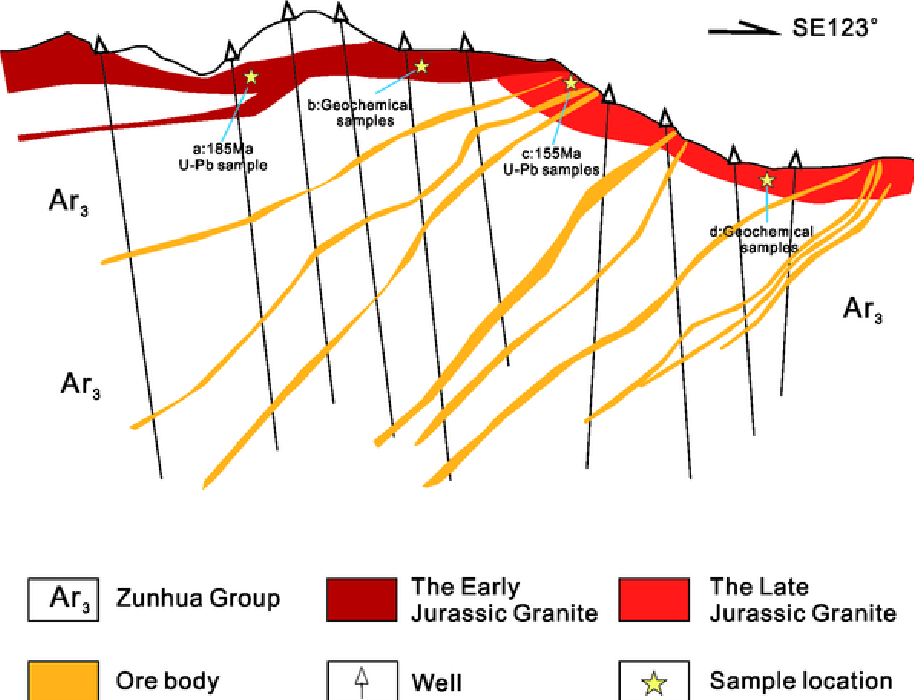
Mineral Exploration
Unit-1

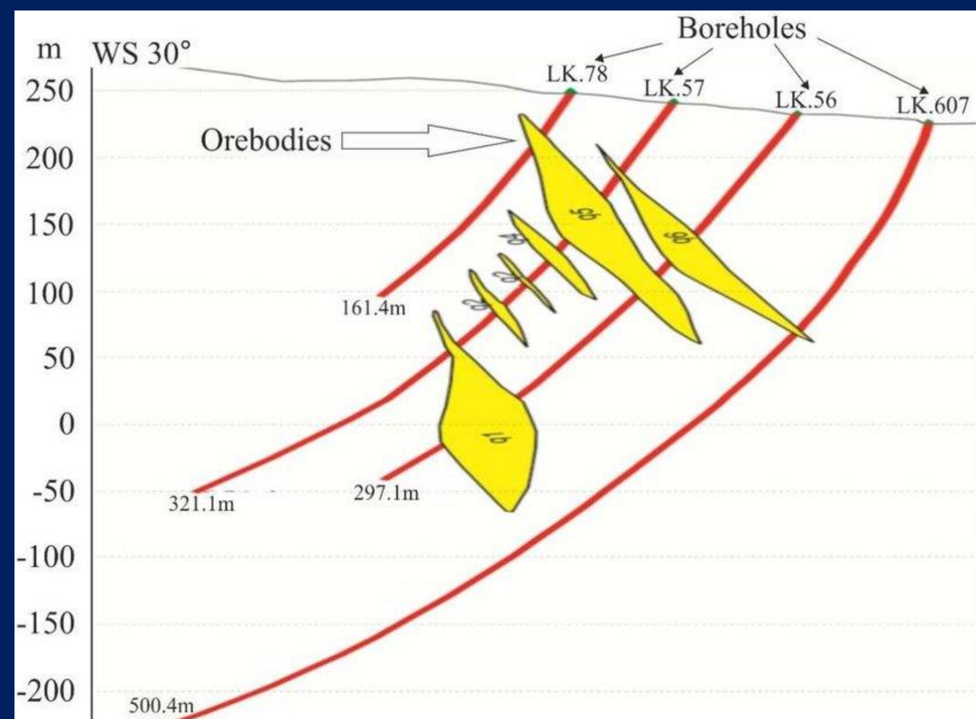
What is Exploration?

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.


SE123°
b:Geochemical samples
a:185Ma U-Pb sample
c:155Ma U-Pb samples
d:Geochemical samples
Ar3
Ar3
Ar3
Ar3 Zunhua Group
The Early Jurassic Granite
The Late Jurassic Granite
Ore body
Well
Sample location


m
WS 30°
Boreholes
LK.78
LK.57
LK.56
LK.607
Orebodies
250
200
150
100
50
0
-50
-100
-150
-200
161.4m
321.1m
297.1m
500.4m

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.

Copper Ore

Malachite is copper carbonate hydroxide mineral, with the formula $Cu_2CO_3(OH)_2$

Iron Ore

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.

Cu: Opencast 0.4%
Underground 1%
Gold ore grade is 5.26 g/t.

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

Coal seams presently being mined range from 2.1m to 12.2m

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 selected 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.

Exploration Stages

Planning and Area Selection

(i) Area of Unknown potential
(ii) Area >50,000 sqkm

Reconnaissance Phase

(i) Area of unknown but speculative potential
(ii) Area >5000 sqkm
(iii) Scale 1:2,50,000 – 1:1,00,000
(iv) Methods

- Remote Sensing
- Airborne Geophysical Survey such as Airborne magnetic, Airborne Electromagnetic and Airborne Gamma ray spectrometer
- Geochemical (1 sample/sqkm) Soil, water and rock

Follow up Phase

(i) Area of interest 200 – 2000 sqkm
(ii) Scale 1:50,000 – 1:25,000
(iii) Methods
- Remote Sensing
- Geological Mapping
- Radiometric (close spaced)
- Geochemical (2-10 samples/sqkm) Soil, water and rock
- Wide spaced drilling (1 BH / 2 sqkm)

Detailed Phase

(i) Significant areas of anomalies , <10 sqkm

(ii) Methods

- Geological Mapping
- Ground Geophysical survey
- Prospecting, trenching, pitting and sampling
- Radiometric survey grid based
- Geochemical (2-10 samples/sqkm) Soil, water and rock
- Grid drilling (1 BH / 0.5 – 1sqkm)

Development Phase

(i) Prospects

(ii) Methods

- Detailed Geological Mapping
- Trenching, pitting and sampling
- Detailed drilling and ore reserve estimation
- Underground testing, petromineralogical studies
- Milling test pilot plant test etc.


16/05/20

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.

History of Mineralisation

- ❖ **Before 2800ma (Archaean)**
  - ❖ There was no large craton, lithosphere was thin and divided into small oceanic plates.
  - ❖ It is assumed that earth crust was enriched in Uranium. Due to anoxygenic condition U^{4+} to U^{6+} was prevented. However mechanical transportation of Uranium, pyrite and gold has formed some local concentration.
- ❖ No Uranium deposits discovered before 2800ma

- **2800 - 2200ma**
  - By 2600ma, The Archaean cratons were stable over large areas. Cratanisation and differentiation was over by 2300ma.
  - Detrital deposits of uranium, pyrite, gold in association with quartz pebble conglomerate.
  - These deposits due to mechanical transportation.

- **2200 - 1200ma**
  - Large stable craton with thickening of continental crust.
  - Around 2000ma, transition from oxygen poor to oxygen (free oxygen) rich environment.
  - Photosynthesis and photo dissociation of water by UV light started.
  - Mechanical transportation superseded by chemical transportation and re-precipitation. (Ex. Uranium; U^{6+} to U^{4+})
  - Red beds appeared around 2200-1200ma

- Risen of O_2 level led to sudden release of U from older cratonic areas.

- Uranium transported in solution into marine and freshwater basin and precipitated in UO_2 as a result of reducing condition provided by organic matter.

