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The Controls of Uranium Mineralization in the Mid-Zambezi- Belt Zambia

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Abstract: The Mid-Zambezi Basin is a rift- like topographical feature, occupying the southern portion of Zambia. It is underlain by sediments of the Karoo Supergroup. The Karoo Supergroup has been divided into two groups. Sandstones of the Escarpment Grit Formation are the suitable foci for uranium mineralization in Mid- Zambezi Valley.This paper high lights the main factors which controls uranium mineralization in the Mid- Zambezi Valley in Zambia.

I. GEOLOGY

Karoo Supergroup

Refers to an extensive and geologically recent (100 to 260 million years old) sequence of sedimentary and volcanic rocks. The Karoo Supergroup deposits are related to rifting at the break-up of Gondwanaland accompanied by the establishment of large-scale graben systems. The sedimentary sequence of the Karoo Supergroup lies unconformably over older rocks.

In the mid-Zambezi area, the **Lower Karoo** starts with the *Siankondobo Sandstone Formation*, followed by the *Gwembe Coal Formation* and the *Madumabisa Mudstone Formation*. Upper Karoo.

II. REGIONAL SETTING

The study area is underlain by the Karoo Supergroup rocks of the coal bearing Mid-Zambezi Valley basin (figure 1). The term “Karoo” has been broadly applied to mean continental sediments deposited from the late Palaeozoic to early Jurassic period that are preserved in many parts of southern and central Zambia. The Zambian Mid-Zambezi Karoo basin (Figure 2), the first of the rift valleys to have been mapped in detail is regarded as the type structurally as well as stratigraphically in Zambia and Zimbabwe (Drysdall and Weller, 1966).

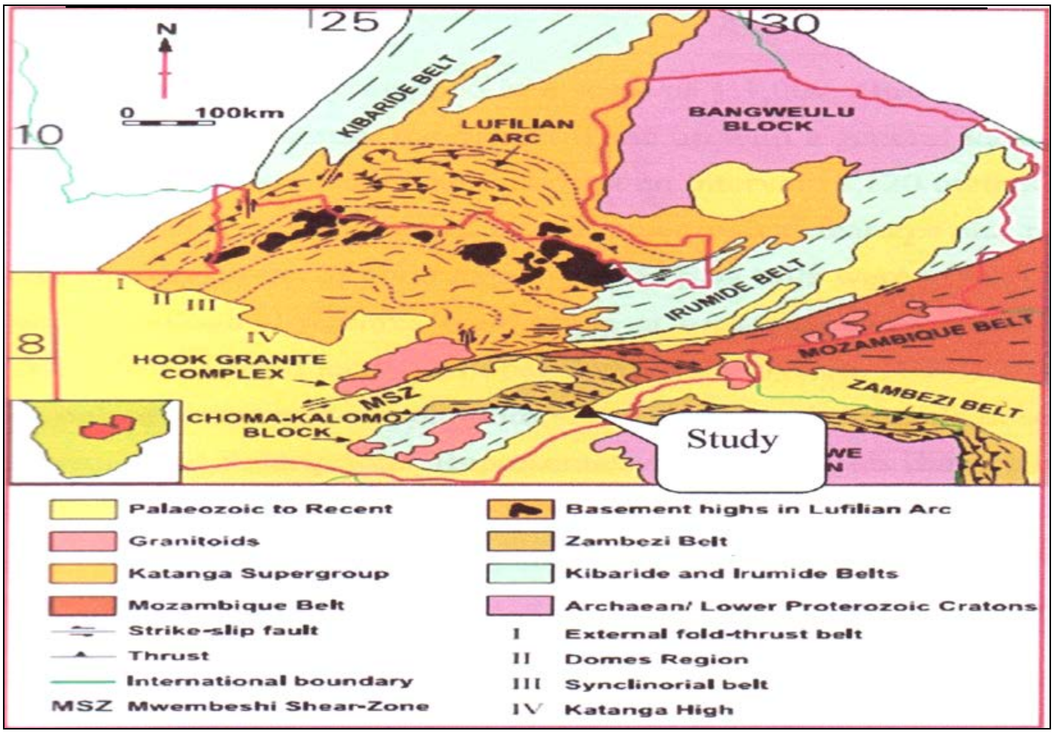

Figure 1: Regional tectonic setting of the study area (after Porada 1989)

The Supergroup has been subdivided into two groups (figure 3), the lower and upper Karoo groups. The Lower Karoo, late carboniferous to Permian is made up of three formations, the basal Siankondobo Sandstone, the Gwembe Coal Formation and the Madumabisa Mudstone Formation at the top. The upper Karoo Group, early to middle Triassic in age, consists of four formations, the basal escarpment Grit Formation, Interbedded Sandstone and Mudstone Formation, Red Sandstone Formation and the Batoka Basalt Formation at the top. The Mid-Zambezi

Valley basin is an extensional fault controlled basin of graben type where the Karoo sediments were deposited forming a thick Karoo succession that started as early as Ordovician times to Middle Triassic times (Prasad, 1982).

