

Mineral Exploration

Unit-1

What is Exploration?

Exploration is the work involved in **gaining a knowledge of the size, shape, position and value of the *ore body*.**

What is Mineral Exploration?

Mineral exploration is the process of **finding ores (commercially viable concentrations of minerals) to mine.**

What is Ore ?

- A natural concentration of one or more minerals from which one or more **minerals/metals can be extracted with economic** significance.
- ❖ Ore is defined as naturally occurring solid material from which a **metal or valuable mineral** can be extracted **profitably**.

What is ore grade?

Ore grade is the concentration of economic mineral or metal in an ore deposit.

Cut Off Grade:

The Grade of ore below which, it is considered that economic mining is not feasible.

Cut Off Thickness:

Minimum thickness of the ore body required for exploitation by proposed mining method. **or**

Width of the ore body which can be economically mined

What is an ore deposit?

An occurrence of minerals or metals in sufficiently high concentration to be profitable to mine and process using current technology and under current economic conditions.

What is Gangue ?

- The **unwanted, waste minerals or rock** with which the economically important minerals occur.
- ❖ Gangue is the **commercially worthless material** that surrounds, or is closely mixed with, a wanted mineral in an ore deposit

What is a mineral?

A solid naturally-occurring compound having a definite chemical composition

Examples:

Quartz - SiO_2 (an oxide)

Hematite - Fe_2O_3 (another oxide)

Covelite - CuS (a sulphide)

The Exploration Process

- Exploration for a mineral deposit is usually conducted in a step-wise fashion which progresses through stages, each of which moves closer to making a valuation of the ore body.
 1. Geological Reconnaissance, Airborne Geophysical and surface geochemical sampling prevail in the **earliest stage**.
 2. Simultaneously or afterwards, ground geophysical surveys are typically conducted.

3. Following surface exploration, the project moves into the drilling stage. Drilling may begin with a small number of exploratory drill holes on select targets. After this drilling stage, extensive, close-spaced drilling (called “**development drilling**”) is conducted.

4. Finally, finding good results, “reserve drilling” is conducted, which is the type of drilling which makes the final assessment of the deposit before actual mining begins.

5. Generally, some amount of drilling will continue throughout the life of the mine, as further definition is required and new information is obtained and used to refine the deposit model.



What is Ore Genesis?

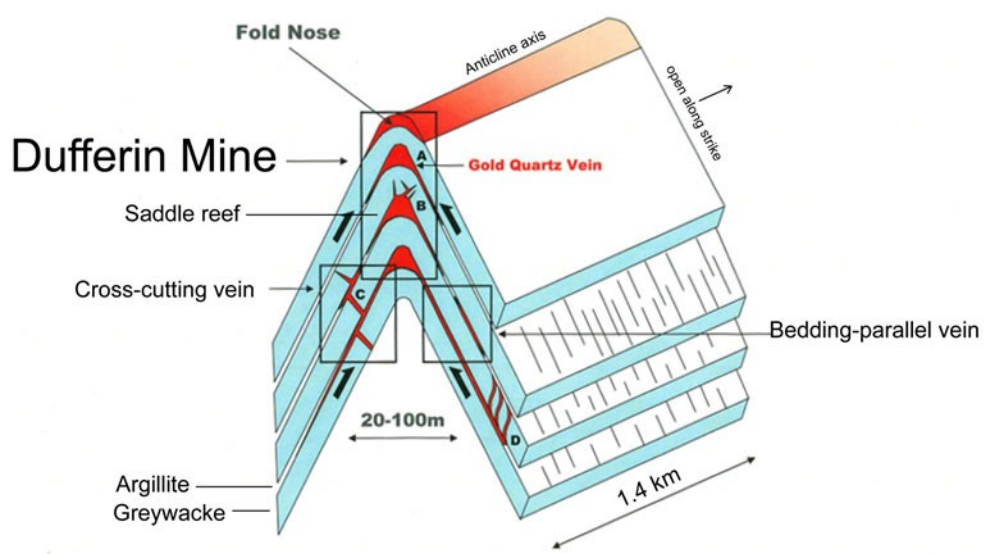
- ❖ **Ore genesis** is a process by which a mineral deposit forms or **The process of ore formation is called ore genesis.**
- ❖ Metalliferous mineral deposits may be **syngeneic** (formed at the same time as the host rocks) or **epigenetic** (deposited later than the host rocks).
- ❖ Deposits may be classified according to their processes of formation into igneous, sedimentary, metamorphic or hydrothermal.

- The **various theories of ore genesis** explain how the various types of mineral deposits form within the Earth's crust.
- Ore genesis theories generally involve three components: **Source, Transport and Trap**. This also applies to the petroleum industry, which was first to use this methodology.
- **Source** is required because metal must come from somewhere, and be liberated by some process.

- ✓ **Transport** is required first to move the metal bearing fluids or solid minerals into the right position, and refers to the act of physically moving the metal, as well as chemical or physical phenomenon which encourage movement.
- ✓ **Trapping** is required to concentrate the metal via some physical, chemical or geological mechanism into a concentration which forms mineable ore.
- ✓ The **biggest deposits** are formed when the source is large, the transport mechanism is efficient, and the trap is active and ready at the right time.

Controls of Ore localization

- **Structural Control**
- **Lithological Control**
- **Stratigraphic Control**
- **Chemical Control**



Schematic diagram for turbidite-hosted gold mineralization









Structural Controls of Ore Localization

- Folding: bending of the rocks
- Faulting: fracturing and displacement
- Shearing: sliding parallel to the plane of contact between two rocks
- Compression: colliding together of two rocks
- Extension: separating or increasing the distance between two rocks.

Metallogens in folded region

Nose of the fold, the axial trace and the closure of the fold act as favorable loci for the remobilization and concentration of metals and minerals.

Geologists are keenly interested in **Pre-mineral** structures because these structures influence the localization of ore by hydrothermal fluids utilizing these pathways.

Structures which form after a mineralizing event, and hence may be responsible for offset or removal of mineralized zones, are referred to as "**Post-mineral**"

- Fractures and fault zones provide excellent pathways for hydrothermal fluids to circulate through.
- Open-space filling has long been recognized as the primary method of vein formation.
- The formation of **breccia and gouge** due to the grinding action of the rocks adjacent to the fault plane increases the '**structural porosity**', which in turn increases the **permeability**.

- Under certain conditions, breccia or gouge may itself provide the host for mineralization.
- Intersections of structural features often are better locations to prospect for mineralization, especially where the structures are high angle.
- It is thought that the intersection of high angle structures provides pathways for fluids from deep sources to move closer to the surface.

- Fault will produce breccia and gouge.
- A zone of fine-grained gouge will frequently hinder the circulation of fluids.
- On the other hand, coarse, clean breccia, containing a minimum of powdered rock material, results in a considerable increase in permeability.

- Accordingly, faults of minor displacement may be much better hosts for ore solutions than faults of large magnitude, which are more likely to develop gouge.
- As a general rule, tight fractures filled with gouge are less favorable places for ore deposition than the more open fractures.

