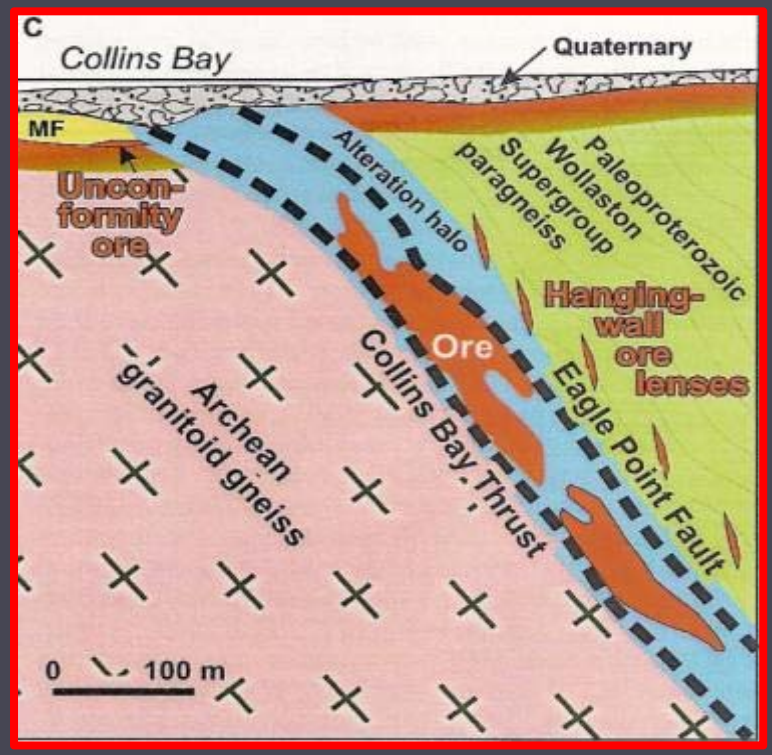
Cigar Lake



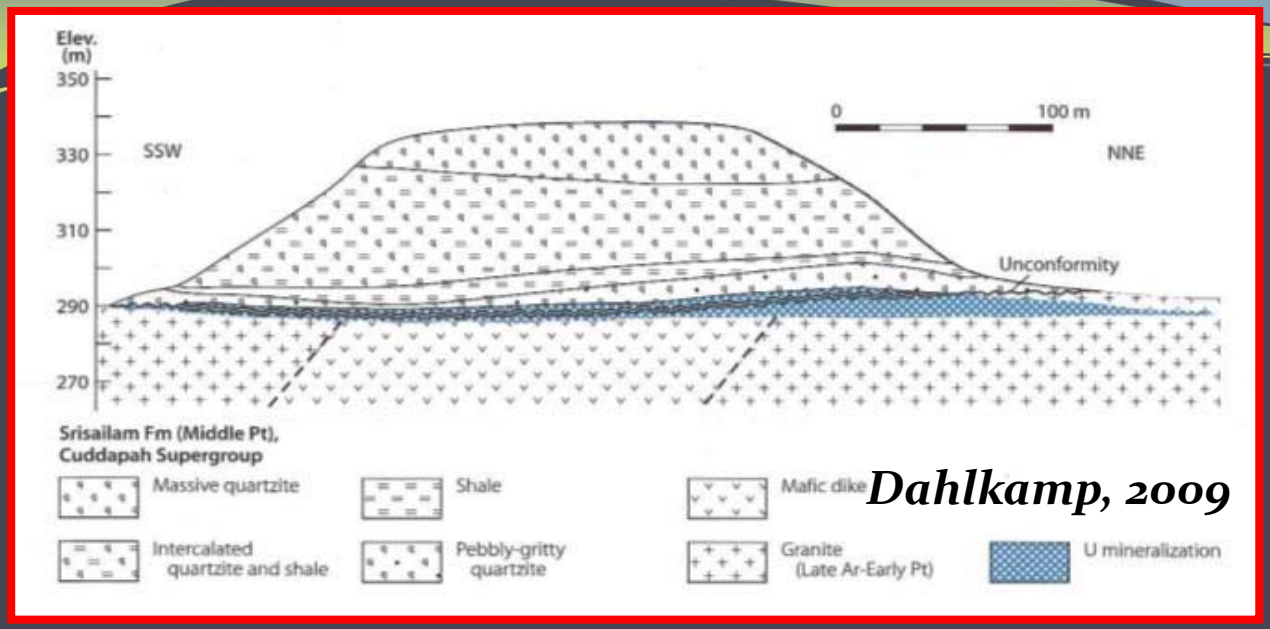
Key Lake



P-Patch

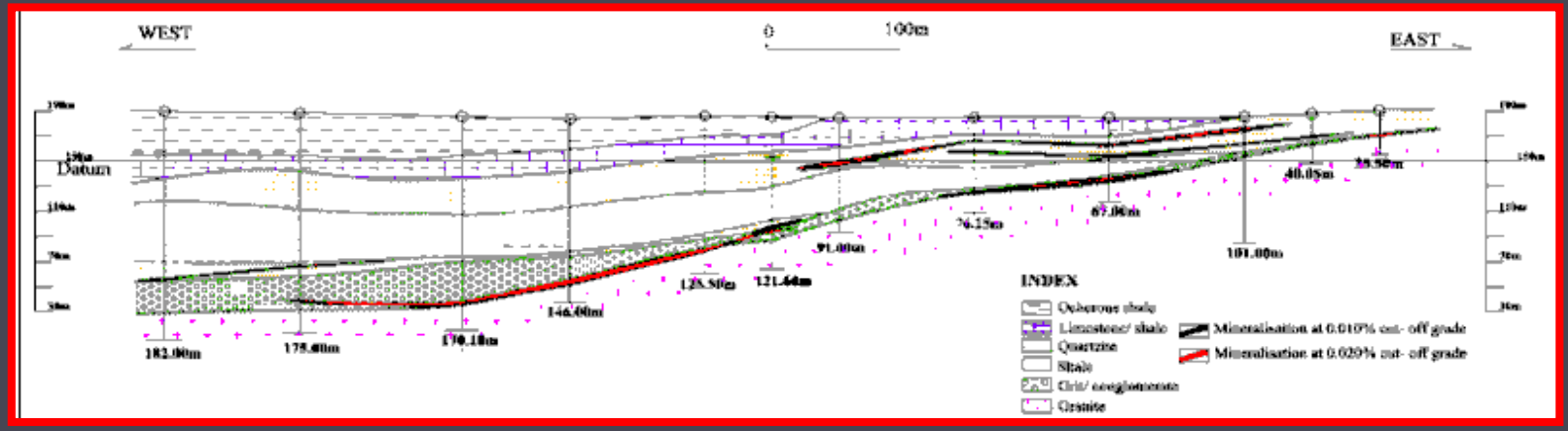