With the beginning of the **Upper Karoo** in early Triassic, the *Escarpment Grit Formation* was deposited followed by the *Interbedded Sandstone and Mudstone Formation* and the *Red Sandstone Formation*. These clastic sediments are topped by the early Jurassic *Batoka Basalt Formation* which is the youngest member of the Karoo Supergroup.

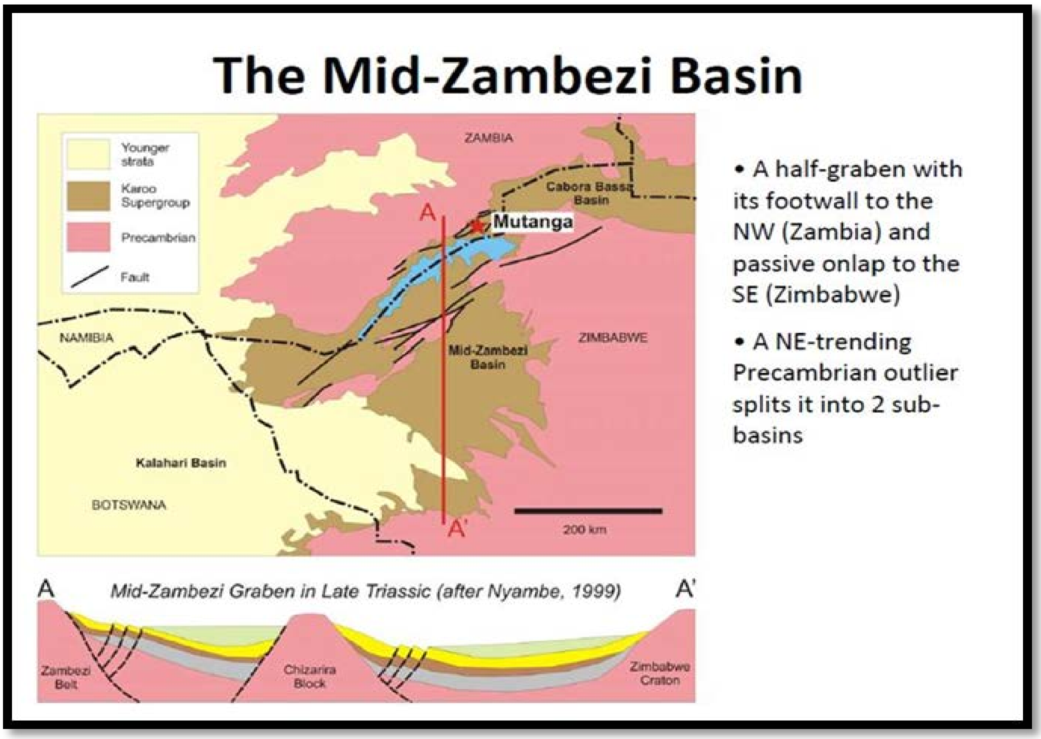

Figure 2: The Geology of the Mid-Zambezi Basin

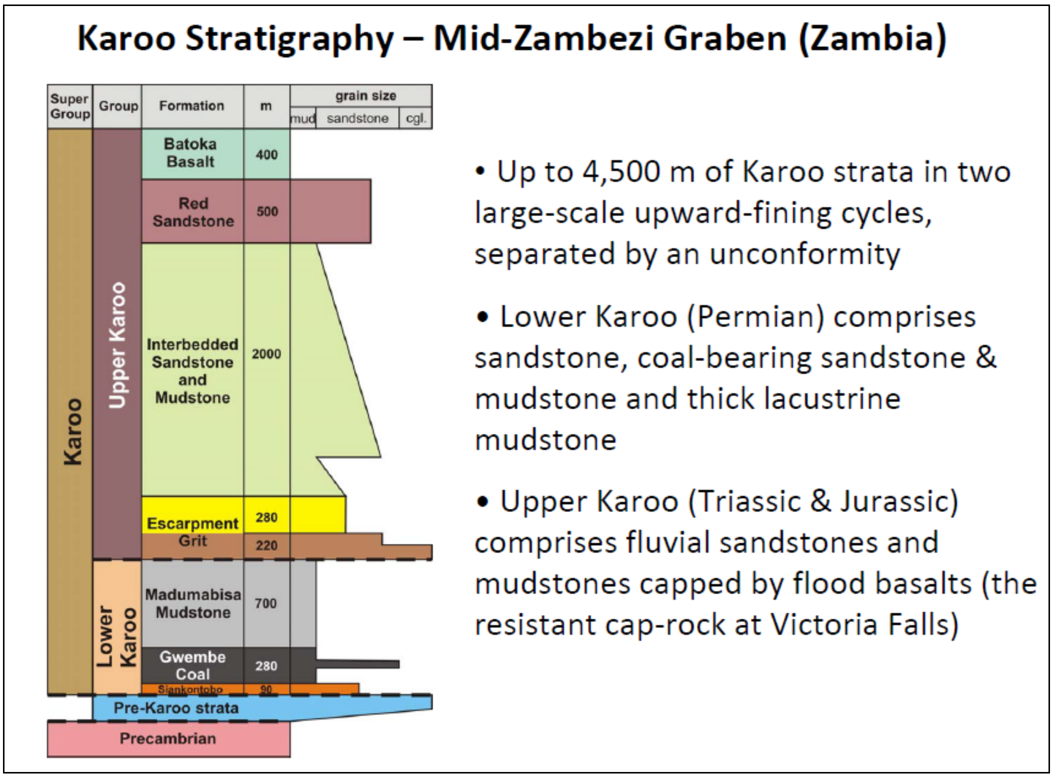

Figure 3: General Stratigraphy, Mid-Zambezi Valley Basin, Southern Zambia(after Nyambe 1993)