Detailed structural controls:

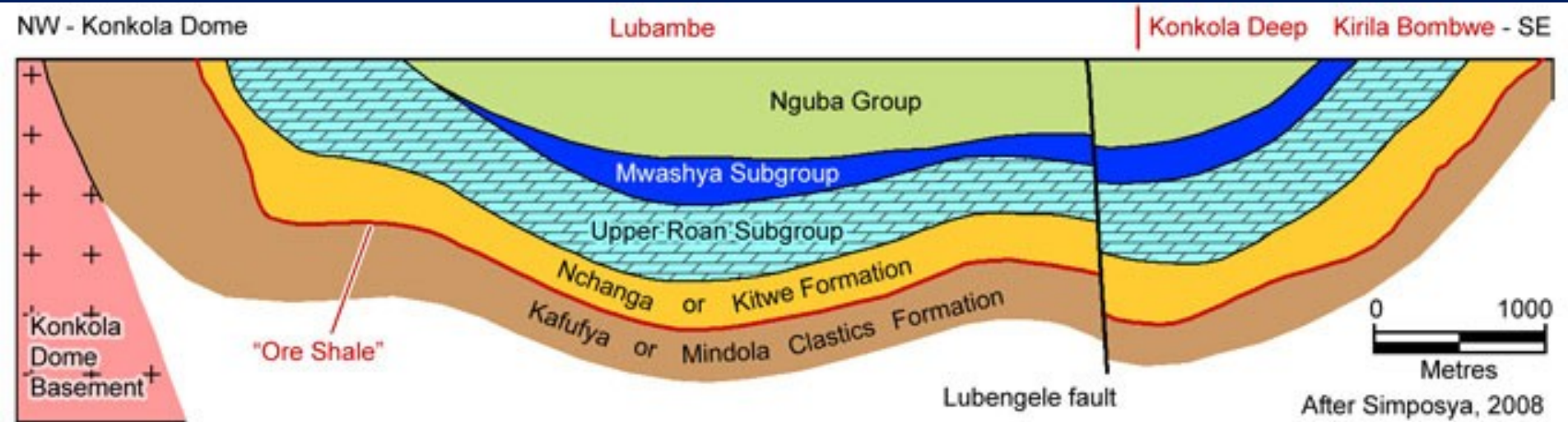
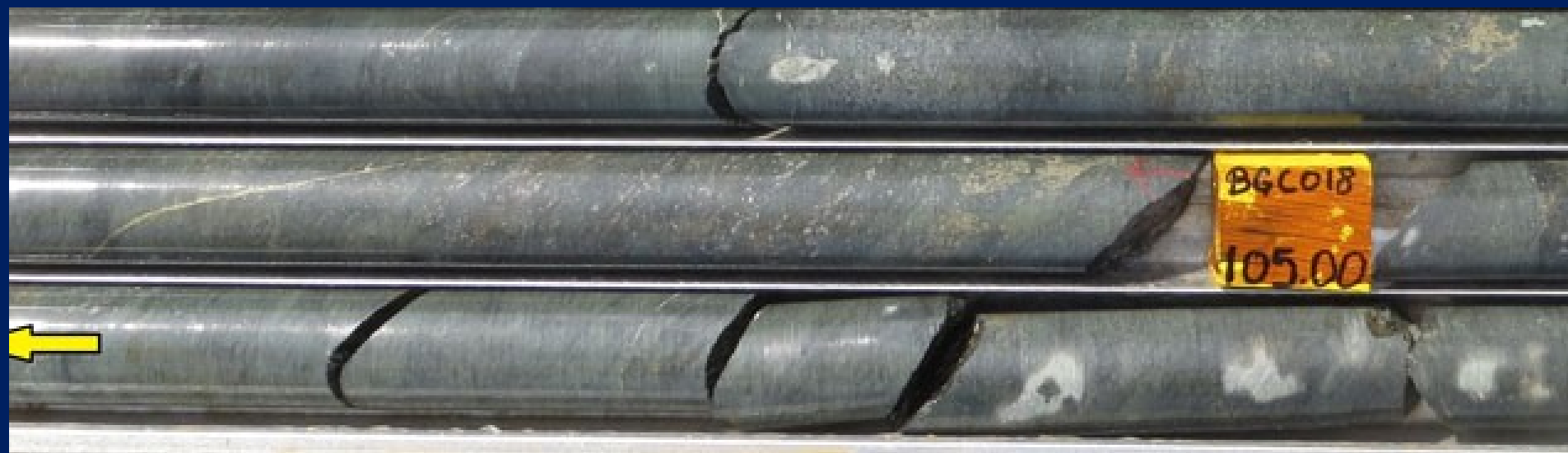
Foliation, bedding plane, lineation, joints etc., are provides passage for mineralizing solution movement.

These structural features receives most attention during mineral exploration.









Idealised longitudinal section through the Lubambe, Konkola Deep and Kirila Bombwe deposits, Zambia

Map 1. A geological map of the Brewery Creek property.

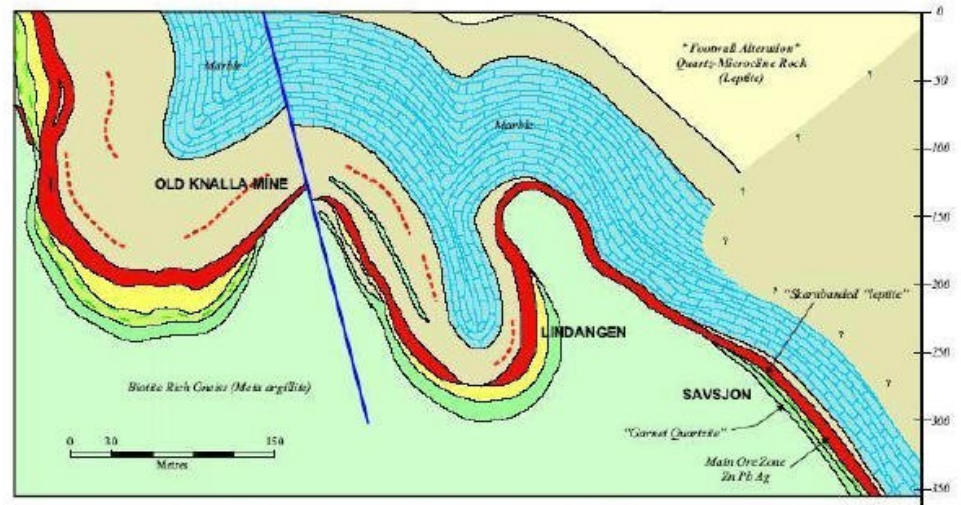
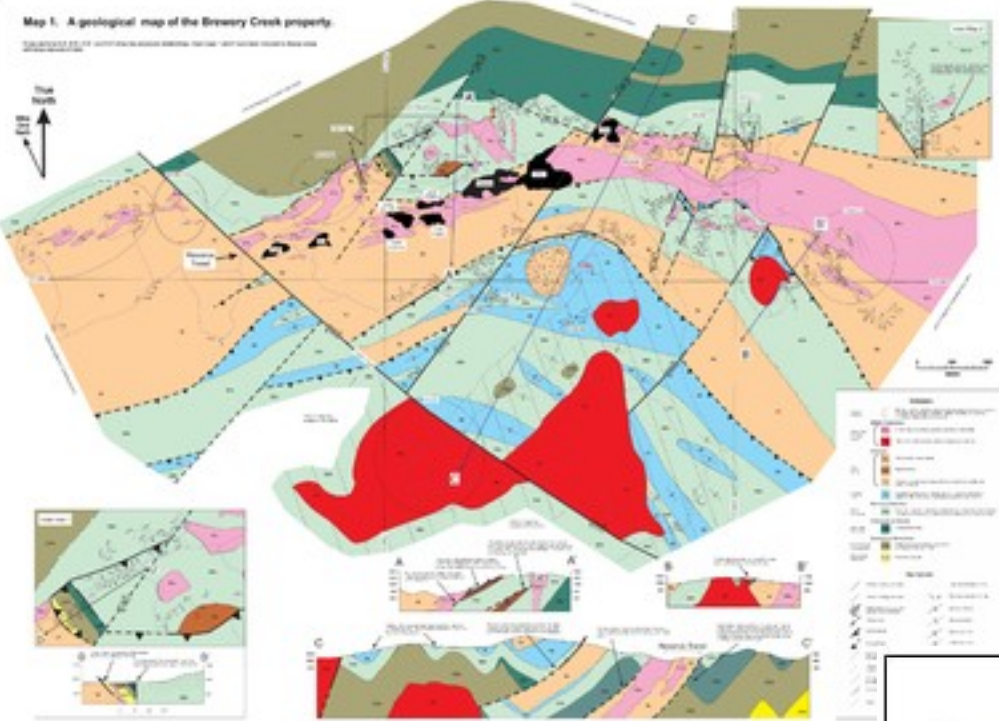


