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A review of the geology & exploration challenges for lenticular chrome deposits in the Zimbabwe Craton and Northern Marginal Zone

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Talk format

1. Introduction to chrome mining in the Tokwe segment in the Zimbabwe Craton.
2. Chromite ore grades, uses & dressing.
3. Distribution of chromitite ore deposits.
4. Formation of chromitite ore deposits.
5. Case studies on chromite deposits from the Zim Craton and Northern Marginal Zone.
6. Challenges for exploring lenticular chromite deposits.
7. Take-Aways

Introduction

- "The heavy, black mineral from the hills äround Selukwe was first mistaken for common iron ore during the early days of mining in the district" (Stowe, 1968).
- Chromite ($Cr_2O_3.FeO$) belongs to the spinel group of minerals; contains varying proportions of Cr, Al, Fe & Mg. Chrome ore main impurities: lime & silica
- Two major types of chrome deposits:
- Podiform (lenticular) deposits; are associated with ultramafic sills; remnant Sebakwian greenstones in Zim.
- Stratiform deposits: large layered ultramafic intrusions e.g., Bushveld Complex & Great Dyke; low & variable Cr#s & Mg#s.
- Chrome deposits from Shurungwi are one of the largest known deposits of high-grade chrome ore in the world.
- Production was by Rhodesia Chrome Mines Ltd, now Zimasco. There are also other players e.g., Zim Alloys.
- Production: mainly Railway Block (immediate north of Shurungwi) and Selukwe Peak (c. 8km S of Shurugwi) Mines.
- First shipment of chrome in Shurugwi to Europe was in 1906.
- Chrome mining has been and is still the mainstay of Shurugwi town, with chrome value coming second to gold. Now there is Unki Platinum Mine in Shurugwi.
- Chrome production has been sensitive to global demand and price fluctuations : starts-and-stops of operations.
- The c. 2.57 Ga Great dyke chrome deposits, post- date the podiform deposits reviewed in this talk.

Introduction…cont.

Chrome ore grades & uses

- Two important parameters for determining chrome ore grade are (a) total chromic oxides (Cr_2O_3) and (b) Cr/Fe ratio.
- High-grade chromite has high Cr/Fe ratio.

Based on its uses, chromite is classified into 3 grades (Stowe, 1968):

Metallurgical chromite grade:

- ✓ Minimum Cr_2O_3 of 46 %. Cr/Fe ratio of at least 2.8
- ✓ Low silica and be free of sulphur & P
- ✓ Is used in the manufacture of ferro-alloys and steels.

Refractory grade:

- ✓ The physical properties are important. Ore should be hard, lumpy & have high melting point.
- ✓ High Cr/Fe ratio of 2 to 3, high Fe is undesirable as it lowers the melting point.
- ✓ Low silica content < 5 %.
- ✓ Is used in furnace linings.

Chemical grade:

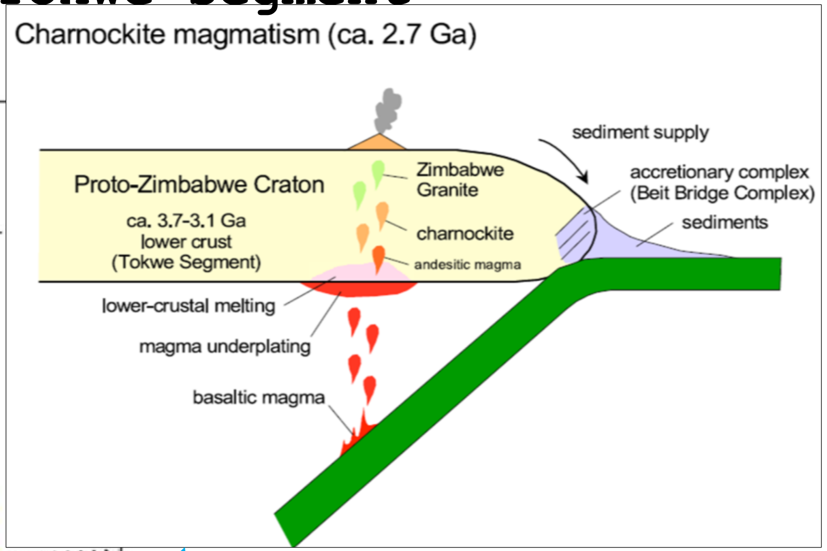
- ✓ Minimum Cr_2O_3 of 42 % and Cr/Fe ratio of c. 1.6.
- ✓ Is used in the tanning, paint & electroplating industries.