Eagle Point

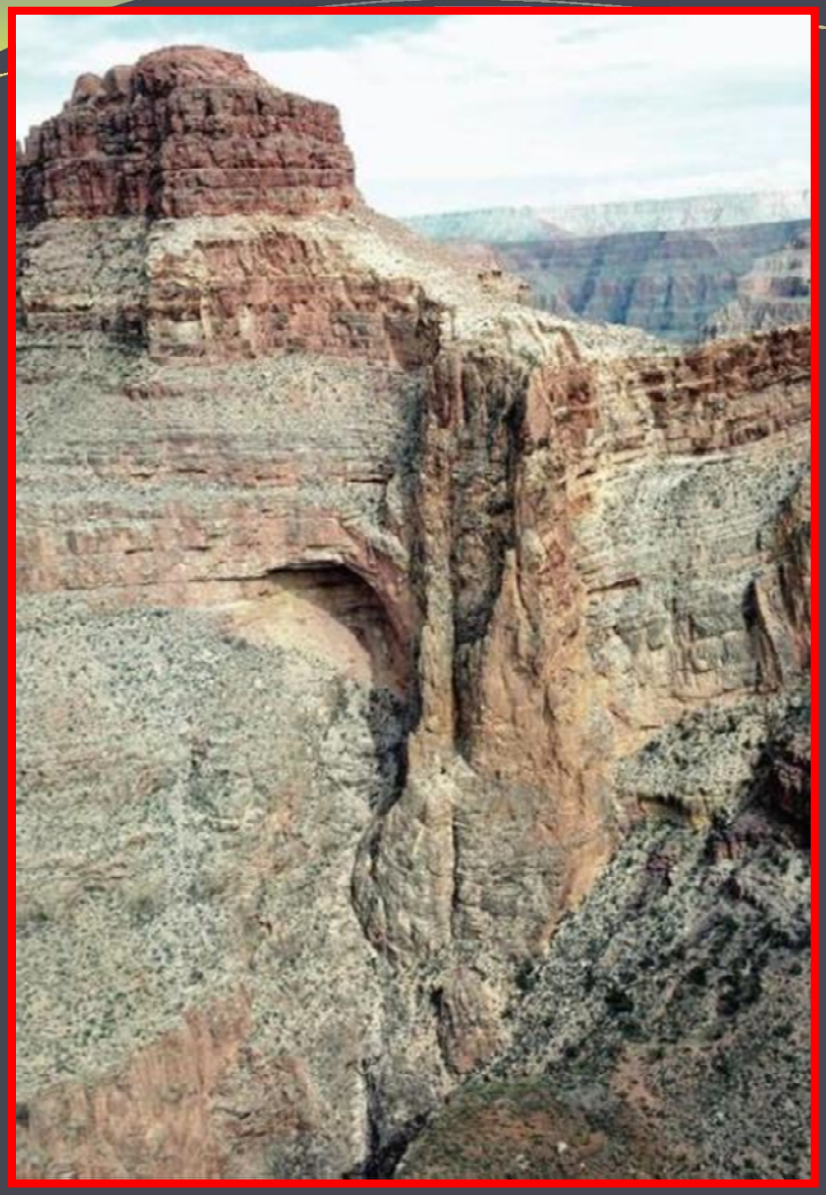


Dahlkamp, 2009

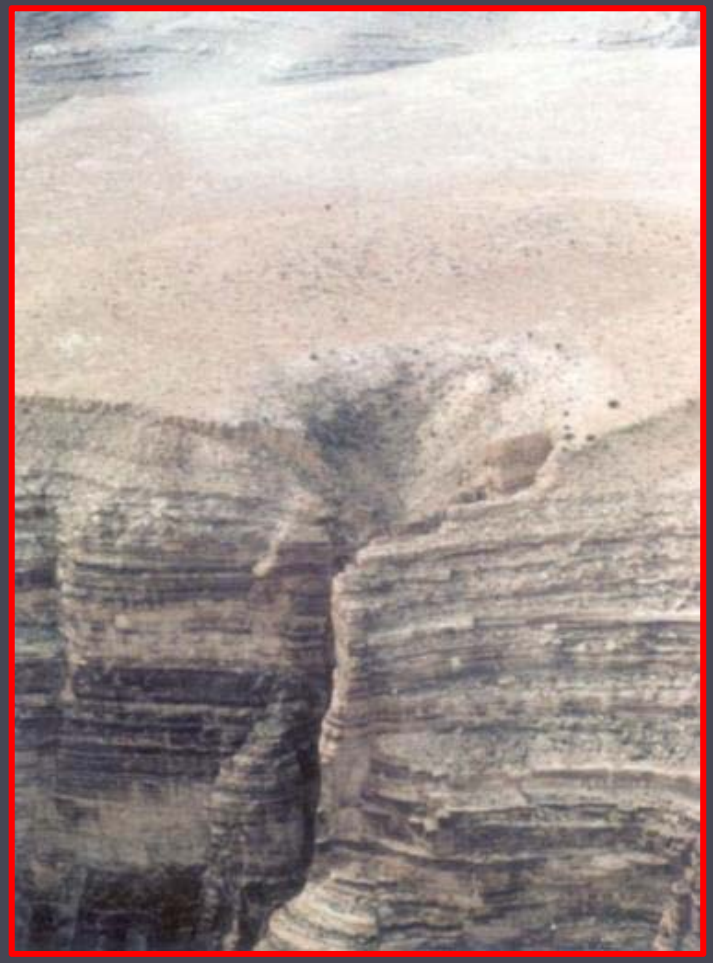
7.3. Stratiform fracture-controlled (India)