Figure 6.6
Zinkgruvan Mining AB
Zinkgruvan Mine
Southern Central Sweden
Schematic Cross-section - Knalla





Stratigraphic Controls of Ore Localization:

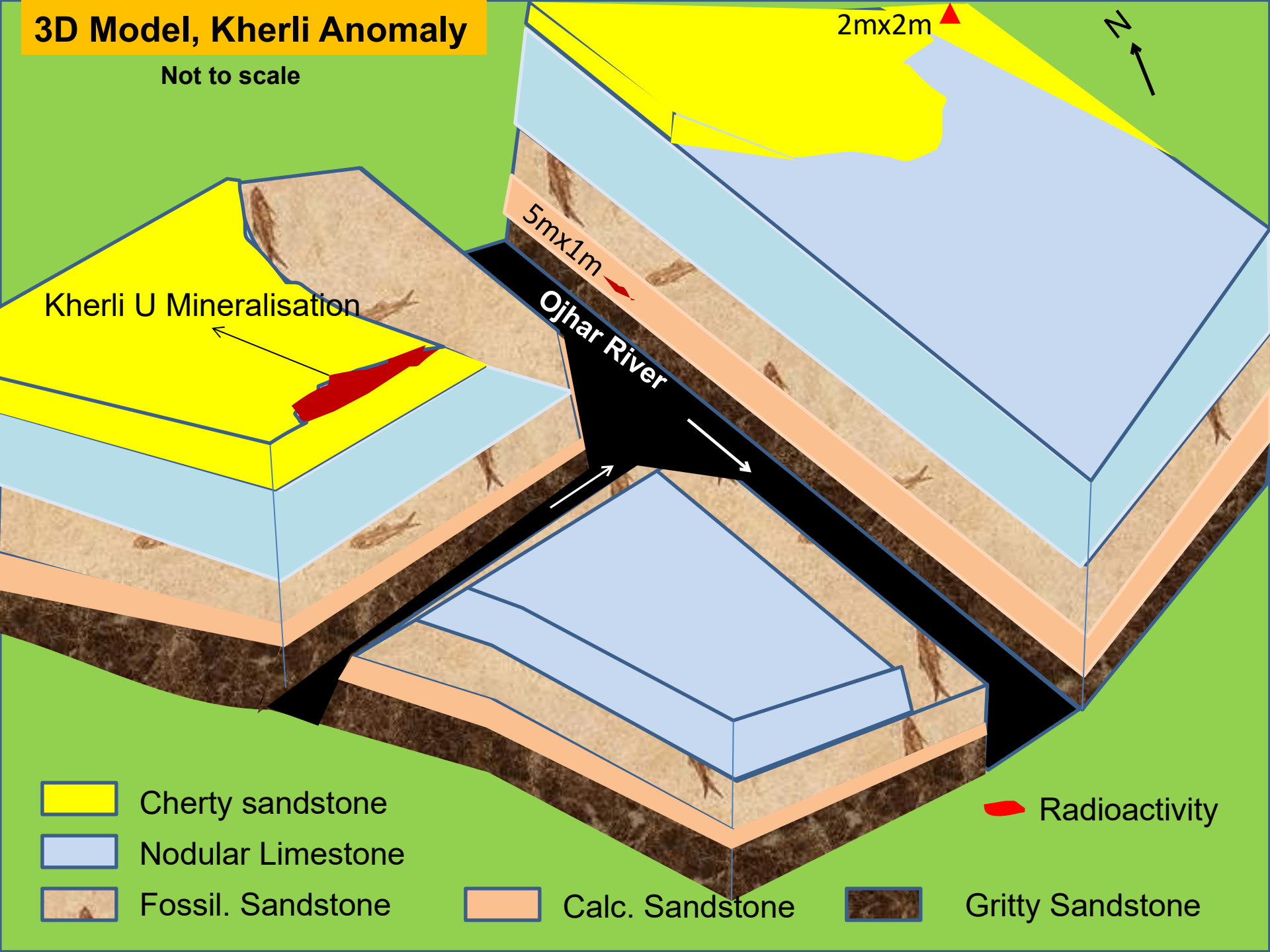
- ✓ Mineral deposits like coal, iron-ore, manganese, phosphate, limestone and also for oil and water come under this group.
- ✓ Impervious rocks acts as barrier for mineral rich fluids.
- ✓ Bedding planes allows fluids to circulate.
- ✓ Unconformities indicate surface of erosion or non-deposition which are favorable loci for accumulation of mineral deposits.
- ✓ Strata-bound mineral deposits

- The majority of sediment-hosted strata bound Cu deposits are formed within continental-rift basins due to movement of moderately low pH and oxidized fluids within permeable, shallow-water sedimentary and, more rarely, volcanic rocks (Brown,1992).
- Copper, silver, cobalt, lead, uranium and other metals are leached from minerals within the sedimentary and/or igneous rocks and carried else where and precipitated.
- Cox et al.(2007) sub divided sediment-hosted Cu deposits into three groups, based primarily on how Cu precipitates from the fluids.

- In the reduced-facies deposits, oxidized mineralizing brine interacts with some form of reductant and deposits Cu±Ag±Co above or lateral to the red-bed sedimentary rocks.
- This reductant may be a reduced unit, such as black shale, or sulphur derived by bacterial reduction of sea water sulphates (Cailteux et al., 2005).
- Presence of these reductant leads to large, high-grade deposits.