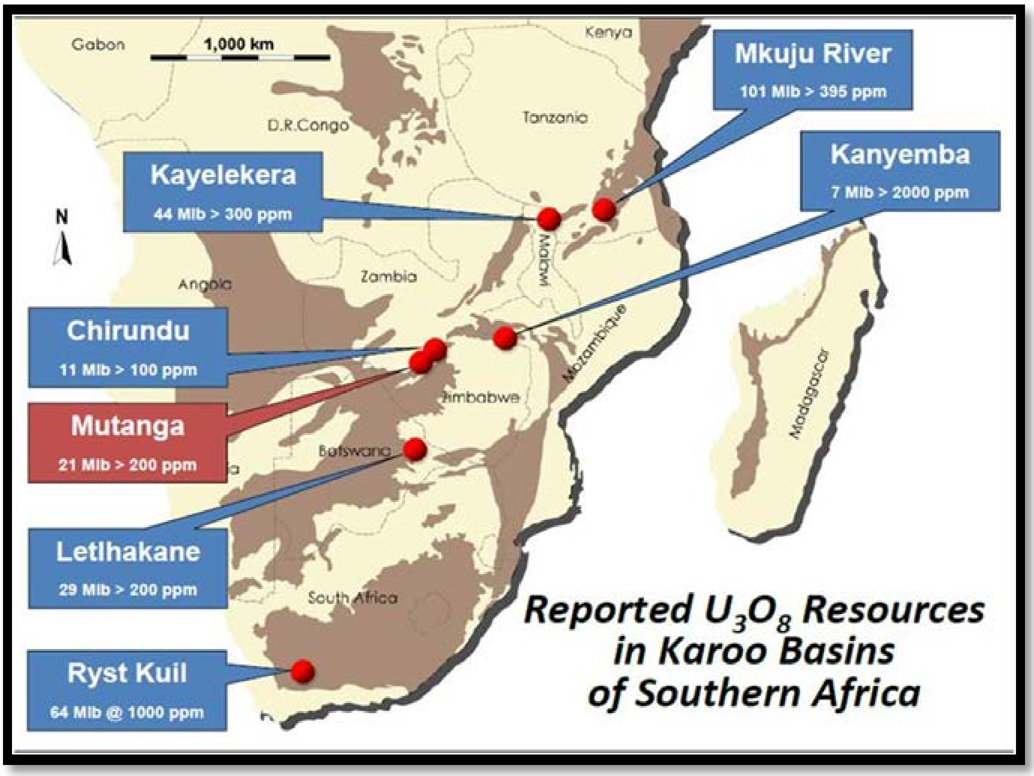

Figure 4: Uranium mineralization in Karoo Basins in Southern Africa

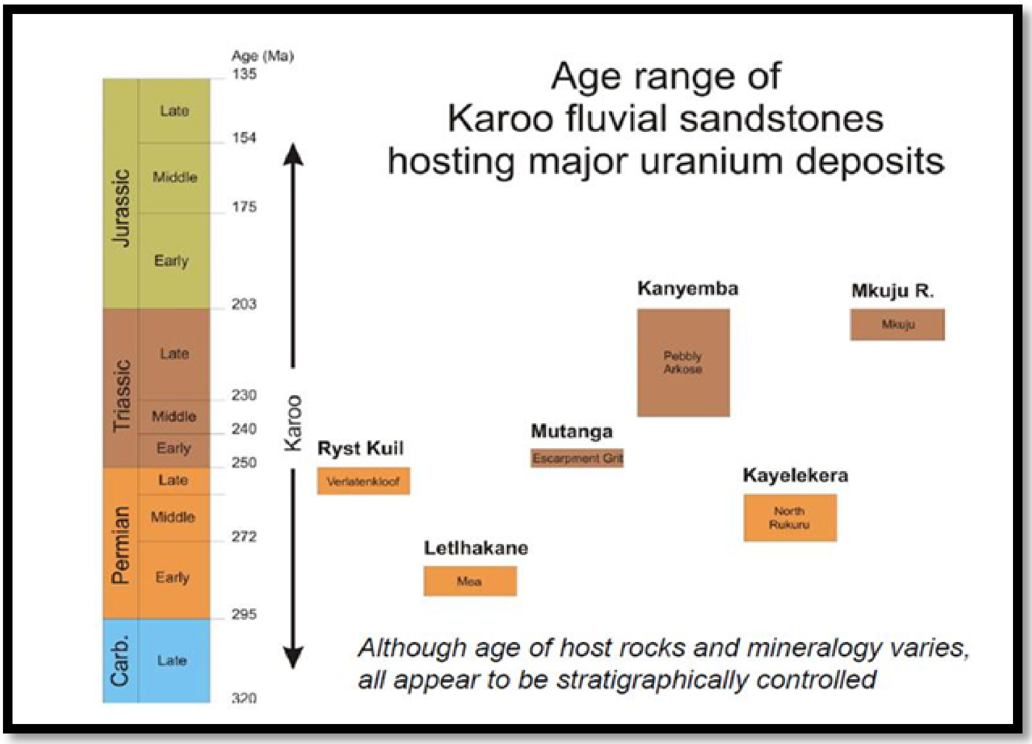

Figure 5: Age of Karoo Sandstones Hosting Uranium

Mineralization

Uranium mineralization is hosted within sandstones confined between impermeable units (Siltstone beds), and is observed that the minerlization decreases down dip and forms a cresent shape, typically the convex side points down the hydraulic gradient (figure 6). The other characterstic of the host rock is that its beds dip gently at an average of 10 degrees.This style is called roll front deposit (Heylmum 2003).