- **1200 - 400ma**
  - Modern plate tectonics initiated around 1200ma. Continental splitting and orogenies with metamorphism and anatexis of metasedimentary.
  - Orogenic peaks occurred during 1200-900ma and 700-400ma (Pan-african age)
  - Vein type of uranium mineralisation is associated with Cu, Co, Ni and Fe. Ex Singhbhum fold belt in Jharkhand.

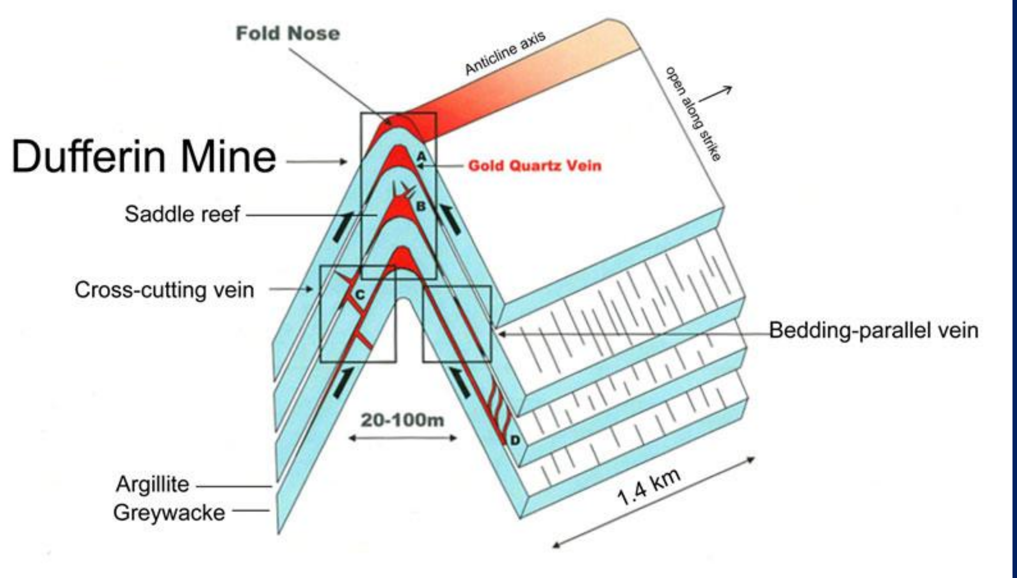
- **The post 400ma**
  - During phanerozoic period, orogenic activity was largely controlled by the movement of many rigid plates, small and large.
  - Subduction, continental collisions triggered widespread magmatism, deformation and metamorphism.
  - Initiation of sedimentation in land locked basins
  - Development of land based flora-fauna
  - Formation of sandstone type mineralisation

Classification of Mineral deposits

- Quartz Pebble Conglomerate type-QPC
- Unconformity contact
- Structure controlled hydrothermal vein type
- Sandstone type
- Breccia complex
- Phosphorite
- Metasomatite
- Surfacial

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.

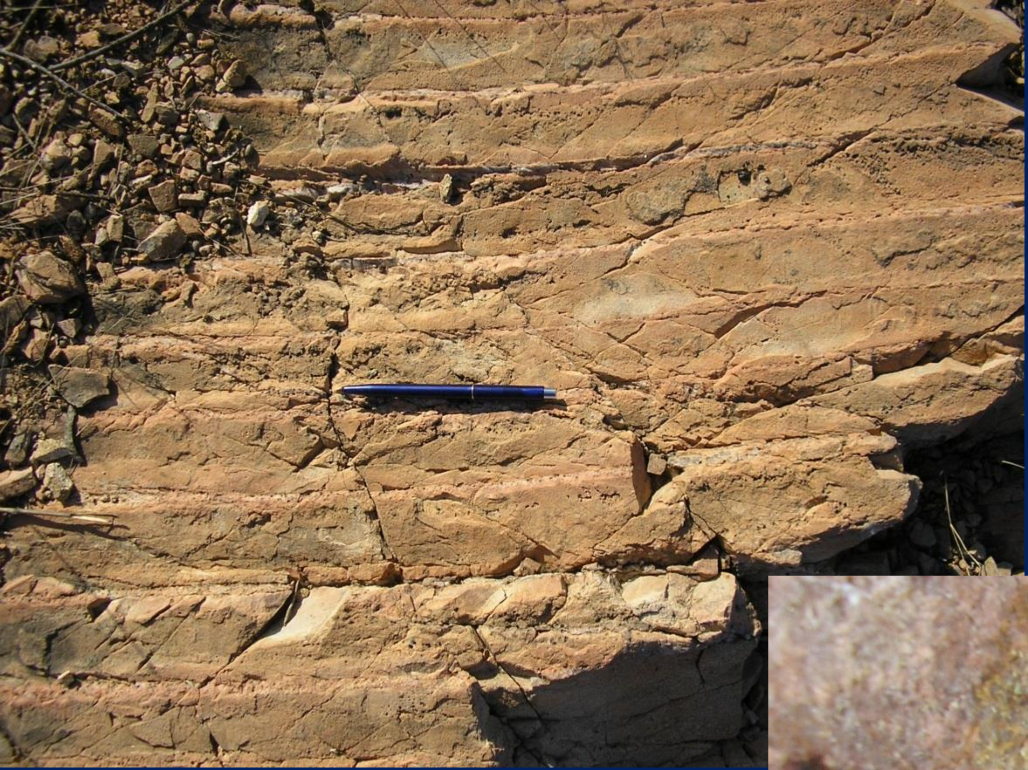
- As a general rule, tight fractures filled with gouge are less favorable places for ore deposition than the more open fractures.

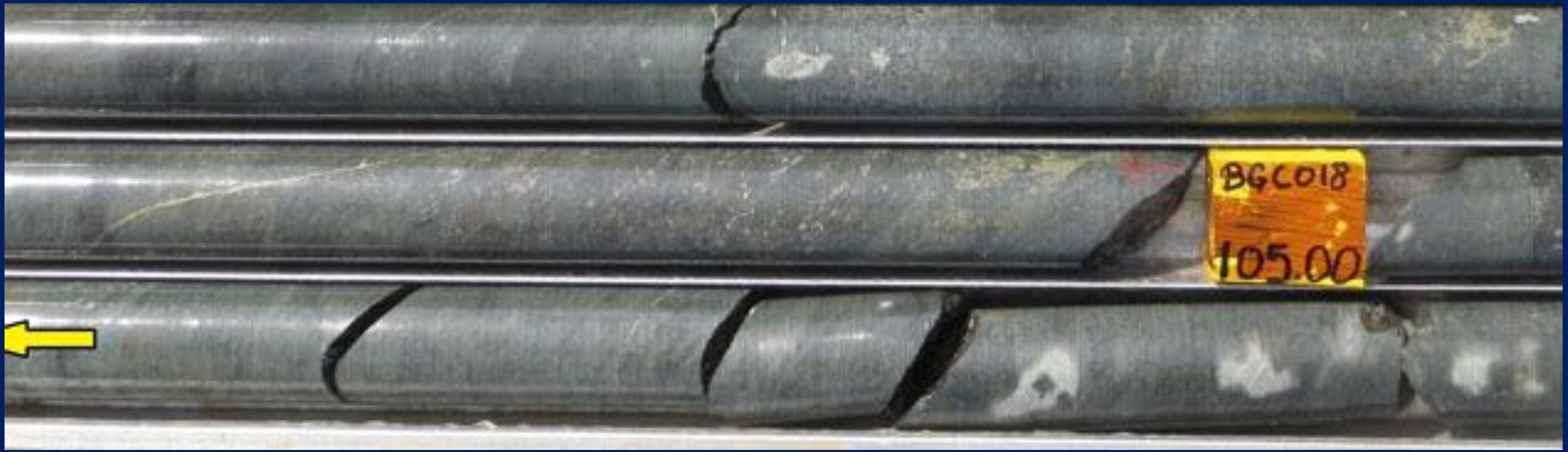
Detailed structural controls:

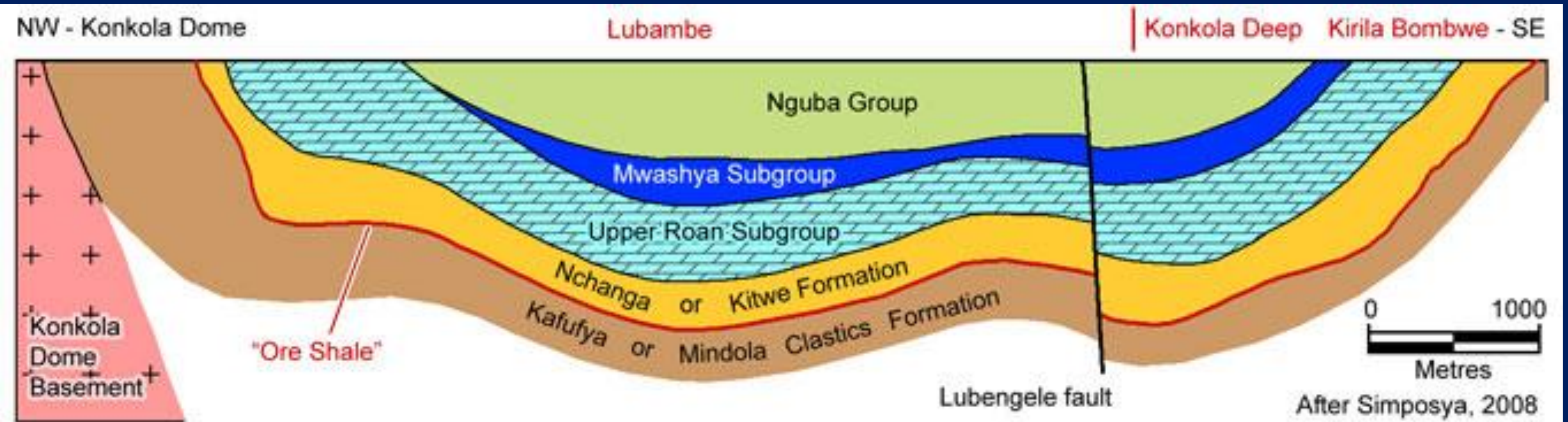
Foliation, bedding plane, lineation, joints etc., are provides passage for mineralizing solution movement.

These structural features receives most attention during mineral exploration.

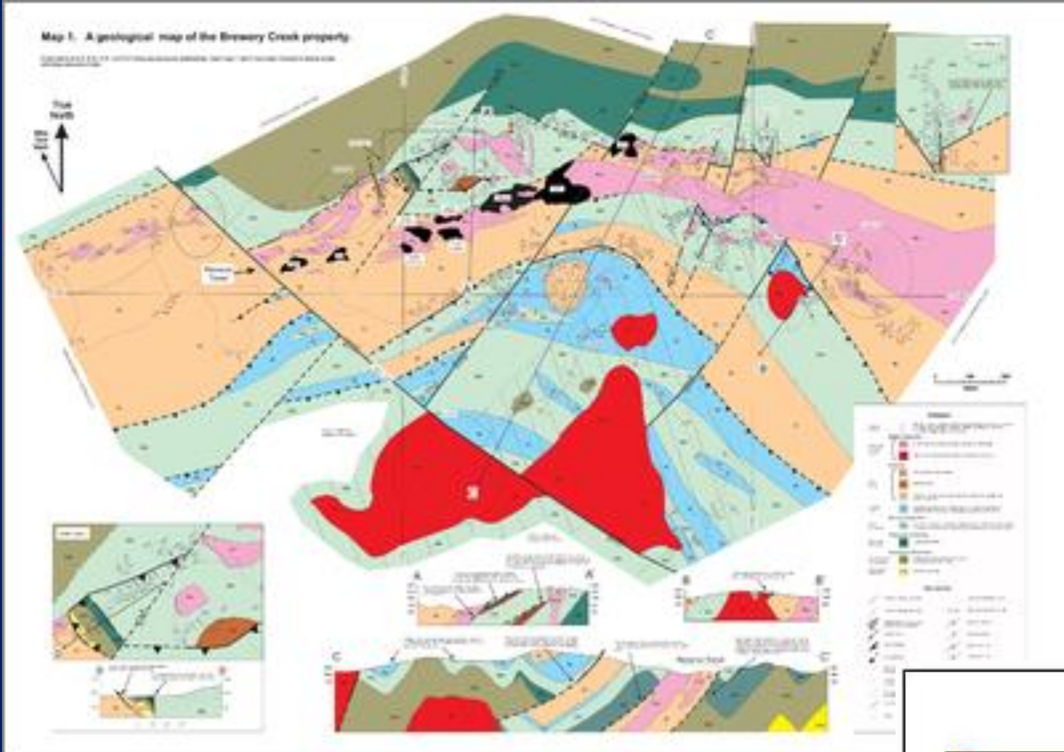

PERMANENT

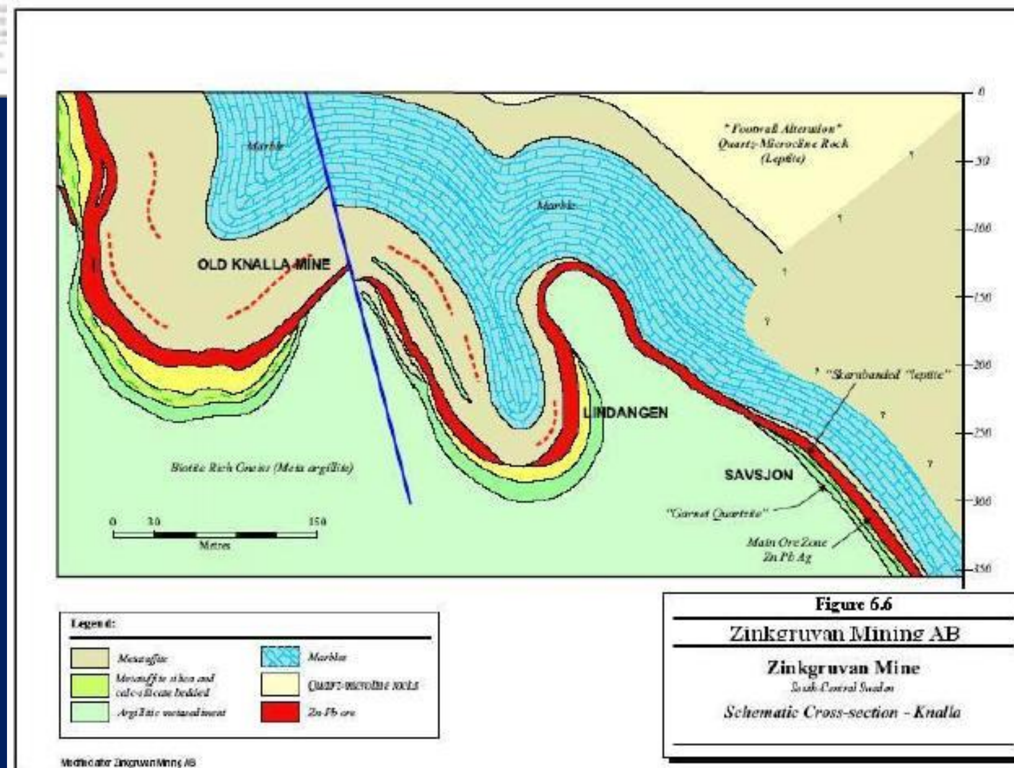





Idealised longitudinal section through the Lubambe, Konkola Deep and Kirila Bombwe deposits, Zambia


Map 1. A geological map of the Brewery Creek property


"Footwall Alteration"
Quartz-Microcline Rock
(Leptite)
Marble
Marble
OLD KNALLA MINE
LINDANGEN
SAVSJON
Biotite Rich Gneiss (Meta argillite)
"Skarnbanded "leptite"
"Garnet Quartzite"
Main Ore Zone
Zn Pb Ag
0
50
100
150
200
250
300
350
Metres
Legend:
Metatuffite
Metatuffite silica and calc-silicate bedded
Argillitic metasediment
Marbles
Quartz-microcline rocks
Zn-Pb ore
Figure 6.6
Zinkgruvan Mining AB
Zinkgruvan Mine
Schematic Cross-section - Knalla
Modified after Zinkgruvan Mining AB