3D Model, Kherli Anomaly

Not to scale



2mx2m

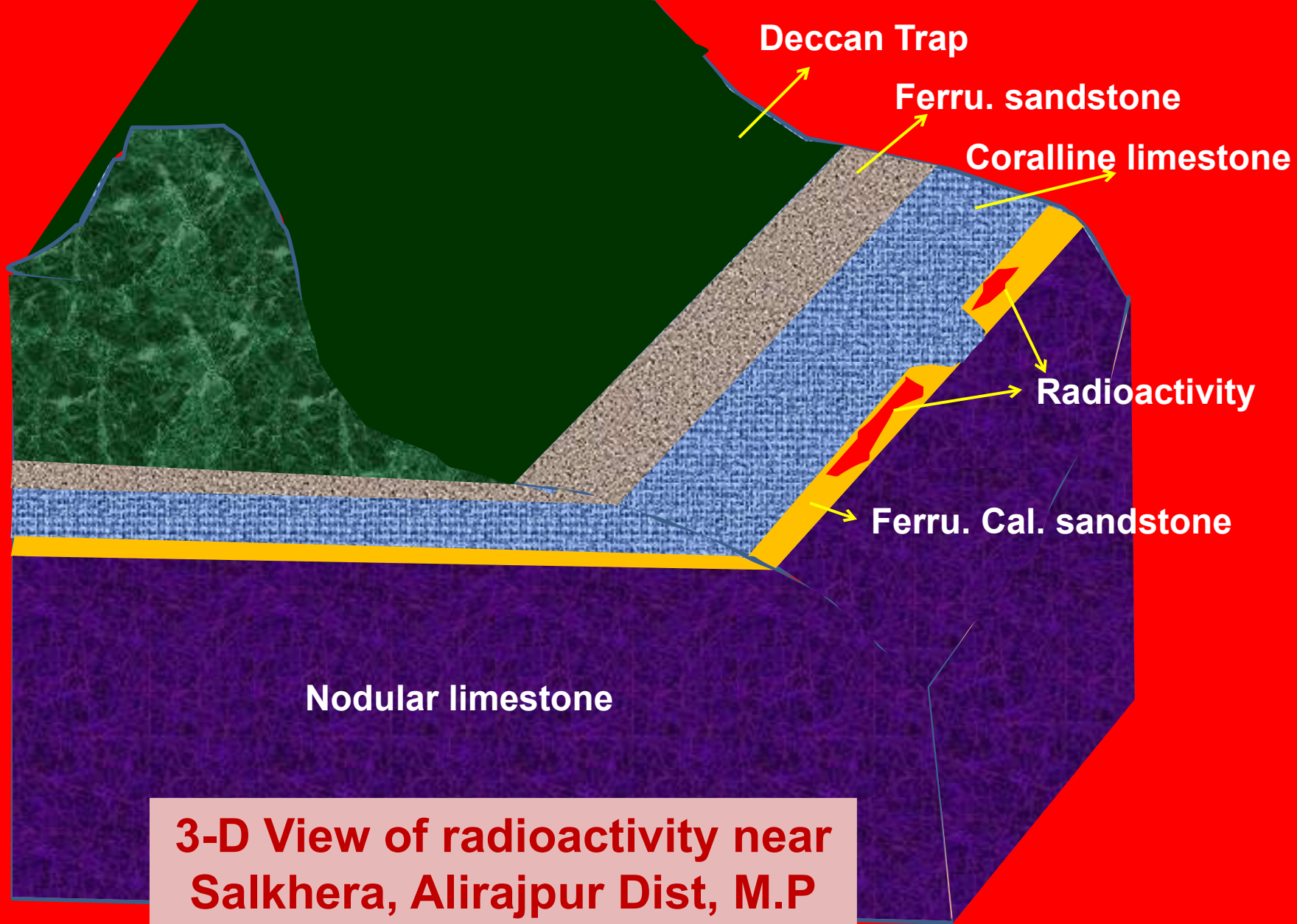


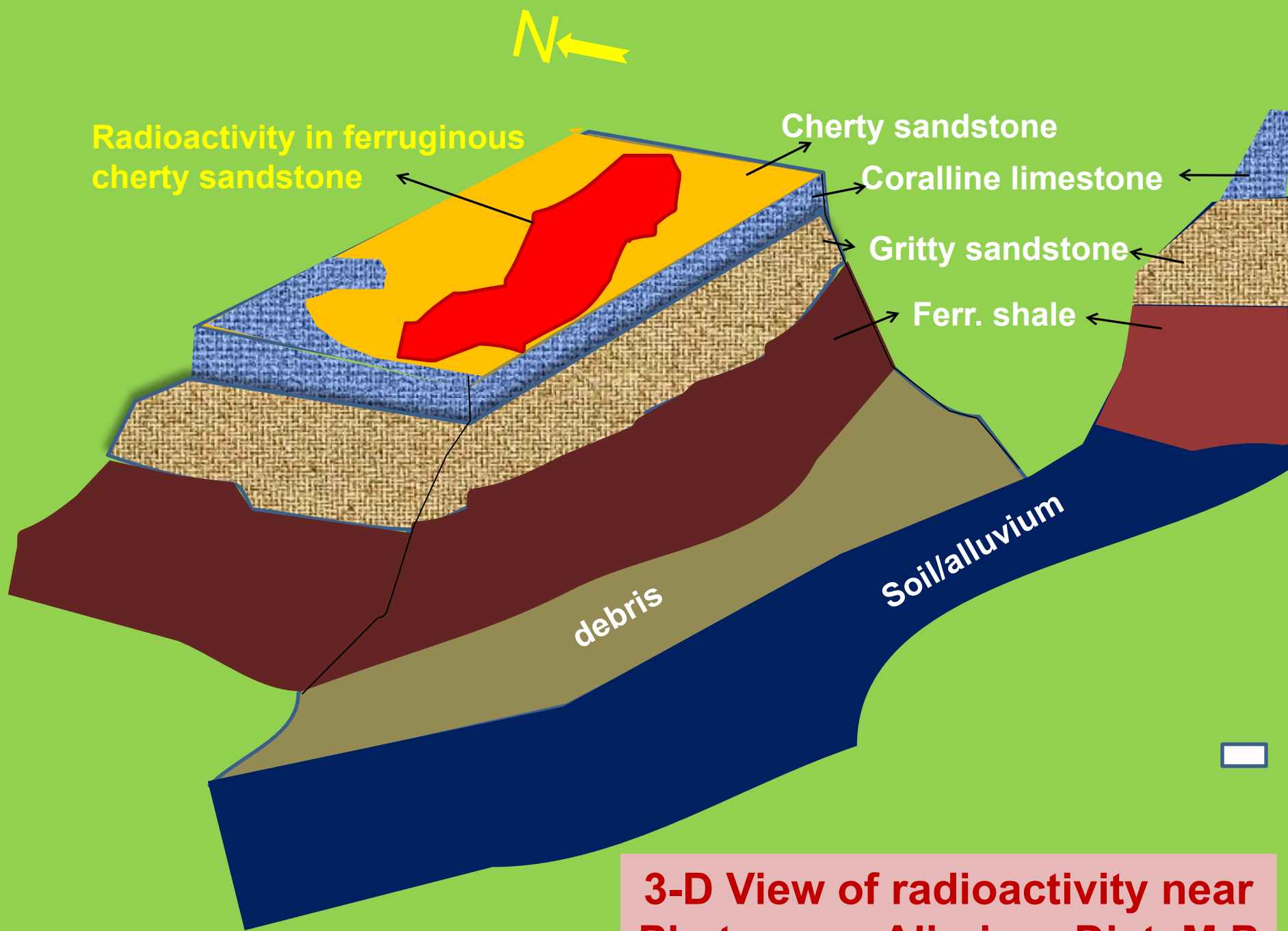
Kherli U Mineralisation

5mx1m