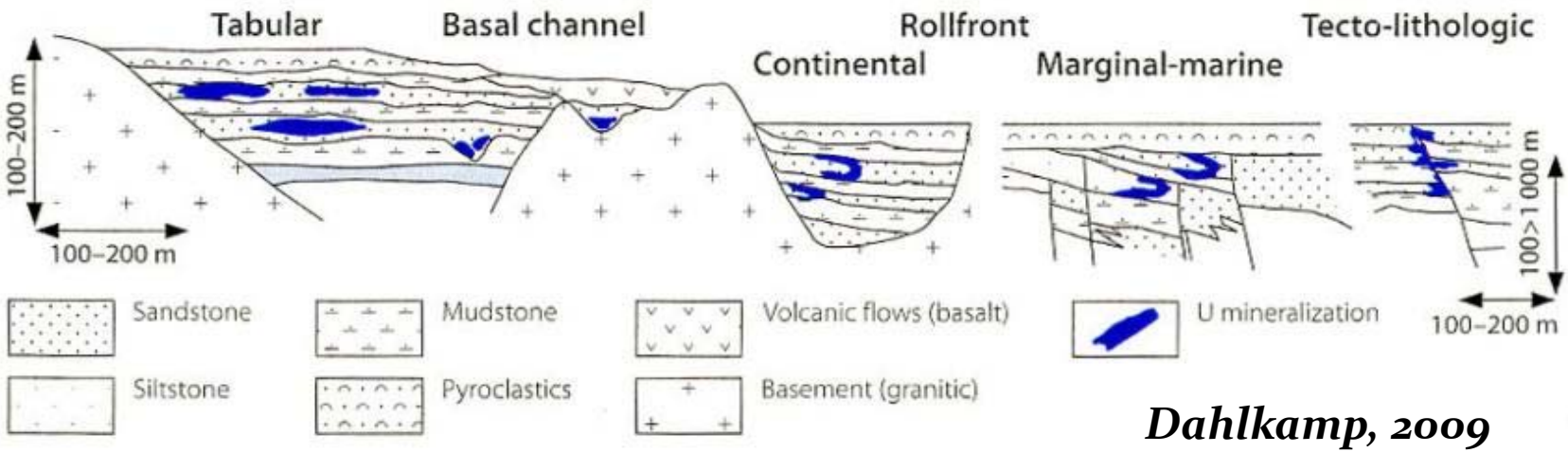
Type 8 – Collapse breccia pipes



Wenrich and Titley, (2008)



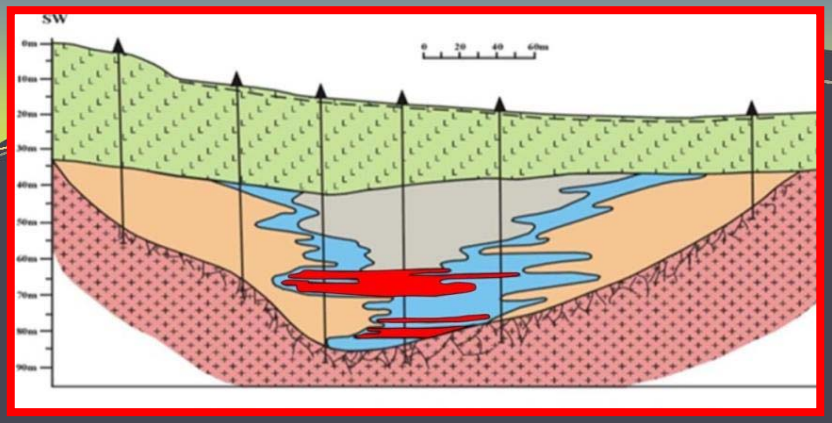
Type 9 - Sandstone



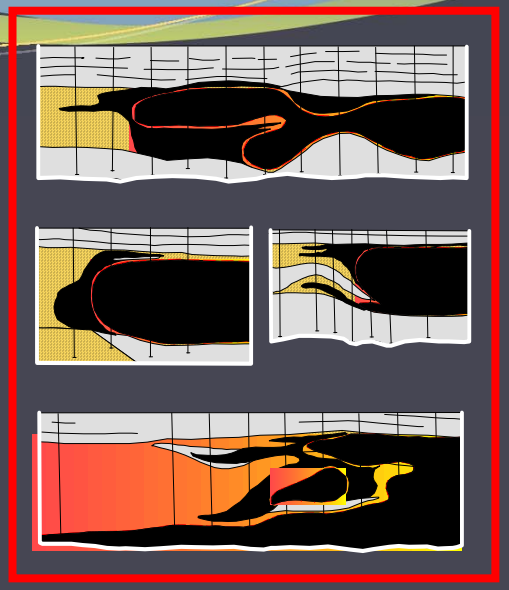
Dahlkamp, 2009

5 sub-types:

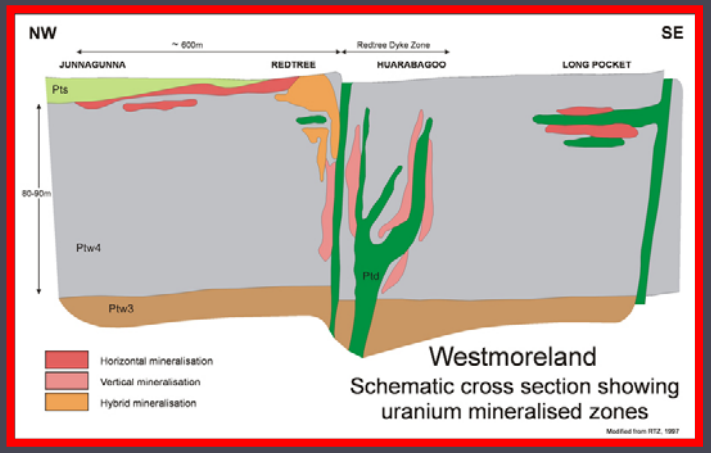
- *9.1. Basal channel (Beverley, Australia)*
- *9.2. Tabular (Niger)*
- *9.3. Rollfront (Wyoming; Kazakhstan)*
- *9.4. Tectonic-lithologic (Lodève; Gabon)*
- *9.5. Mafic dikes/sills in Proterozoic sandstones (Wesmoreland, Australia)*