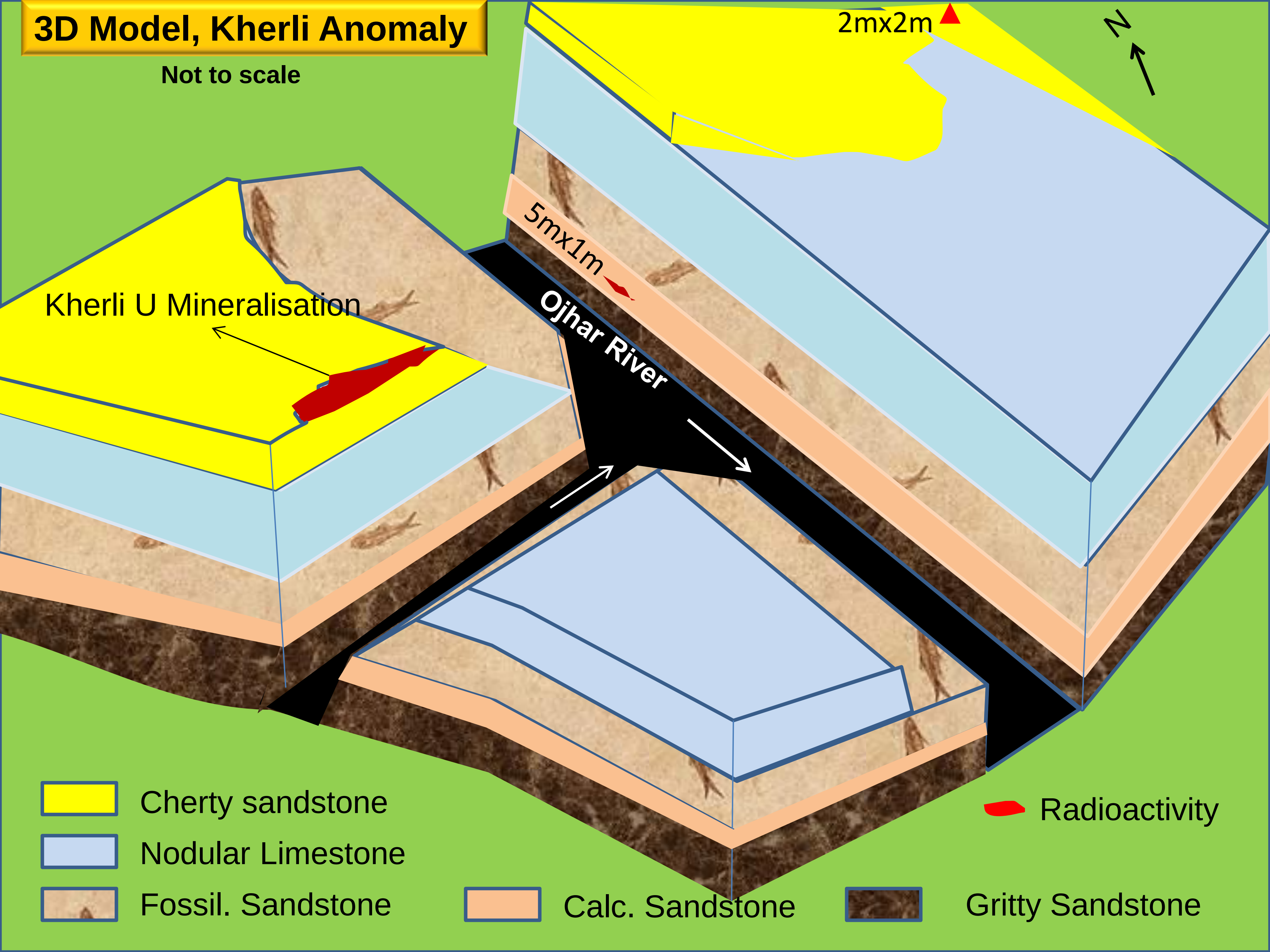

1
RUPEE
2002


Stratigraphic Controls of Ore Localization:

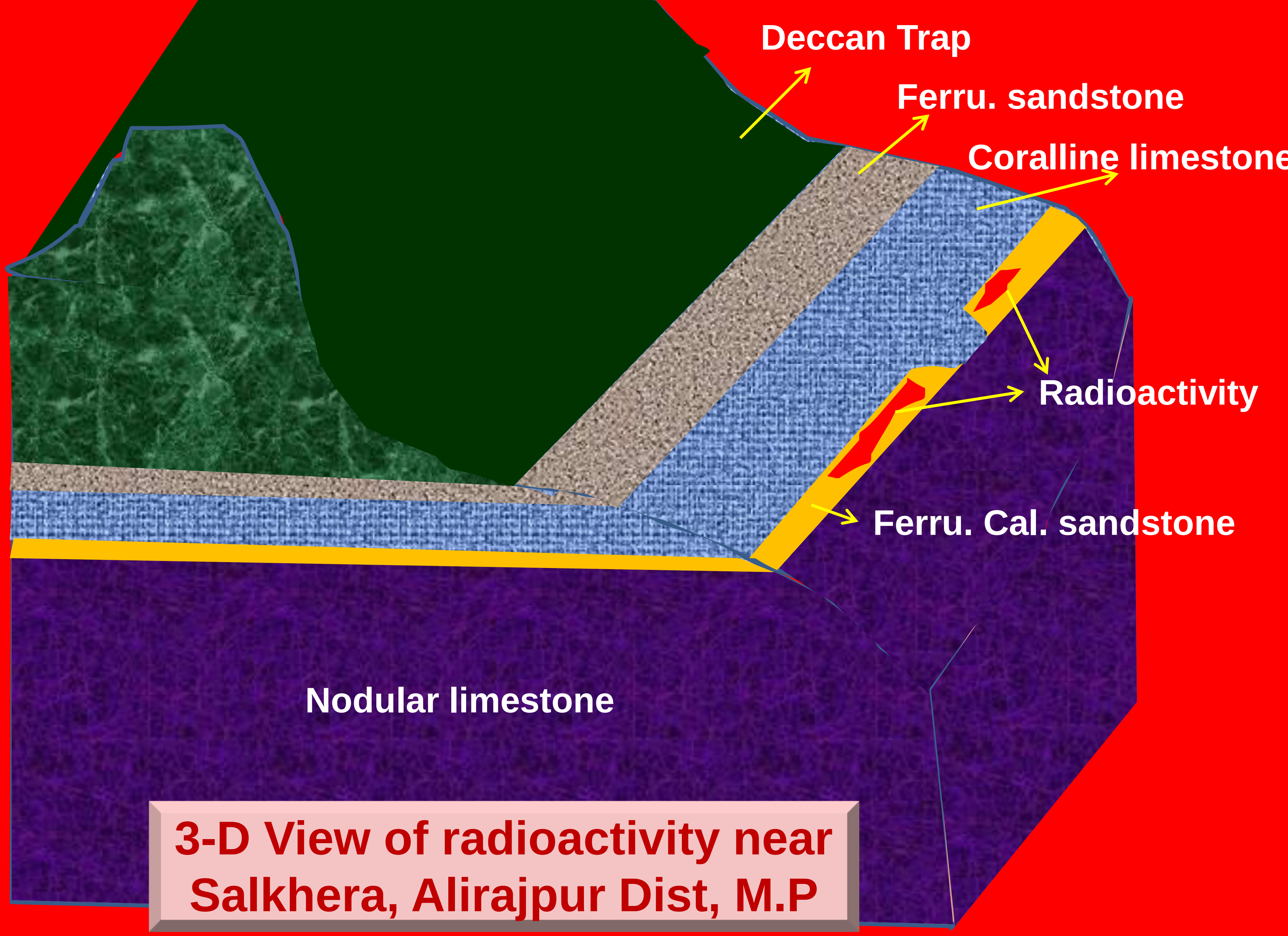
- ✓ Mineral deposits like coal, iron-ore, manganese, phosphate, limestone and also for oil and water come under this group.
- ✓ Impervious rocks acts as barrier for mineral rich fluids.
- ✓ Bedding planes allows fluids to circulate.
- ✓ Unconformities indicate surface of erosion or non-deposition which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