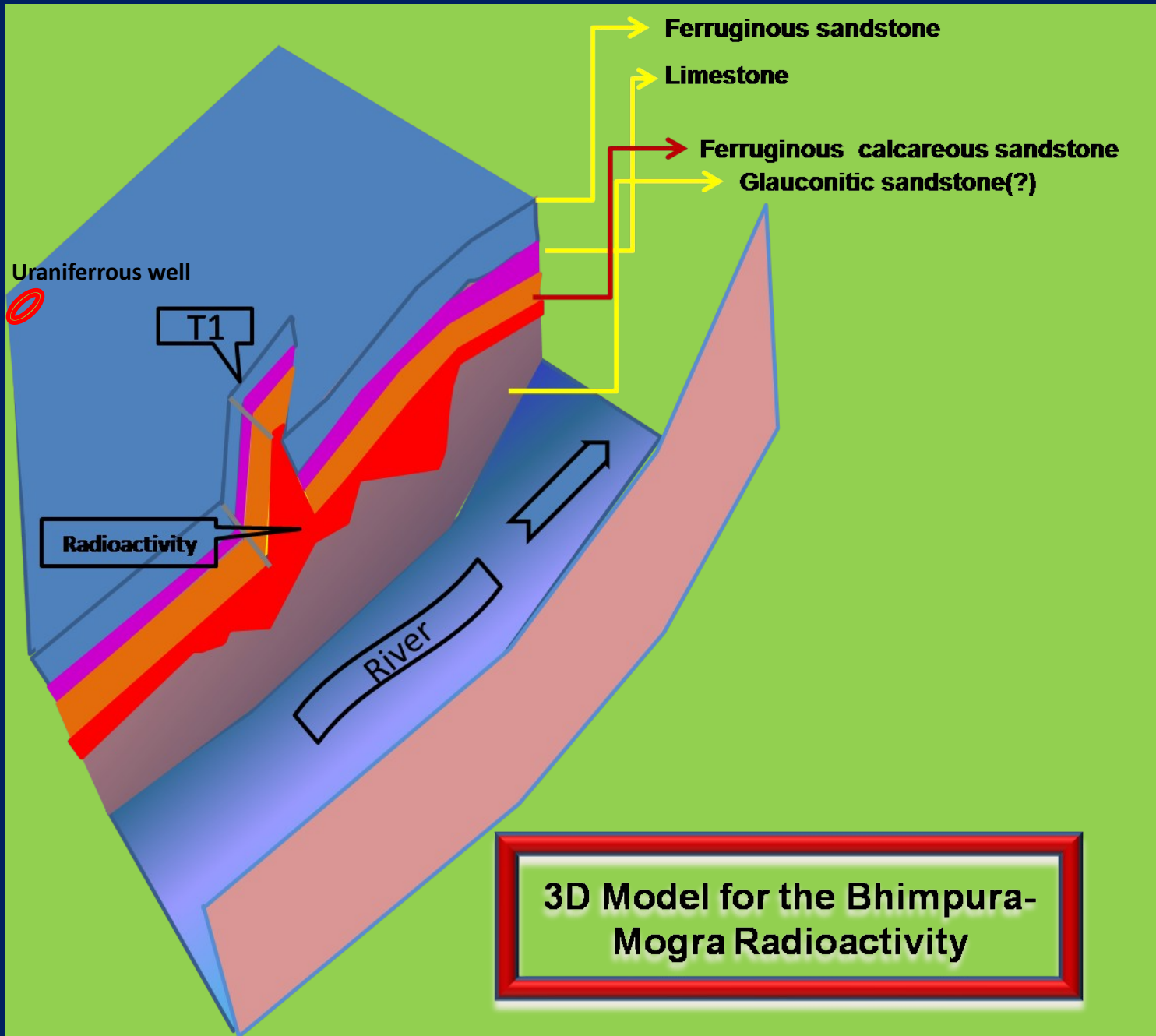
Ojhar River

-  Cherty sandstone
-  Nodular Limestone
-  Fossil. Sandstone
-  Calc. Sandstone
-  Gritty Sandstone
-  Radioactivity