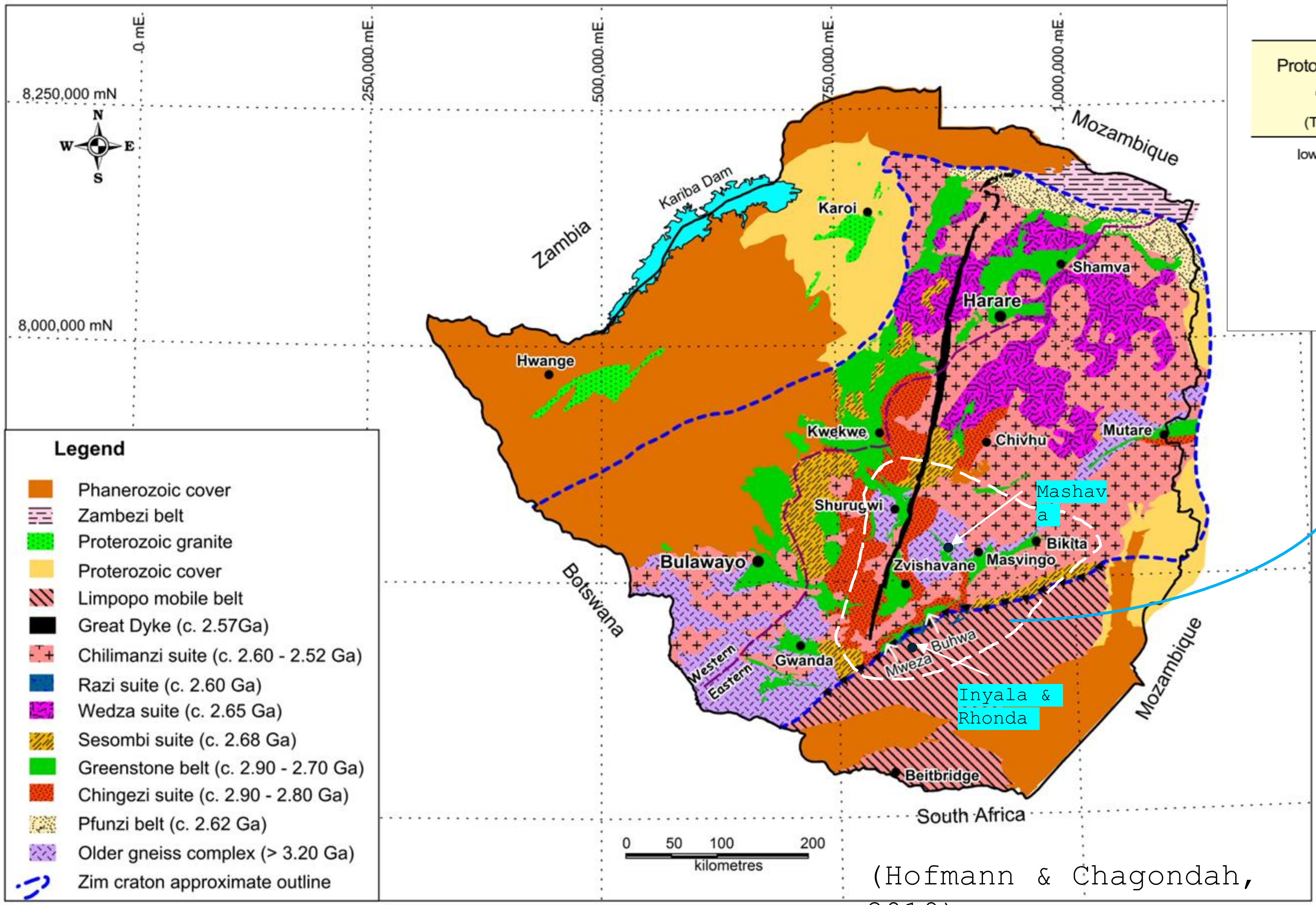
Chrome ore dressing

- Typically, chromite grain size are up to 3 mm.
- Most of the ore is massive, with interlocking grains, with little matrix. Some chrome ore is fine-grained & appears amorphous.
- Chromite usually breaks cleanly from the softer more schistose ultramafic host rocks.
- High-grade ores require only washing and hand dressing before hauling as lumpy chromite.