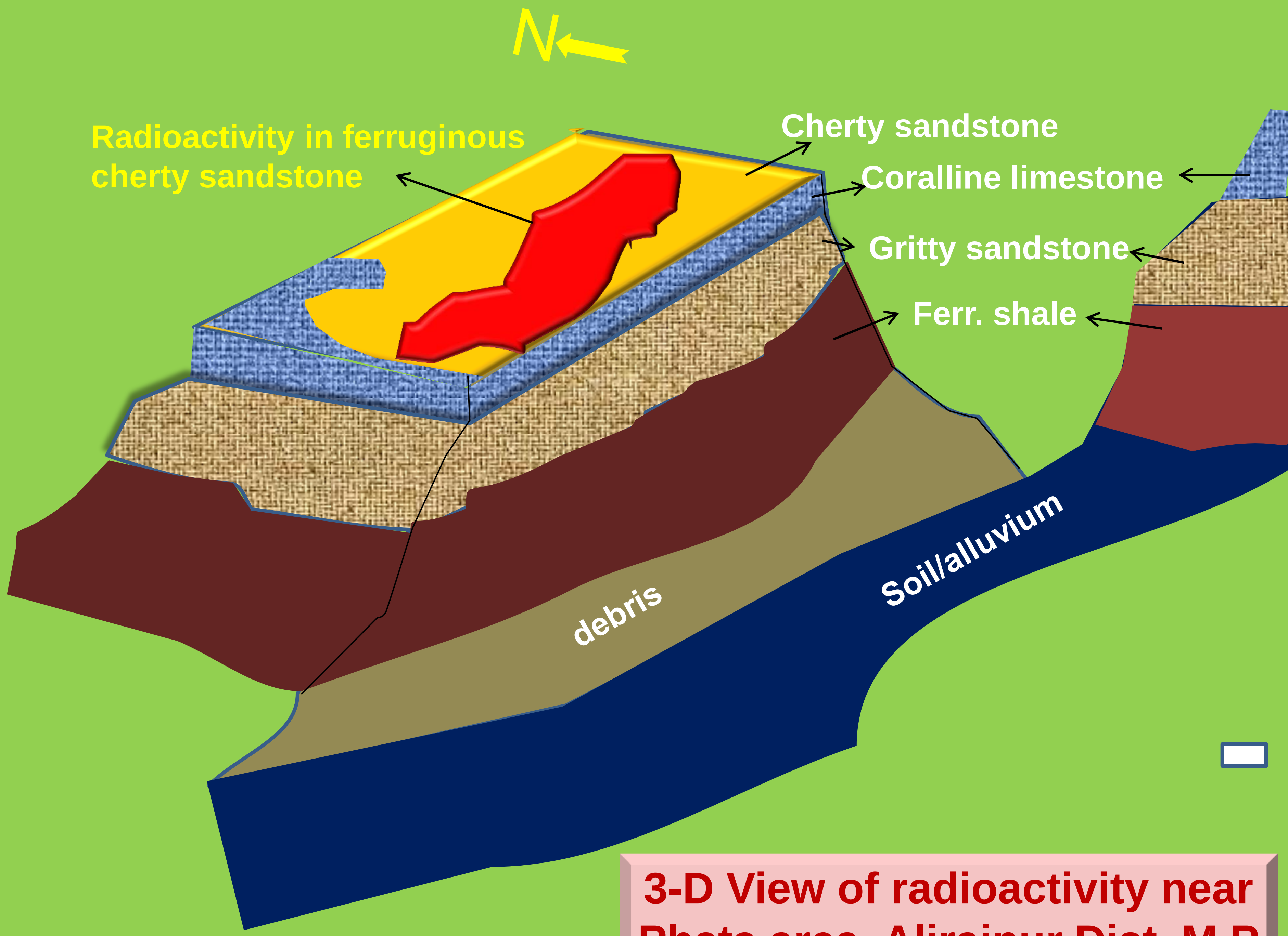
- In the reduced-facies deposits, oxidized mineralizing brine interacts with some form of reductant and deposits Cu±Ag±Co above or lateral to the red-bed sedimentary rocks.
- This reductant may be a reduced unit, such as black shale, or sulphur derived by bacterial reduction of sea water sulphates (Cailteux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



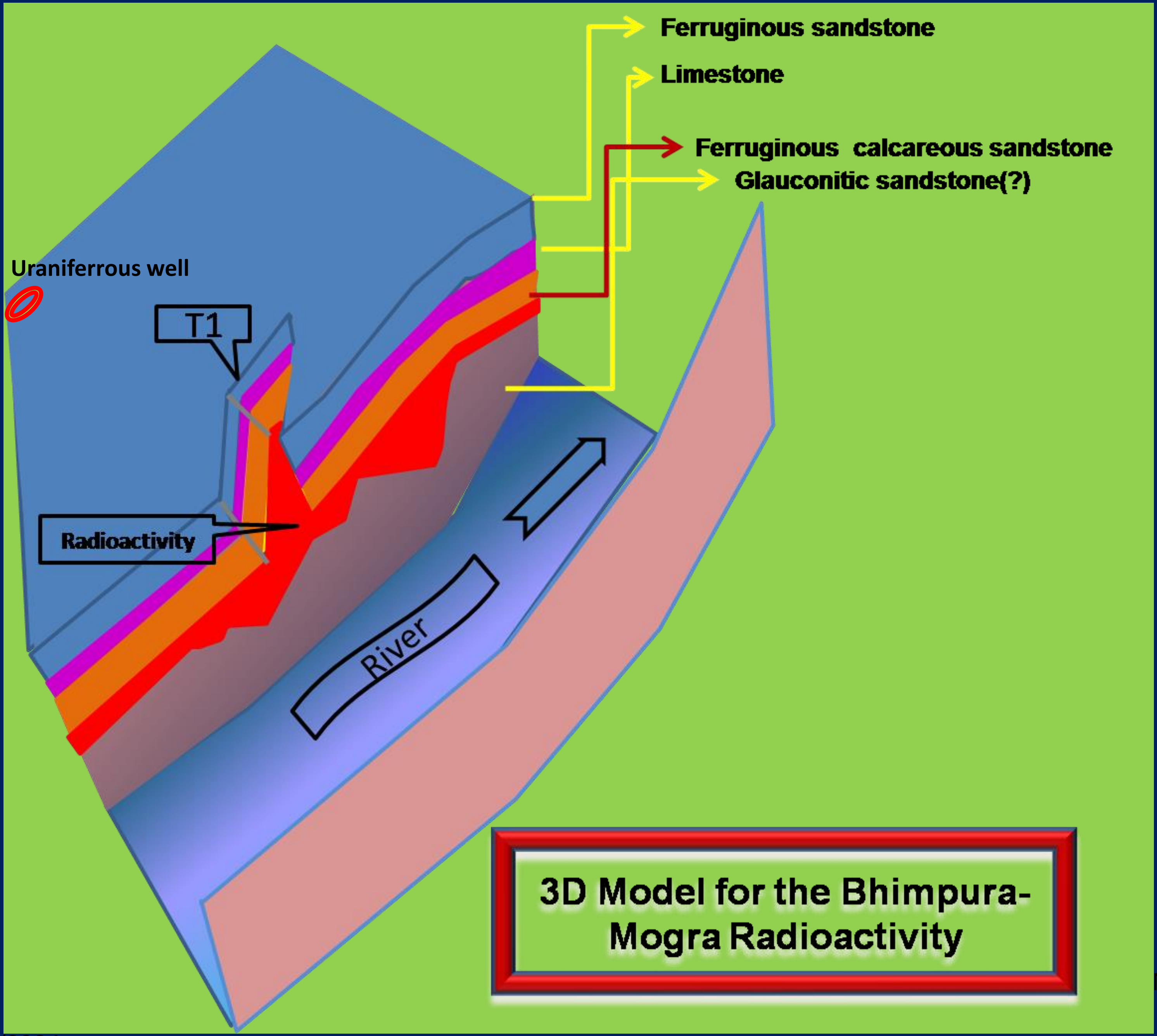
3D Model, Kherli Anomaly
Not to scale
2mx2m
N
5mx1m
Ojhar River
Kherli U Mineralisation
Cherty sandstone
Nodular Limestone
Fossil. Sandstone
Calc. Sandstone
Gritty Sandstone
Radioactivity