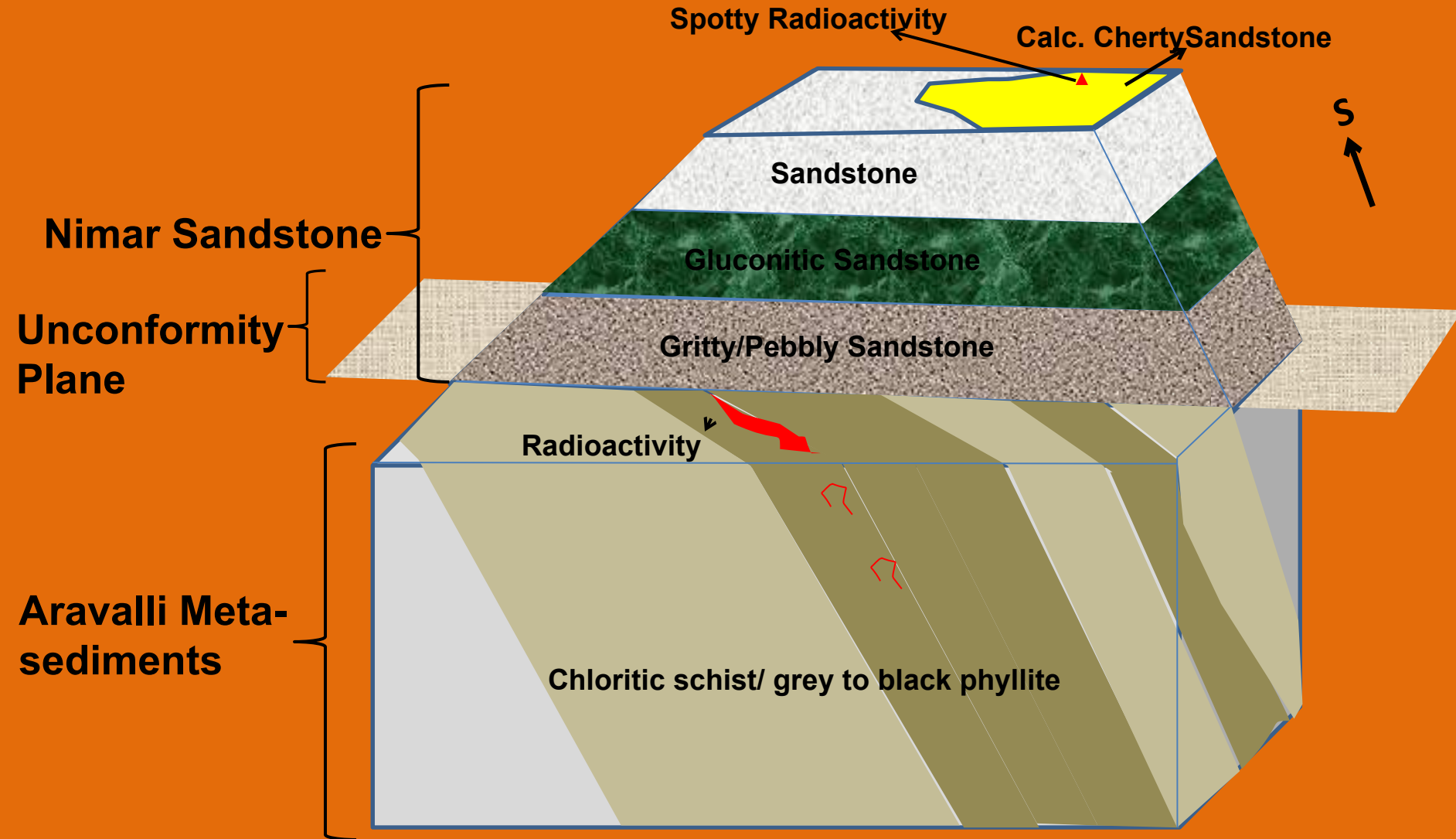


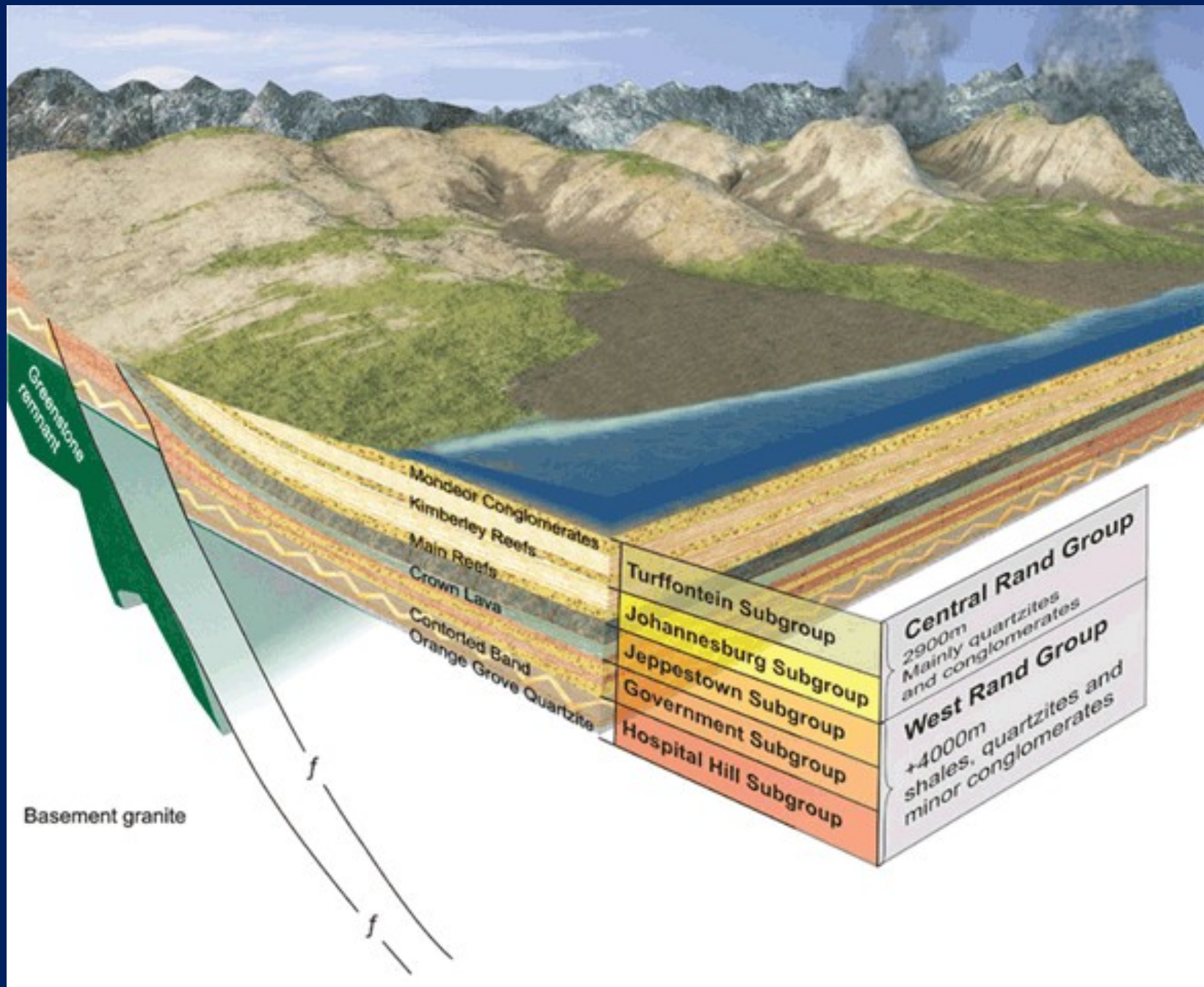
3-D View of radioactivity near Phata area, Alirajpur Dist, M.P

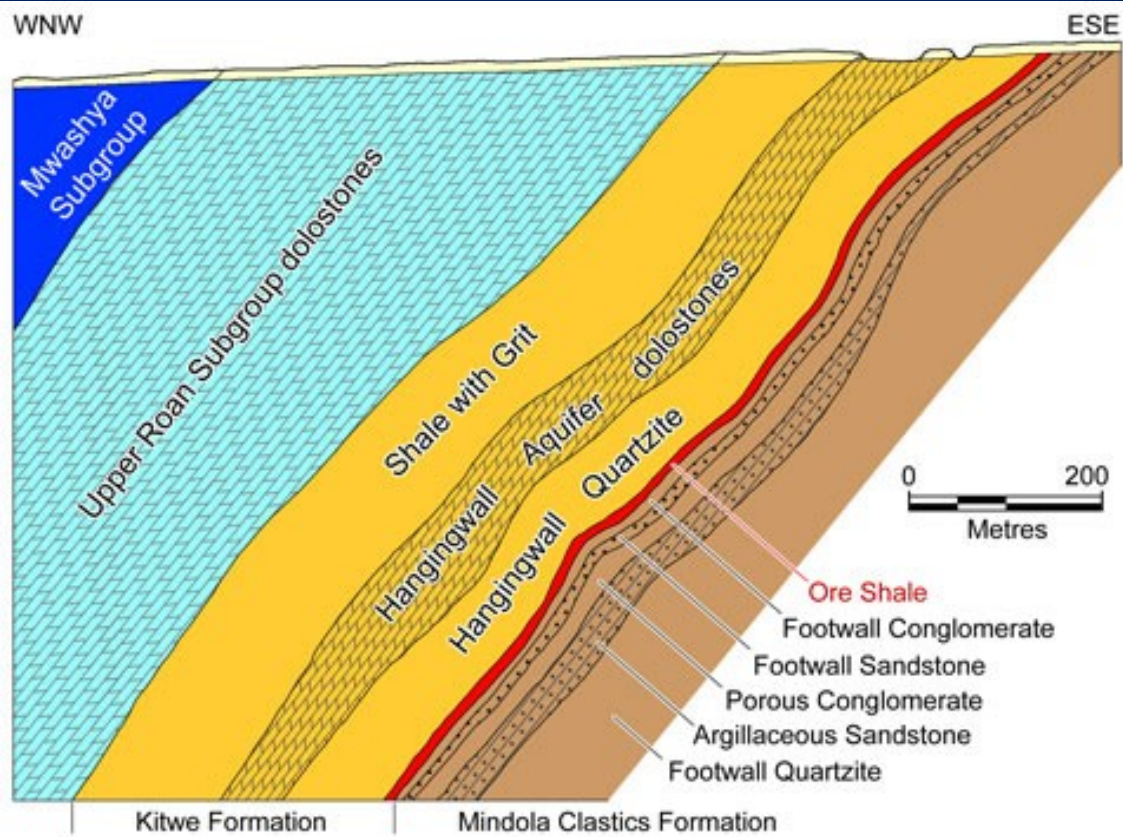
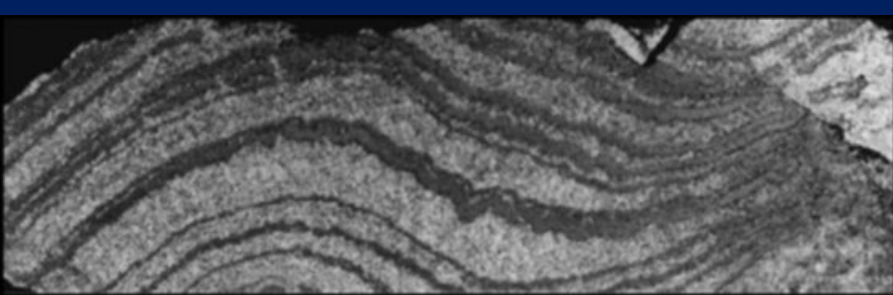