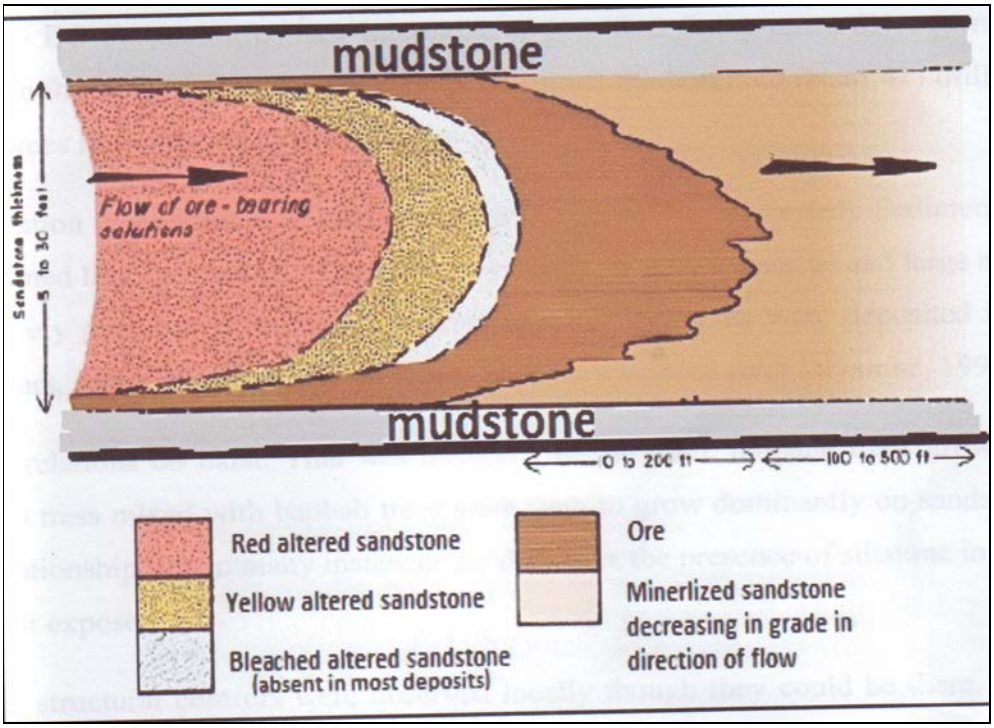

Figure 6: Roll front deposition model (modified after Heylmum, 2003)

III. CONTROLS OF URANIUM MINERALIZATION

Stratigraphic Control

As there is a vertical variation in lithological units, there is also lateral variation in sedimentary environments with increasing distance from the source area and lateral facies changes will occur within a single stratigraphic unit (Le Roux, 19850). It was observed that radiometric counts were higher up-dip and decreased down dip within a same lithology. This can be explained as due to vertical variations in lithological units as suggested by Le Roux (1985) or geochemical barriers (figure 7). All known uranium mineralization is confined to the Escarpment Grit Formation (EGF). Within the EGF, uranium mineralization is not confined to any particular lithology. The underlying Madumabisa Mudstone Formation is believed to have prevented the mineralizing fluids from going further down the stratigraphy.

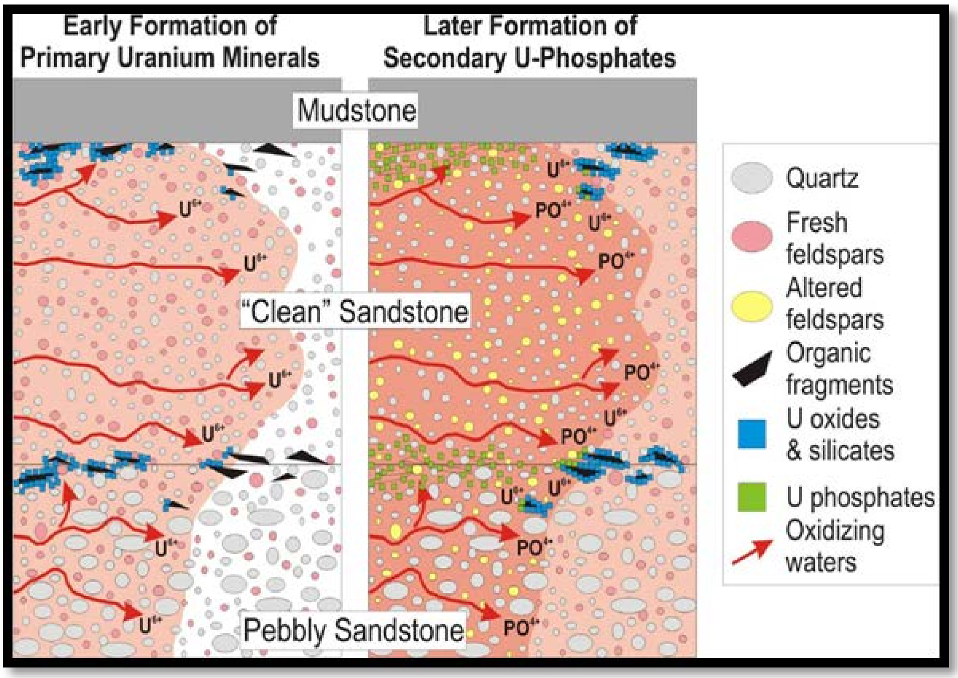

Figure 7: Control of mineralization by lithologies

Structural Control

The permeability of sandstones determines the extent and rate of uraniferous solutions. The original permeability depends on texture, bedding planes and other sedimentary structures. In general, roll-type uranium deposits require better permeability than peneconcordent deposits. Secondary factors such as jointing, brecciation or cementation would also affect its properties as a reservoir rock.