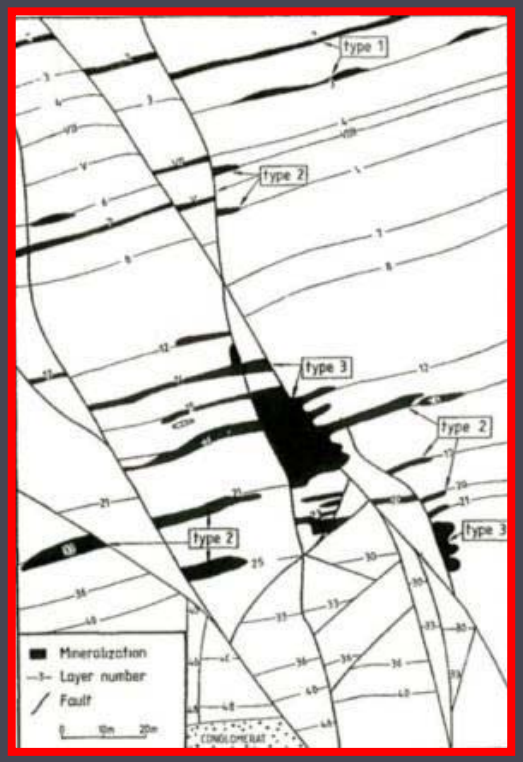
9.1. Basal channel



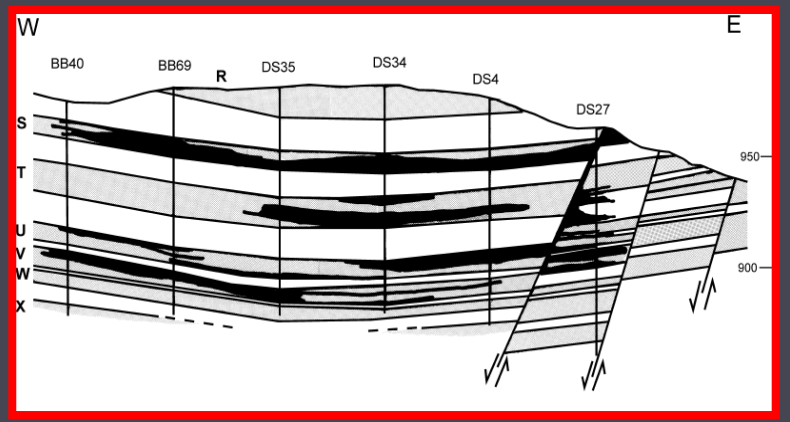
9.3. Roll-front



9.2. Tabular

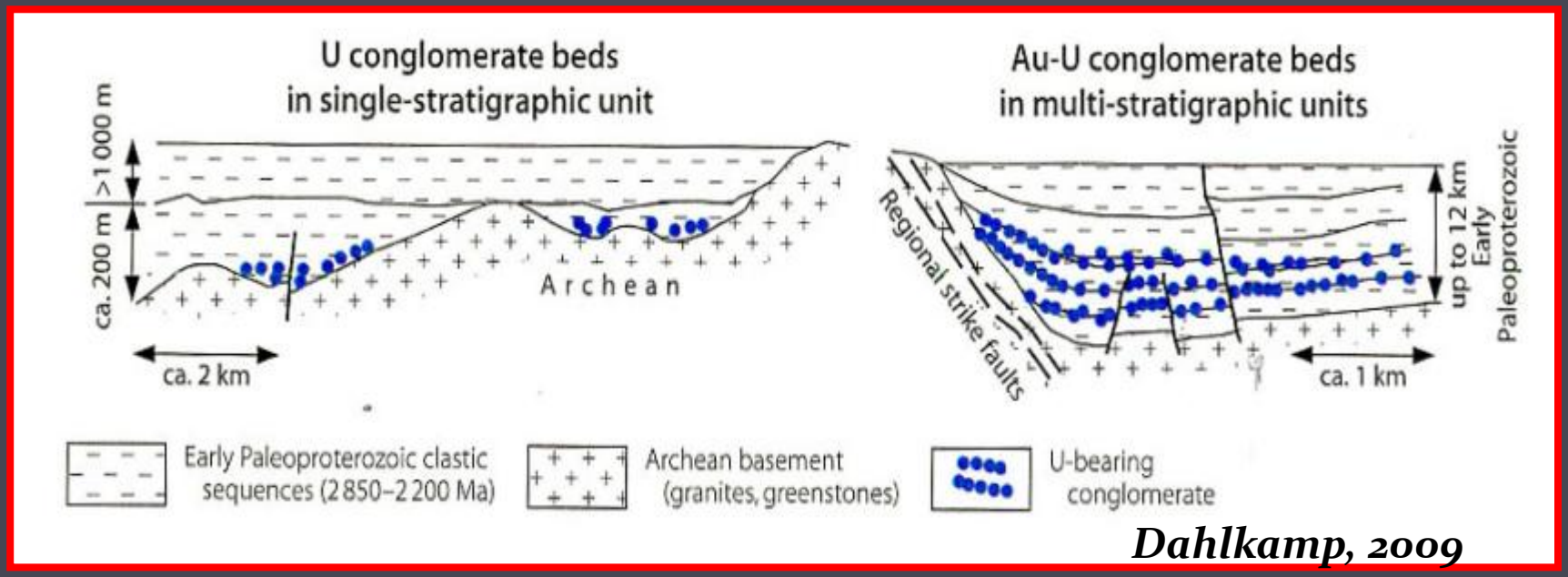


9.5. Mafic dikes in Proterozoic sandstones



9.4. Tectono-lithologic

Type 10 - Paleo quartz-pebble conglomerate