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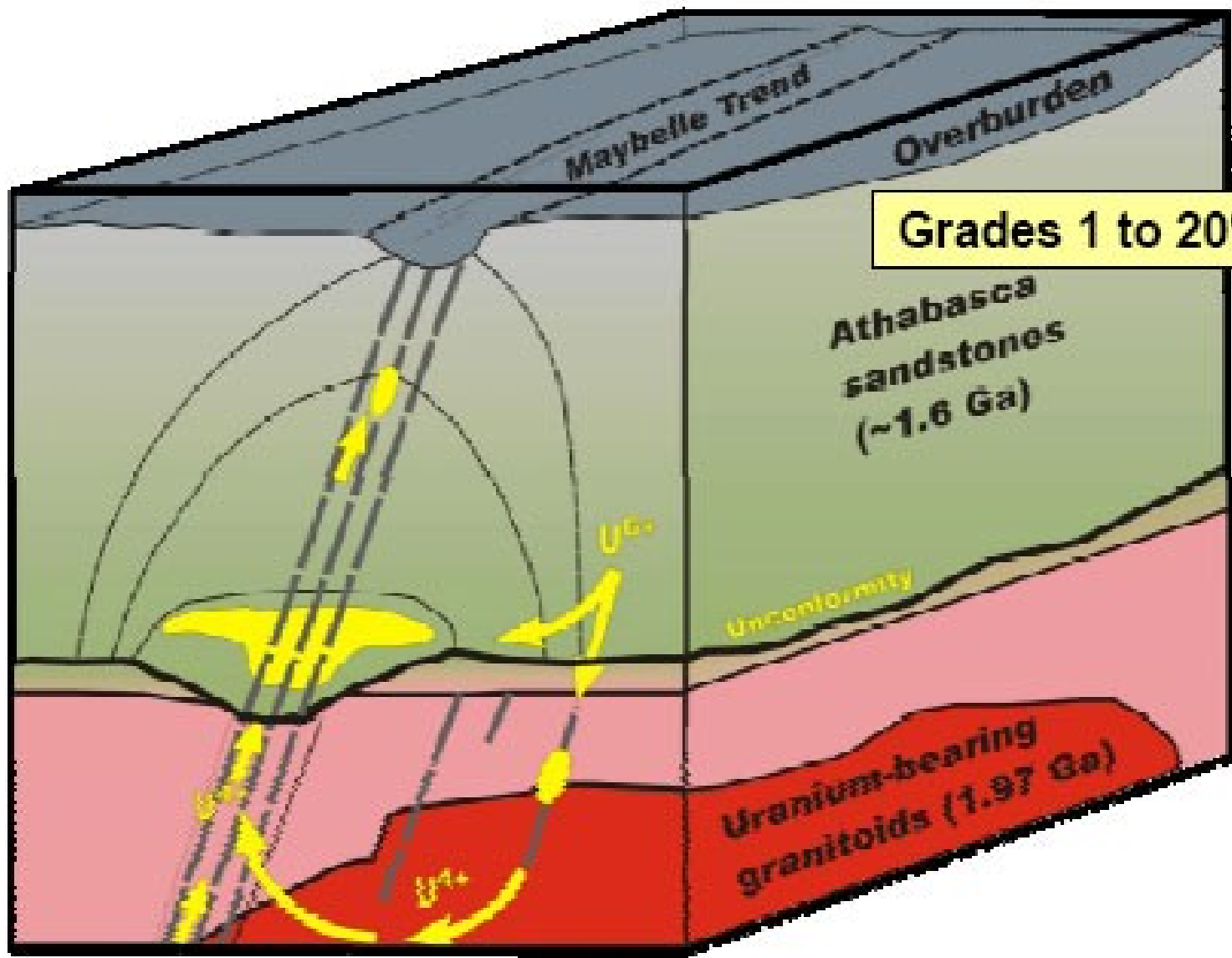
3D View for Jamni Radioactivity, Alirajpur Dist., M.P







Representative cross section through the Kirila Bombwe North deposit Konkola, Zambia



Grades 1 to 20% U³O₈

Athabasca sandstones (~1.6 Ga)

Unconformity

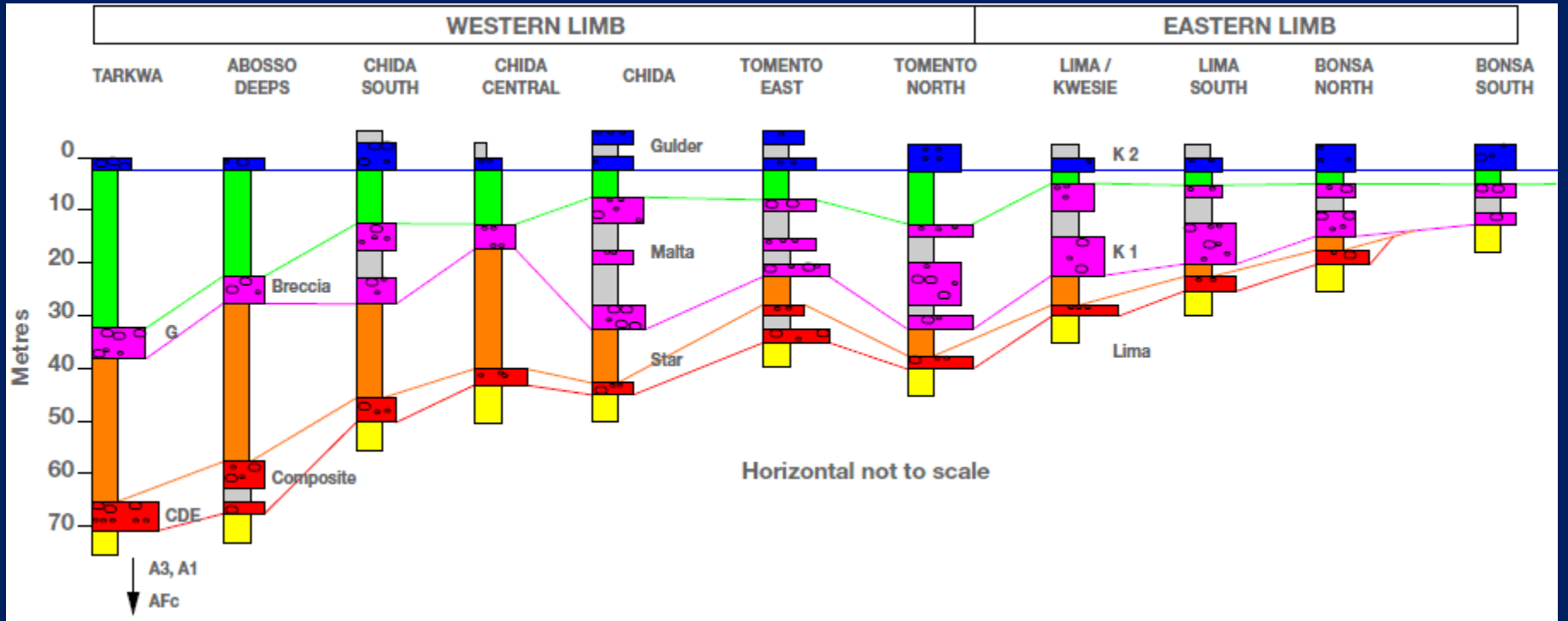
Uranium-bearing granitoids (1.97 Ga)