Although a fault was inferred in the study area, it has no control on mineralization (Fig. 4). Facies relationship localizes the ore deposits by inhibiting the rate of groundwater flow (Le Roux, 1985). The contact between sandstone and mudstones is particularly of interest because it is an interface that may induce precipitation of uranium. The presence of mud-clasts (Fig. 6) observed in the sandstone also has some effects on mineralization. Adsorption and ion exchange properties of clays within the sand bodies also extract uranium from solutions migrating along the interface contacts. Organic compounds act as reductants or absorbants also favour precipitation of uranium.

Porosity

This includes the open spaces within a rock or soil. Pore spaces have a direct relationship to the porosity and permeability of the rock which is influenced by the way the sand grains are packed together. Permeable rocks allow mineralizing fluids to flow through them and when the conditions are suitable, uranium precipitates.

Ground water flow

Flow of ground water helps to transmit minerals in solution until they reach where conditions are favorable for precipitation (fig 8). The presence of path ways such as fractures is very important as they provide pathways for fluid flow. When the path ways contain reductants such as pyrite or organic material, the dissolved uranium in solution precipitates.

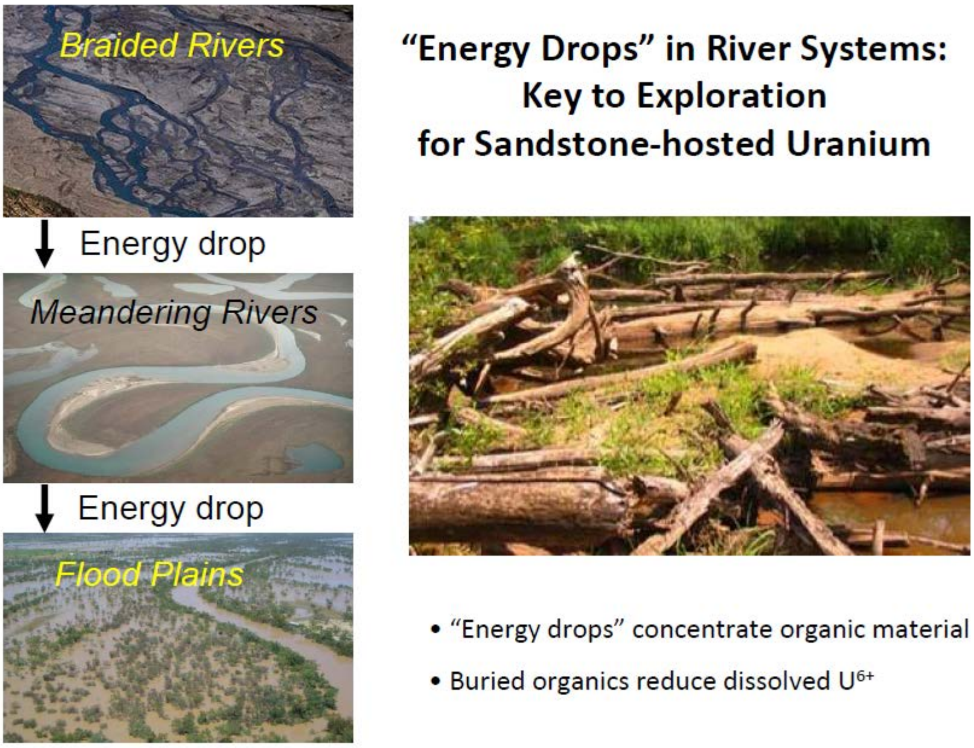

Figure 8: Control of mineralization by ground water flow

pH

The pH of the mineralizing fluids is a very important factor in uranium mineralization. The pH is influenced by factors such as organic processes (e.g. respiration and decay), reduction-oxidation (redox) reactions involving iron, sulphur and carbon, and the topography. Minerals like uranium are highly mobile under oxidizing and acidic conditions while precipitation occurs under reducing conditions.

Organic material helped reduce dissolved Uranium to form primary uranium minerals such as Brannerite and Coffinite which concentrated at energy drops in the Escarpment Grit fluvial system.

Mud clasts are rich in clay and tend to bind minerals to their surfaces due to their high adsorptive capacities. These mud clasts also provide reducing conditions for uranium to precipitate. Clay minerals in the clasts such like kaolinite, Gibbsite and Montmorillonite can adsorb and bind uranium onto their surfaces.

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