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



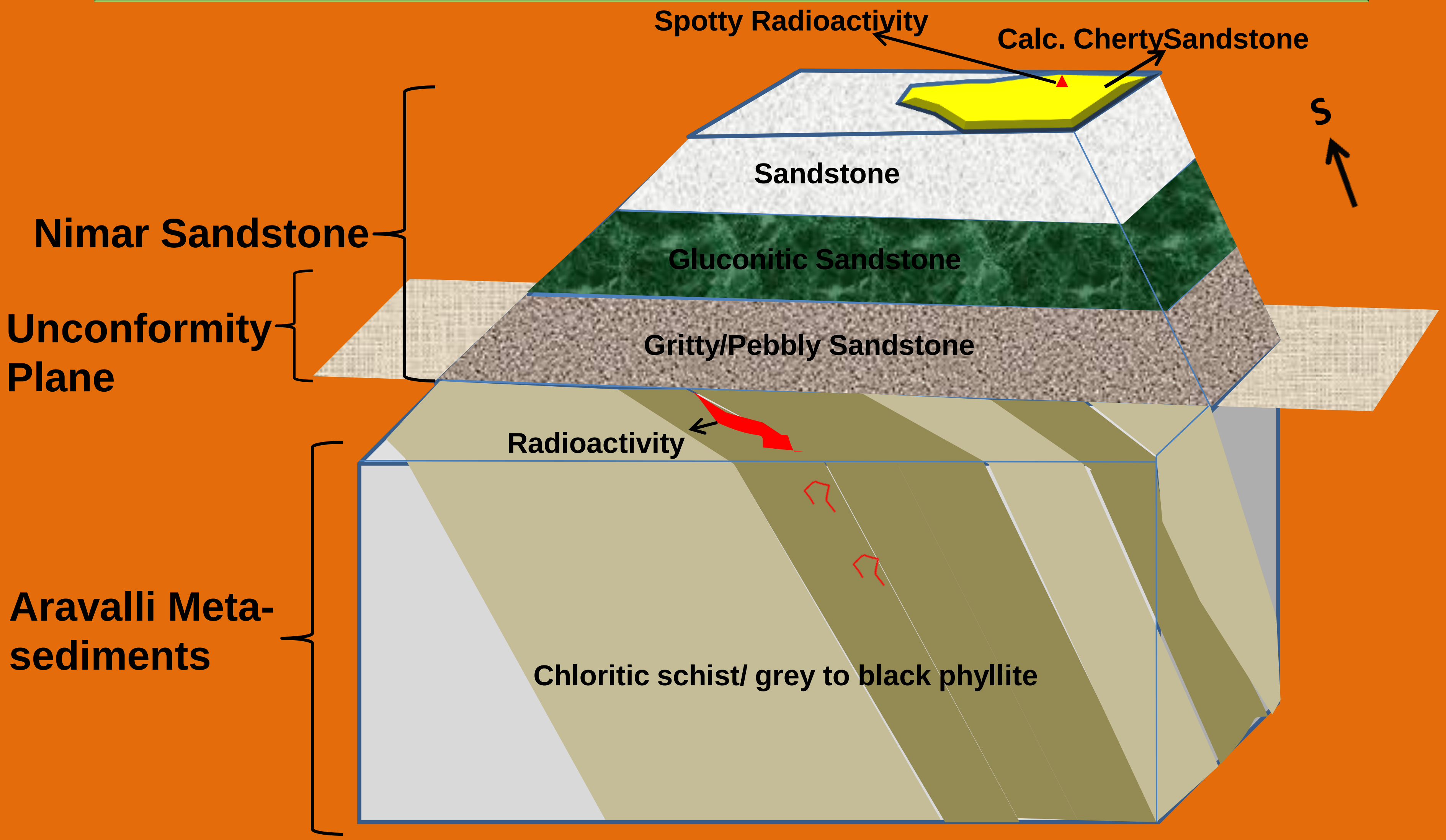
3-D View of radioactivity near Phata area, Alirajpur Dist, M.P