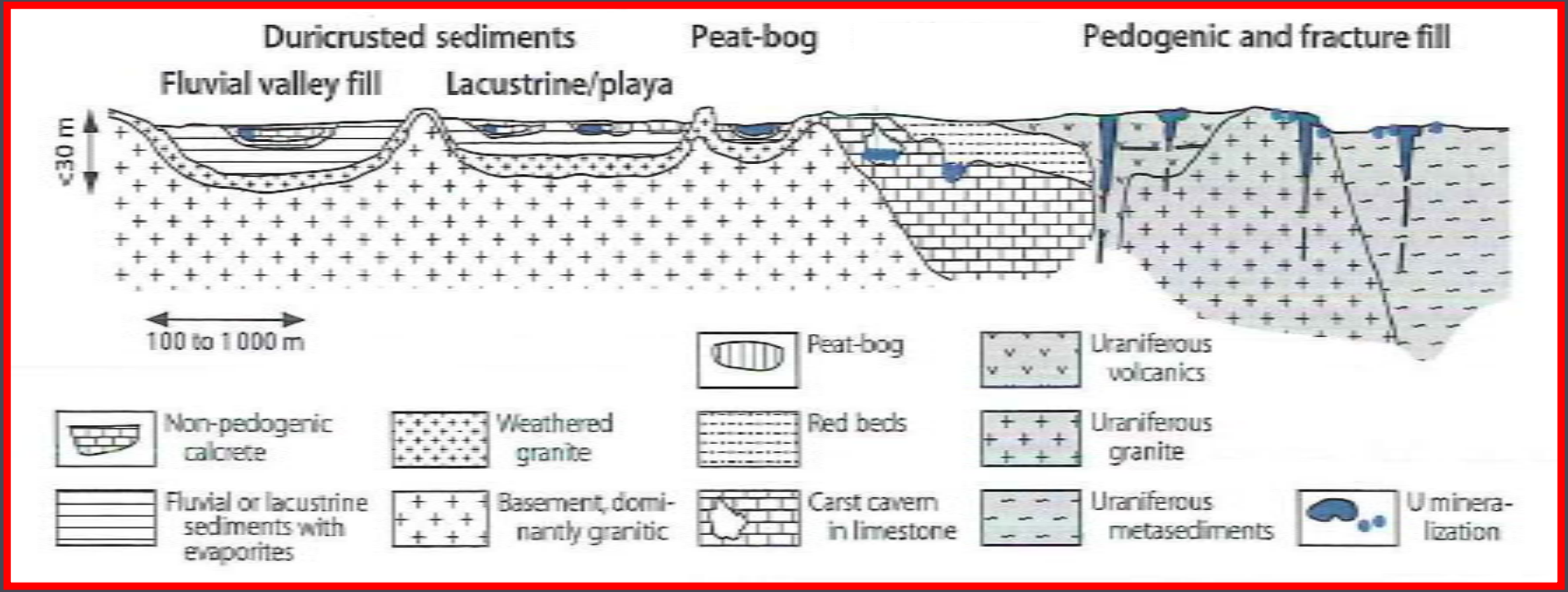


Dahlkamp, 2009

Two sub-types :

- *10.1. Au-dominant (Witwatersrand Basin, South Africa)*
- *10.2. U -dominant (Blind River-Elliot Lake area, Canada)*

Type 11 - Surficial deposits

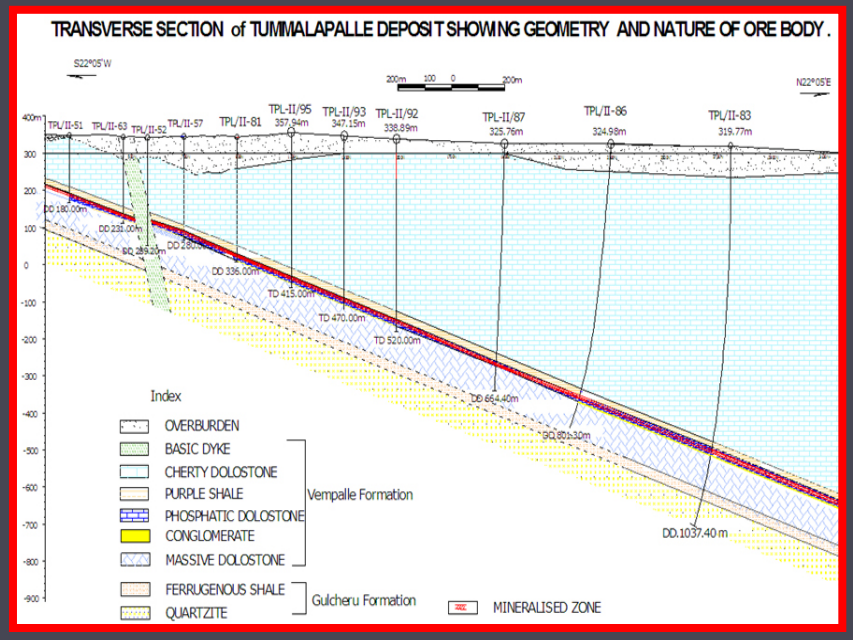


Dahlkamp, 2009

Four sub-types:

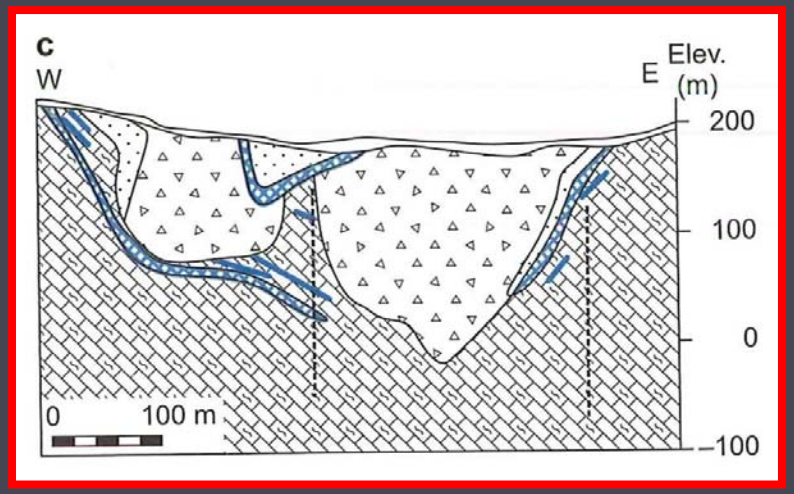
- *11.1. Peat-bog (Kamushanovskoye, Kyrgyzstan)*
- *11.2. Fluvial valley (Yeelirrie, Australia)*
- *11.3. Lacustrine-playa (Lake Maitland, Australia)*
- *11.4. Pedogenic and fracture-filled (Beslet, Bulgaria)*

Type 13 - Carbonate



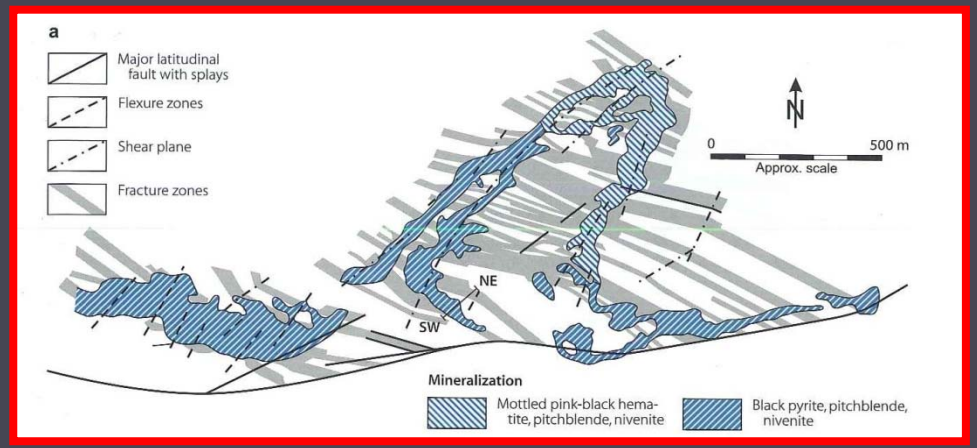
13.1. Stratabound
(Tumalappalle, India)

13.3. Karst
(Sanbaqi, China)



Dahlkamp, 2009

13.2. Cataclastic
(Mailuu-Suu, Kyrgyzstan)

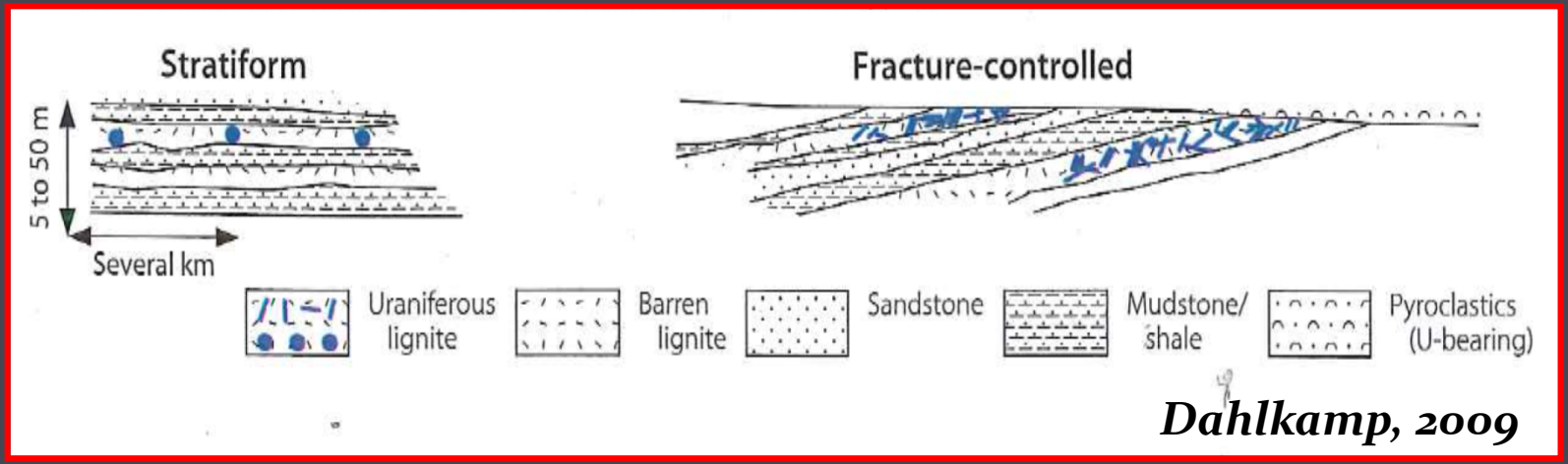


Type 12 – Coal-lignite

(Koldzat, Kazakhstan; Freital, Germany)

Type 15 – Black shale

(MMS Vicken, Sweden; Ronneburg District, Germany)