- The fines and low-grades are milled & concentrated by gravity techniques.
- Ore dressing is aimed improving the Cr2O3 content.
- Cr/Fe ratio may be improved by magnetic separation of Fe & pyrite using magnets.

Distribution of podiform chrome deposits across the Tokwe segment

(Tsunogae et al. 2025);

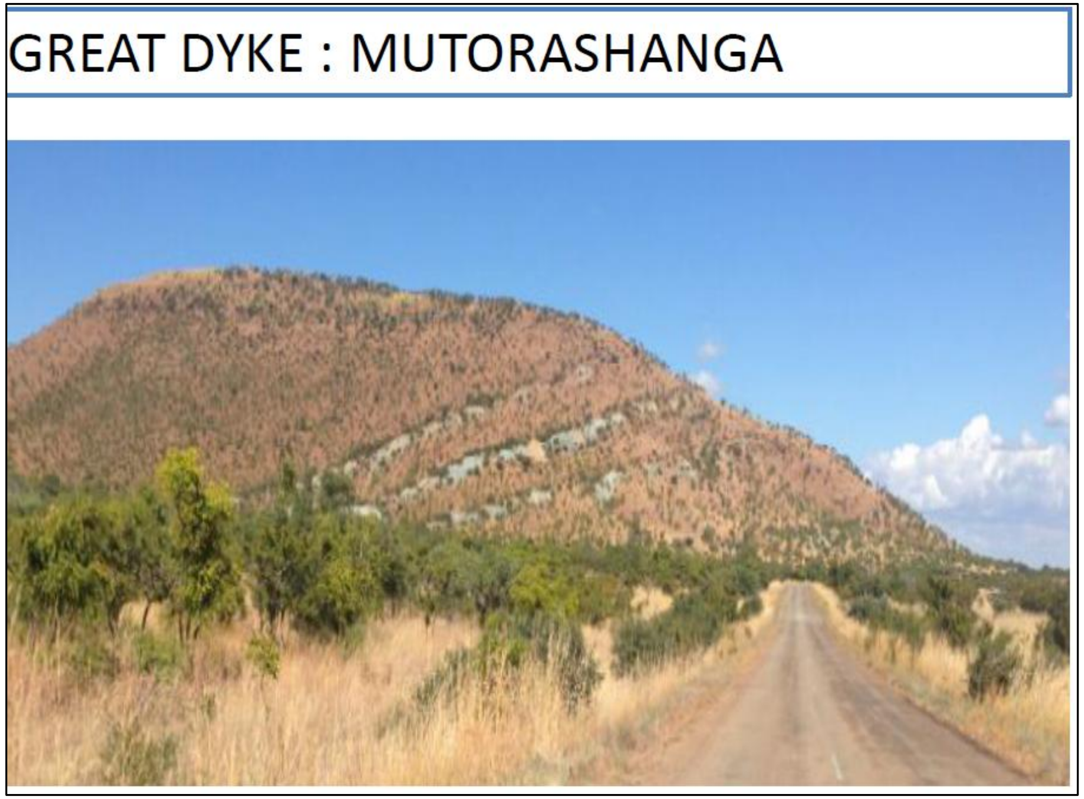




(Hofmann & Chagondah, 2019)