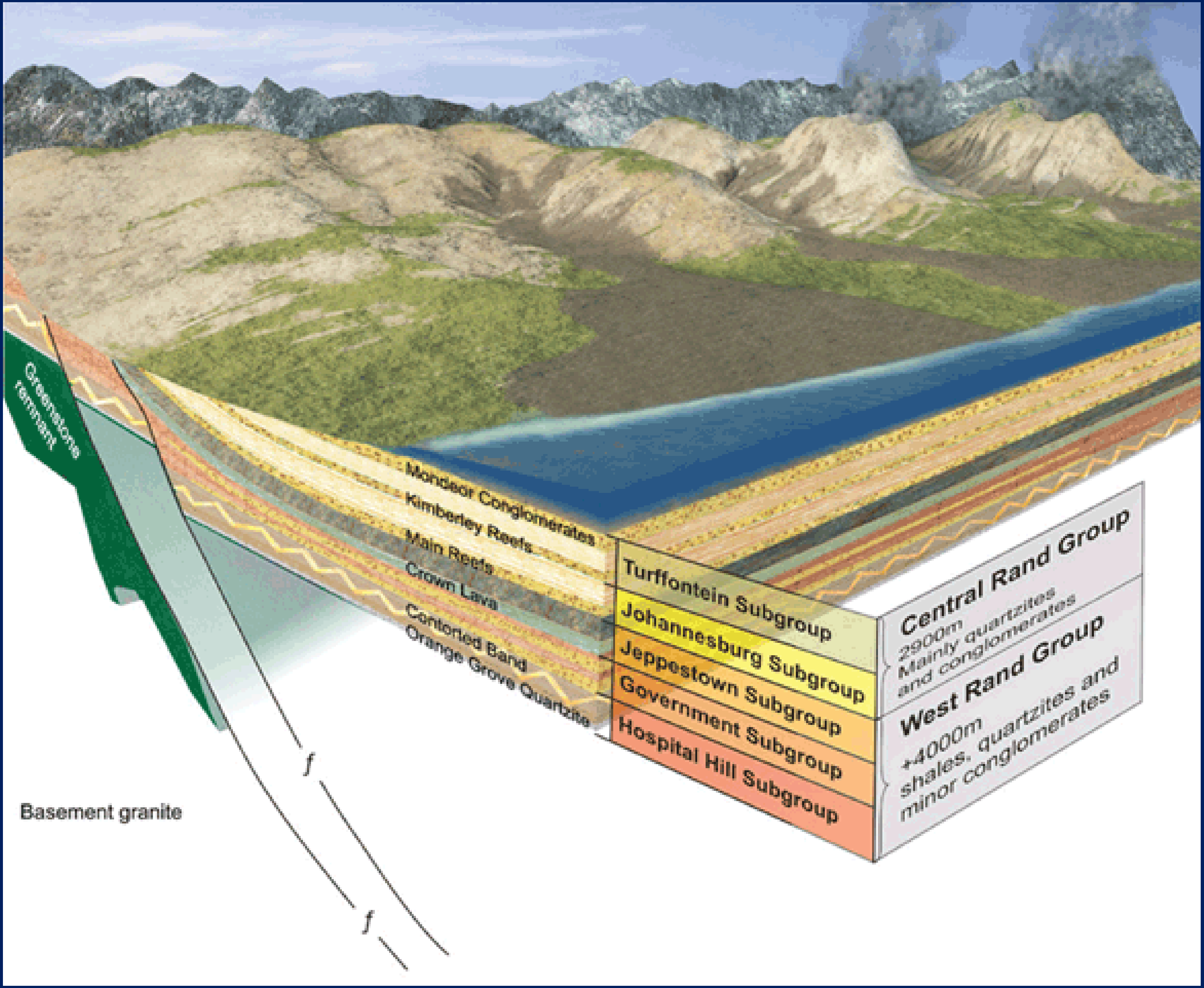


3D Model for the Bhimpura-Mogra Radioactivity

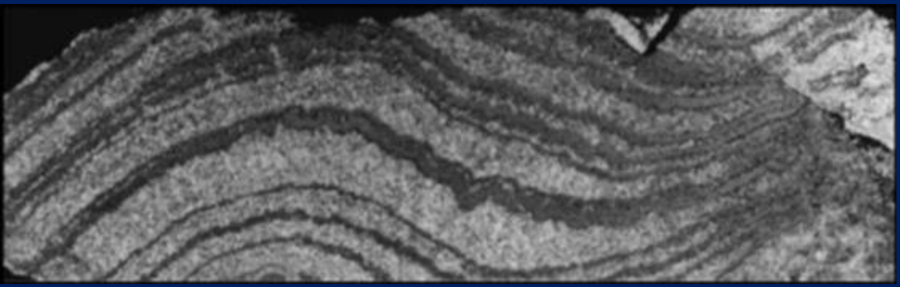
Not to scale

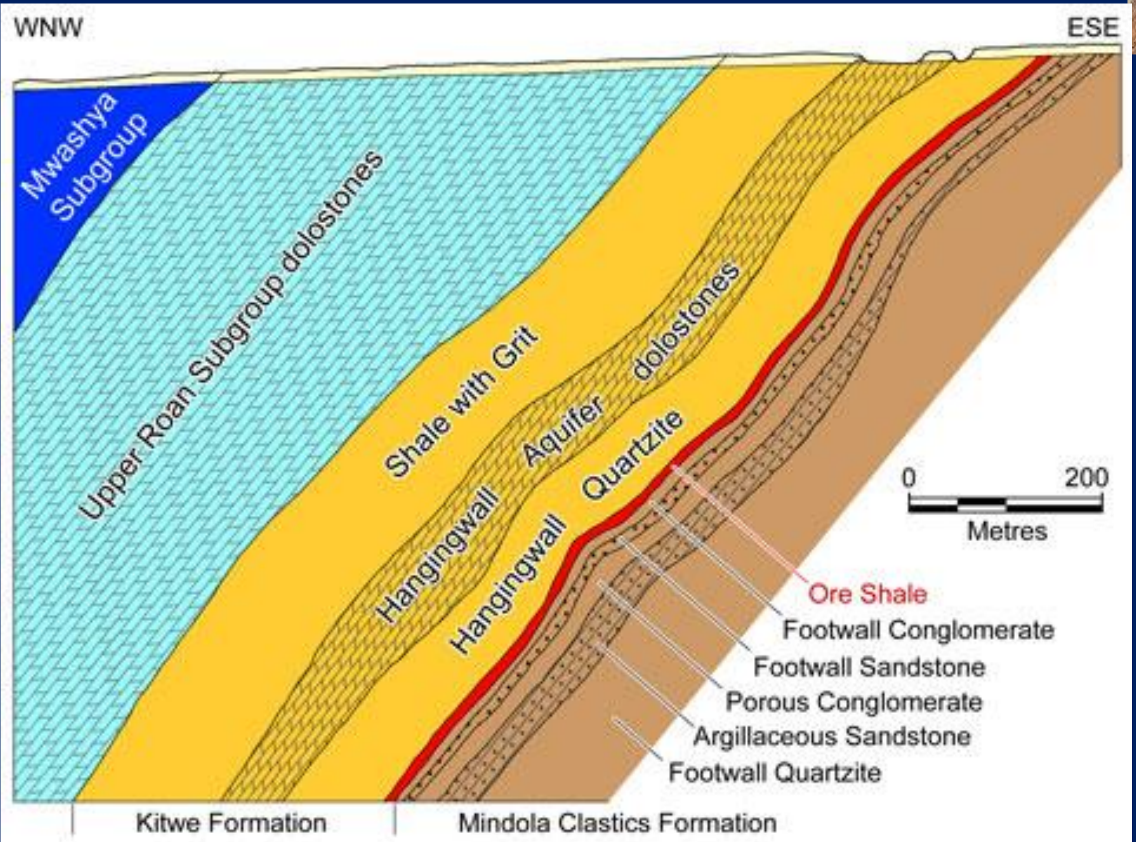
3D View for Jamni Radioactivity, Alirajpur Dist., M.P





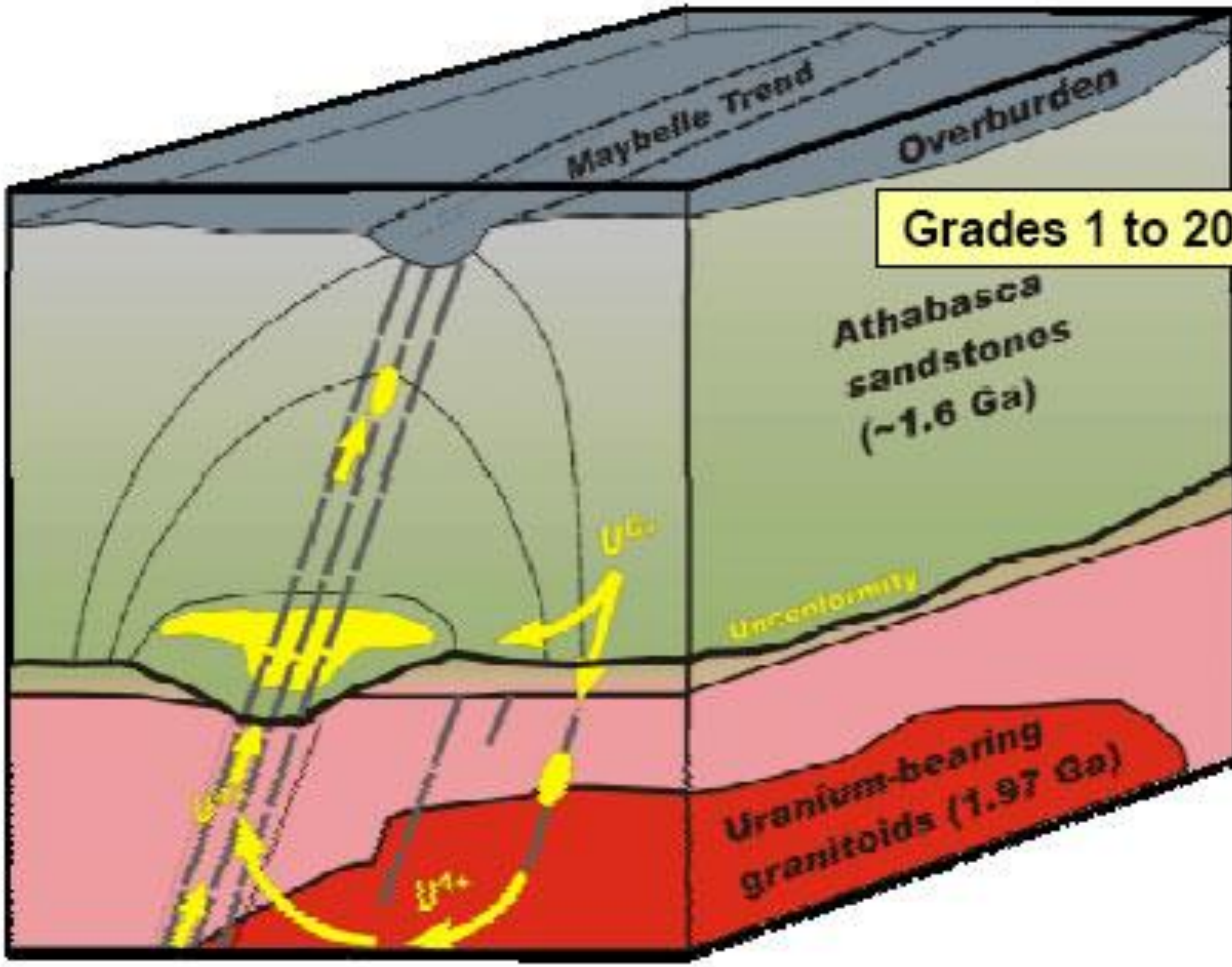
Greenstone remnant
Mondeor Conglomerates
Kimberley Reefs
Main Reefs
Crown Lava
Contorted Band
Orange Grove Quartzite
Turffontein Subgroup
Johannesburg Subgroup
Jeppestown Subgroup
Government Subgroup
Hospital Hill Subgroup
Central Rand Group
2900m
Mainly quartzites
and conglomerates
West Rand Group
+4000m
shales, quartzites and
minor conglomerates
Basement granite
f
f