Maybelle Trend

Overburden

U₆₊

U₆₊





Lithologically controlled mineralization

Minerals like Barite, chromite, copper, gold, graphite, iron, manganese, molybdenum, pyrite, pyrhotite etc minerals are controlled by lithology.

For example, Barite is typically associated with charnockite. Chromite with ultrabasic rocks. Copper with hornblende gneiss. Gold with quartz veins, iron ore with BMQ. Diamond is associated with Kimberlite. Tin, Tungsten&Uranium associated with Granite and Pegmatite.

Physiographic controlled mineralization

- **Denudational domains**
- **Fluvial Sediments**
 1. **Bajadas**
 2. **Paleochannels**
 3. **Levees**
- **Marine domains**
 1. **Coastal area**
 2. **Beach ridges**

Physiographic controlled mineralization

- **Denudational domains**

During the process of denudational activities, the rare minerals are transported away leaving the denser minerals segregated in the debris slope.

- **Fluvial Sediments**

- 1. Bajadas**

The river in catchment stage erode materials and dump them in foot hills as alluvial cone and fan which in course of time form piedmont and bajada zones. In due course, owing to the specific gravity differences the heavy metals and minerals are concentrated in bajadas while the lighter ones are transported by river system

- **Fluvial Sediments**

- 1. Paleochannels**

Paleochannels are remnants of river and stream channels that have been filled with sediments and overlain by younger units. It is formed due to constant migration of the river or due to major tectonic activity.

Physiographic Guide:

- **It may serve either as direct or indirect evidence of the presence of ore.**
- **Surface expression of an ore body is direct indication. Fault scarp, hogbacks and cuesta serve as indirect indications.**

Eminences and Depressions

- **Quartz vein makes ridge and unsilicified rocks makes valleys**
- **Special kind of debris may act as guide for mineral exploration**

- **Oxidational Subsidence** forms due to removal of support through shrinkage of ore bodies during oxidation.
- Topography as a guide to **Iron ore**. (Massive and large)
- Physiographic relation of **placer deposits** (Gold, heavy minerals etc)
- Physiography in relation to **oxidation and enrichment**. (Residual ore- bauxite, laterite iron ore and some manganese ore. Supergene enrichment ore- sulphide enrichment of copper and silver ore)

Mineralogical Guide

- The minerals that are present and their relative abundance serve as very important practical guides in ore search.
- Oxidized minerals at the surface serve as an indication of what lies beneath.
- **Nature of Alteration**

Mineralogical changes are very common in rocks surrounding the epigenetic ore deposits which is due to introduction of certain new chemical elements or removal of others.

Common alteration minerals characteristics of various types of mineralization:

- 1. With Hypothermal mineralisation: garnet, amphibolite, pyroxenes, tourmaline and biotite.**
- 2. With Mesothermal mineralisation: sericite, chlorite, carbonates and silica.**
- 3. With Epithermal mineralisation: some sericite, often much chlorite, carbonate and alunite**

Stratigraphic as a guide

- If the ore occurs exclusively in a given sedimentary bed, the bed constitute an ideal stratigraphic guide.
- The ore may be syngenetic (an original part of the body of rock) or epigenetic (introduced into the rock)

In Syngenetic Deposits

- If the ore is an original part of the body of rock, the rock itself will serve as a guide; that is the ore will be found within the particular rock formation and will be absent outside it.

- Stratigraphic sequence and structure of the beds must be known in order to predict where the outcrop will be found or at what depth the ore will be at any given point.
- Syngenetic deposits of igneous origin are usually less regular than sedimentary beds. However in some thick sills and lopolith, the rocks constituents have a very regular stratiform arrangement.

In Epigenetic Deposits

- Ore has been introduced into the rocks/formations where the ore follows the fracture or replaces the rock/formation.
- Replacement ore bodies differ from most syngenetic deposits because not all of the stratum is favorable for ore localization.
- Replacement within the bed is often controlled receptive nature of the bed. For example, chloritic slates and phyllites are most receptive to gold deposits

Ground water as Guide

- Ground water analysis result gives indication about the elemental concentration and enrichment. So it will guide to locate the area of interest for mineral exploration.

Geobotanical as a guide:

- Metals and other elements may modify the appearance of foliage. Certain elements play a major role in determining what species of plants which are able or unable to grow in a given place.
- Plants can also take certain elements selectively.

GEOLOGIC TIME

- When evaluating the ages of rocks we speak of two types of terms of ages called “absolute age” and “relative age”.
- “Absolute age” is measured in years, and depends on having some type of time scale to measure against, typically by using a highly technical chemical dating method.
- “Relative age” simply means placing one geologic event or feature in context with another in a timing sequence.

Absolute Age During the early 1900's, shortly after the discovery of radioactivity, it was discovered that radioactive decay involves the transformation of radioactive atoms into completely different elements.

Uranium changes into lead at a rate such that half of the original amount will be converted to lead after a period of 4,500 million years. Half of the remaining uranium will convert to lead in another 4,500 million years, and so on. Therefore the “half life” of uranium is 4,500 million years. .

By measuring the ratio of unchanged uranium to lead in a sample, and knowing the rate of decay, we can calculate the length of time the sample has been disintegrating, or in other words, the age of the rock. Besides the Uranium-Lead method, several other radiometric techniques are available, including Carbon 14 and Rubidium-Strontium

- *Relative Age*
- Where different rocks are in physical contact and observable, the relative ages of the rocks can often be determined evaluating superposition and cross-cutting relationships.
- Rocks comprising the upper strata are younger than rocks comprising the lower strata. Rocks formed from an intruding magma are younger than the rocks they intrude.
- Inclusions within an igneous rock are older than the magma which formed the matrix.

When different rocks are in close proximity but their actual contacts are not visible, a geologic map and cross-section can be made which illustrate the geometric relationships of the rocks, and allows the determination of relative age.

Difficulty is encountered when attempting to correlate rocks which are not in direct contact or even close proximity.

Fortunately geologists have worked out the evolutionary succession of fossil forms. It was found that sedimentary rocks containing fossils could easily be placed in a successive sequence with respect to time by identifying the fossil assemblages present.