Dahlkamp, 2009

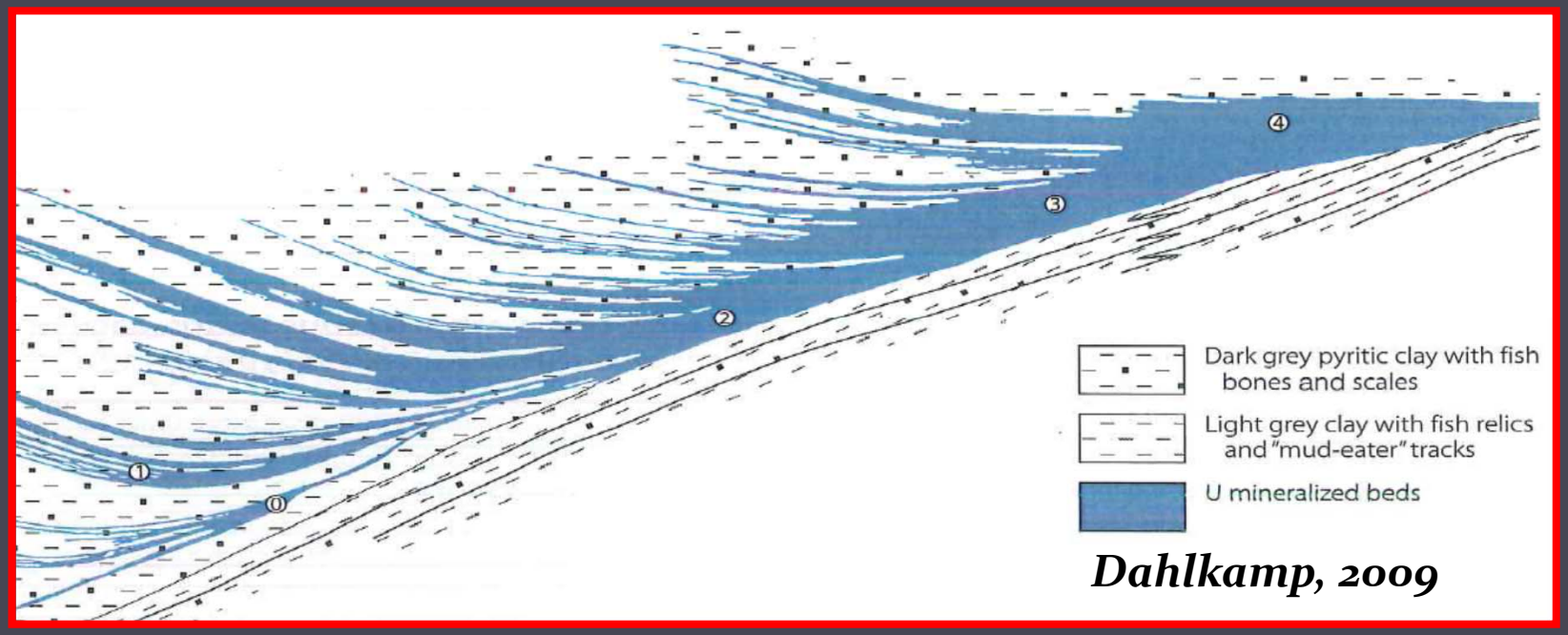
Two sub-types:

- ***Stratiform***
- ***Fracture-controlled***

Type 14 - Phosphate

3 sub-types:

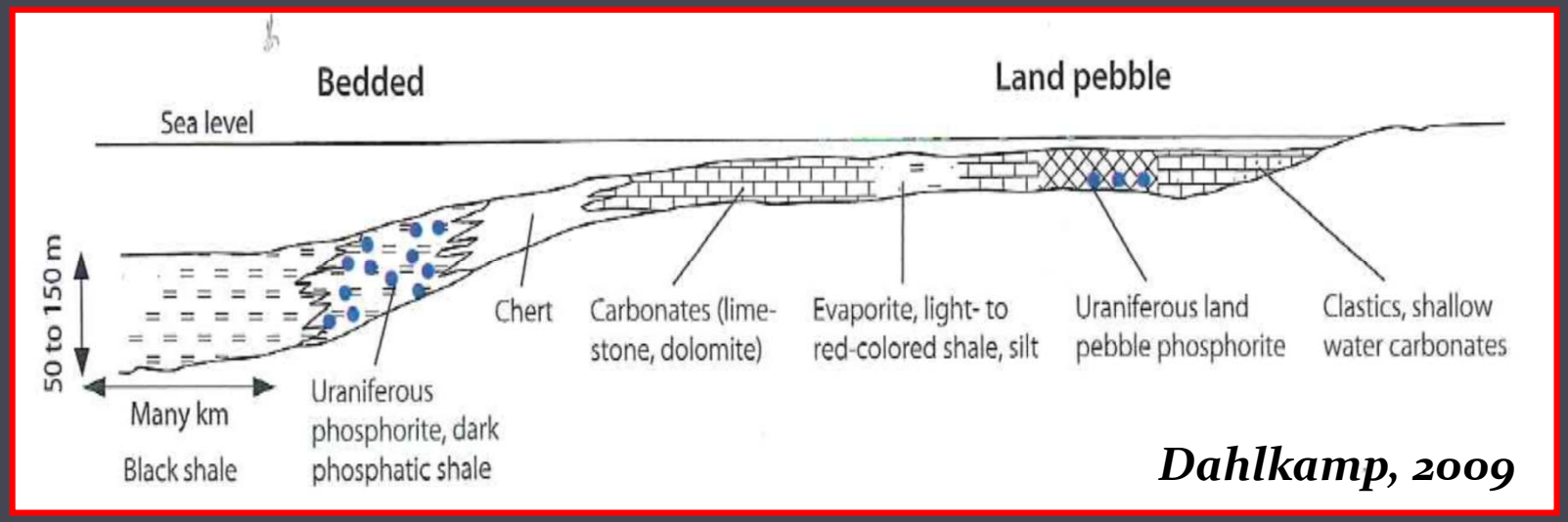
- *14.1. Organic phosphorite (Mangyshlak District, Kazakhstan; Minjingu, Tanzania)*



Dahlkamp, 2009

Type 14 - Phosphate

14.2. Minerochemical phosphorite (Morocco, Florida)



Dahlkamp, 2009

14.3. Continental phosphate (Bakouma District, Central African Rep.)

AREVA document

« Unconventional resources »

- Conventional resources are defined as resources from which uranium is recoverable as a primary product, a co-product or an important by-product

- *Unconventional resources* are resources from which uranium is only recoverable as a minor by-product, such as uranium associated with phosphate rocks, non-ferrous ores, carbonatite, black shale and lignite (Red Book 2012)

« Unconventional resources »