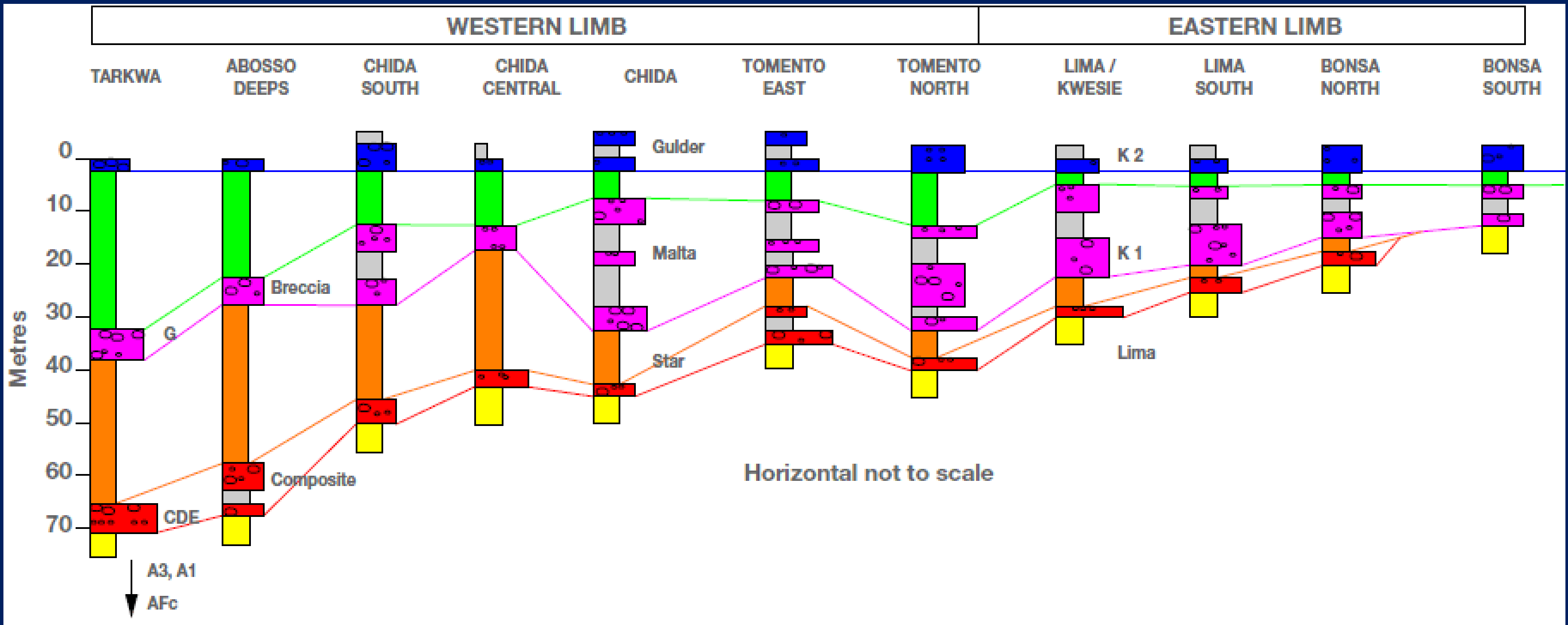




Representative cross section through the Kirila Bombwe North deposit Konkola, Zambia

Grades 1 to 20% U^3O^8





WESTERN LIMB
EASTERN LIMB
TARKWA
ABOSSO DEEPS
CHIDA SOUTH
CHIDA CENTRAL
CHIDA
TOMENTO EAST
TOMENTO NORTH
LIMA / KWESIE
LIMA SOUTH
BONSA NORTH
BONSA SOUTH
Metres
0
10
20
30
40
50
60
70
Gulder
Malta
Star
Breccia
G
Composite
CDE
K 2
K 1
Lima
A3, A1
AFc
Horizontal not to scale

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 quatrz 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**

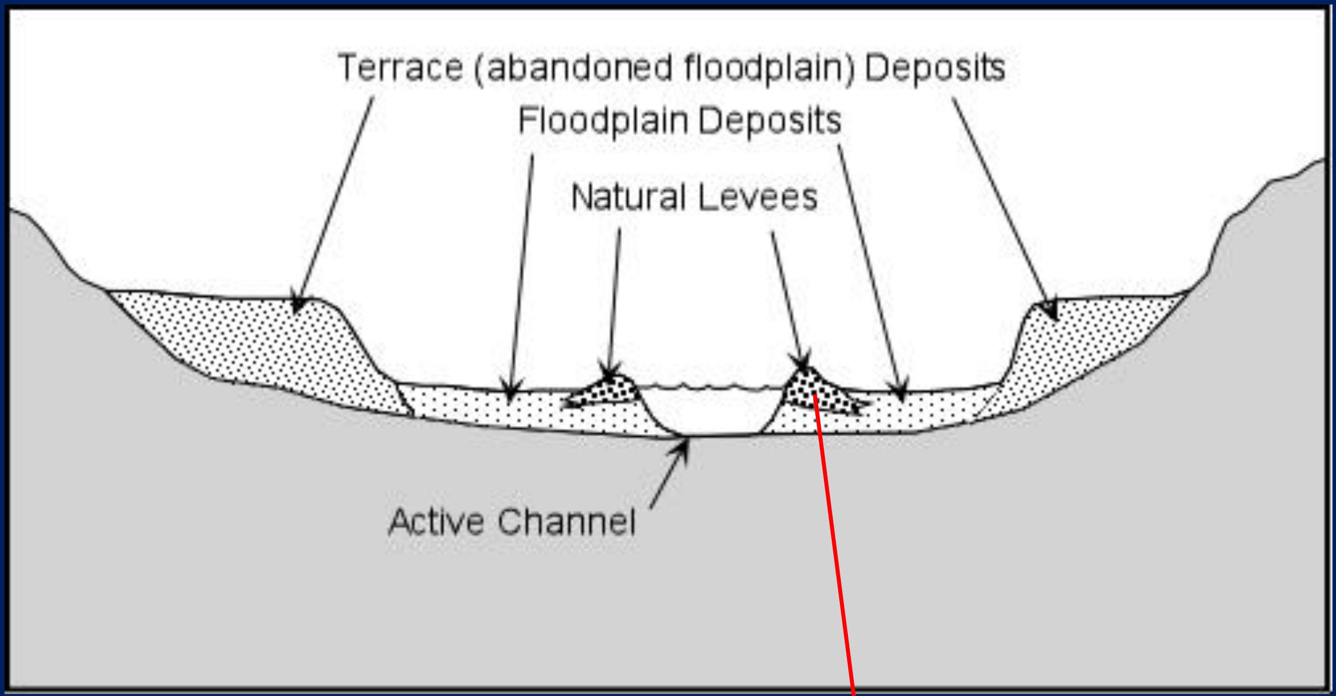
1. **Paleochannels**

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.

2. Levees

The Paleochannels show characteristic linear, curvilinear and loop like ribbons with typical black tone in black and white image and reddish tone in colour coded images.

Once these architecture of these paleochannels network is brought out then it become easy to interpret that all sand backs as paleo levees which are the storehouses of placer deposits.



Occurrences of Heavy Minerals

3. Paleosubmaraine delta

Paleo deltas shows typical concentration of tanks with flower shaped dispositions. This suggest that all these delatas have grown under tidal flat conditions and the tanks are ripple troughs and the bunds are ripple crests. Tank bunds are favorable areas for the search of heavy minerals and metals

4. Metallogens in marine data

Beach ridges are formed due to the reworking the fluvial dumps by the waves have been deposited after considerable winnowing action and hence potential areas for the heavy minerals and metals

Guide to Ore mineralisation

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, chlrite, 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.