1. Intrusive anatectic and plutonic	51 - 32
2. Granite-related	129
3. Polymetallic hematite breccia complex	15
4. Volcanic-related	124
5. Metasomatite	76
6. Metamorphite	106
7. Proterozoic unconformity	85
8. Collapse breccia pipe	16
9. Sandstone	627
10. Paleo-quartz pebble conglomerate	69
11. Surficial	65
12. Coal-lignite	33
13. Carbonate	10
14. Phosphate	49
15. Black shale	45

UDEPO total resources (2013)

(41.600.000 t U)

Phosphate	13.700.000
Coal-lignite	7.400.000
Black shales	6.650.000
Sandstone	4.200.000
Polymetallic breccia complex	2.300.000
Proterozoic unconformity	1.300.000
Intrusive anatectic-plutonic	780.000 – 600.000
Paleo-quartz pebble conglomerate	1.250.000
Metasomatite	1.000.000
Volcanic-related	620.000
Metamorphite	500.000
Granite-related	460.000
Surficial	425.000
Carbonate	100.000
Collapse breccia pipe	16.000

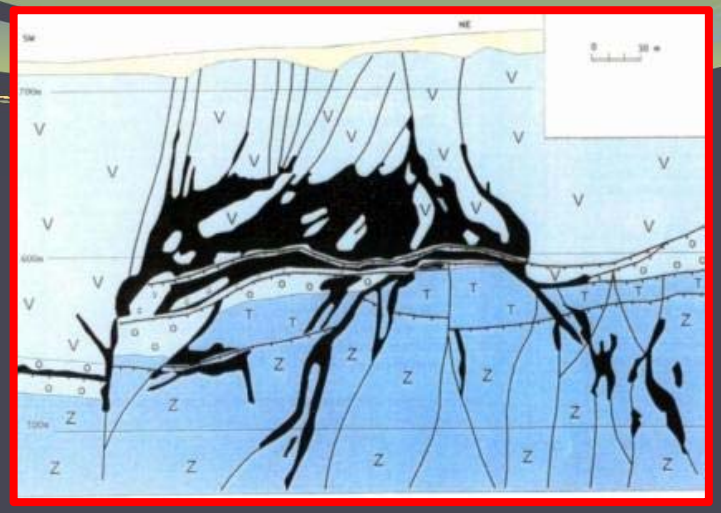
Final remarks ……

- Revised and improved geological classification of uranium deposits with **15** main types covering most geological formations
- Detailed classification with **50** sub-types and classes
- The UDEPO Database with **1532** « deposits », useful tool being improved regularly
- A new sub-database (UncvDEPO) for unconventional ressources

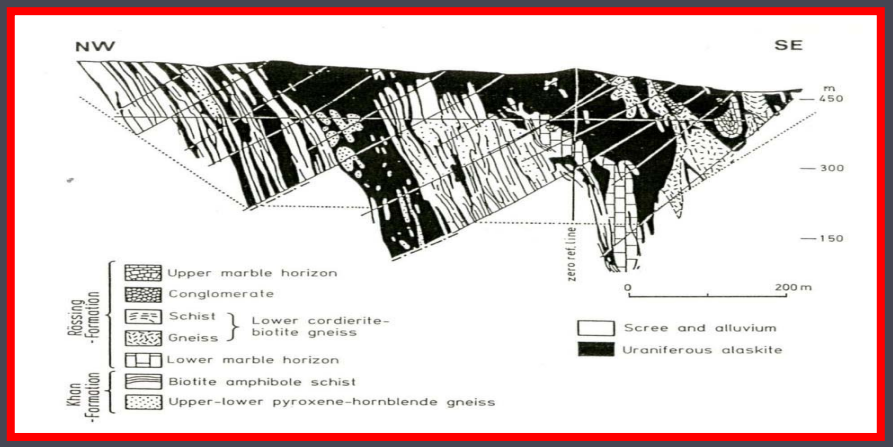
IAEA technical documents in preparation

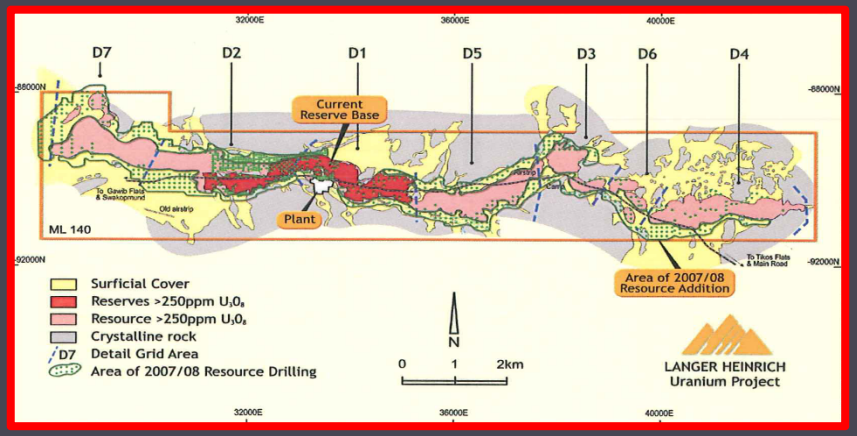
- *"Geological Classification of Uranium Deposits and Description of Selected Examples"*

- *"World distribution of uranium deposits - The UDEPO Database"*



THANK YOU !


NW
SE
m
450
300
150
zero plane
0
200 m
Upper marble horizon
Conglomerate
Schist
Gneiss
Lower cordierite-biotite gneiss
Lower marble horizon
Rossing Formation
Biotite amphibole schist
Upper-lower pyroxene-hornblende gneiss
Khan Formation
Scree and alluvium
Uraniferous alaskite


32000E
36000E
40000E
D7
D2
D1
D5
D3
D6
D4
88000N
92000N
Current Reserve Base
Plant
ML 140
Area of 2007/08 Resource Addition
Surficial Cover
Reserves >250ppm U3O8
Resource >250ppm U3O8
Crystalline rock
D7 Detail Grid Area
Area of 2007/08 Resource Drilling
N
0 1 2km
LANGER HEINRICH
Uranium Project