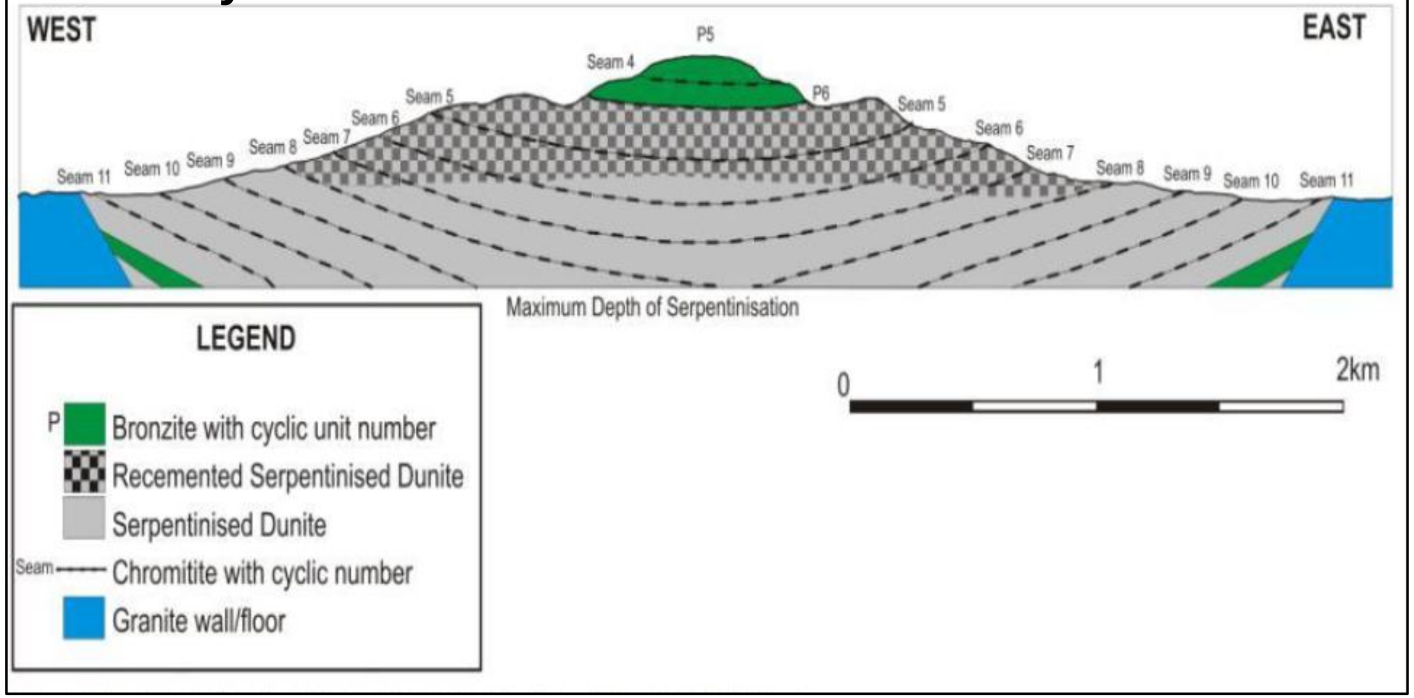
- Mesoarchean ultramafic sills magmatism in the Tokwe segment.
- Podiform chromite deposits are off & pre-date the c. 2.57 Ga Great Dyke in Shurugwi, Mashava, Valley, Nhema, Inyala & Rhonda.
- Regarded to constitute c. 3% of Zims chromite resource.

Stratiform chrome deposits in the Great Dyke of Zimbabwe



(Source: Makwara, F)

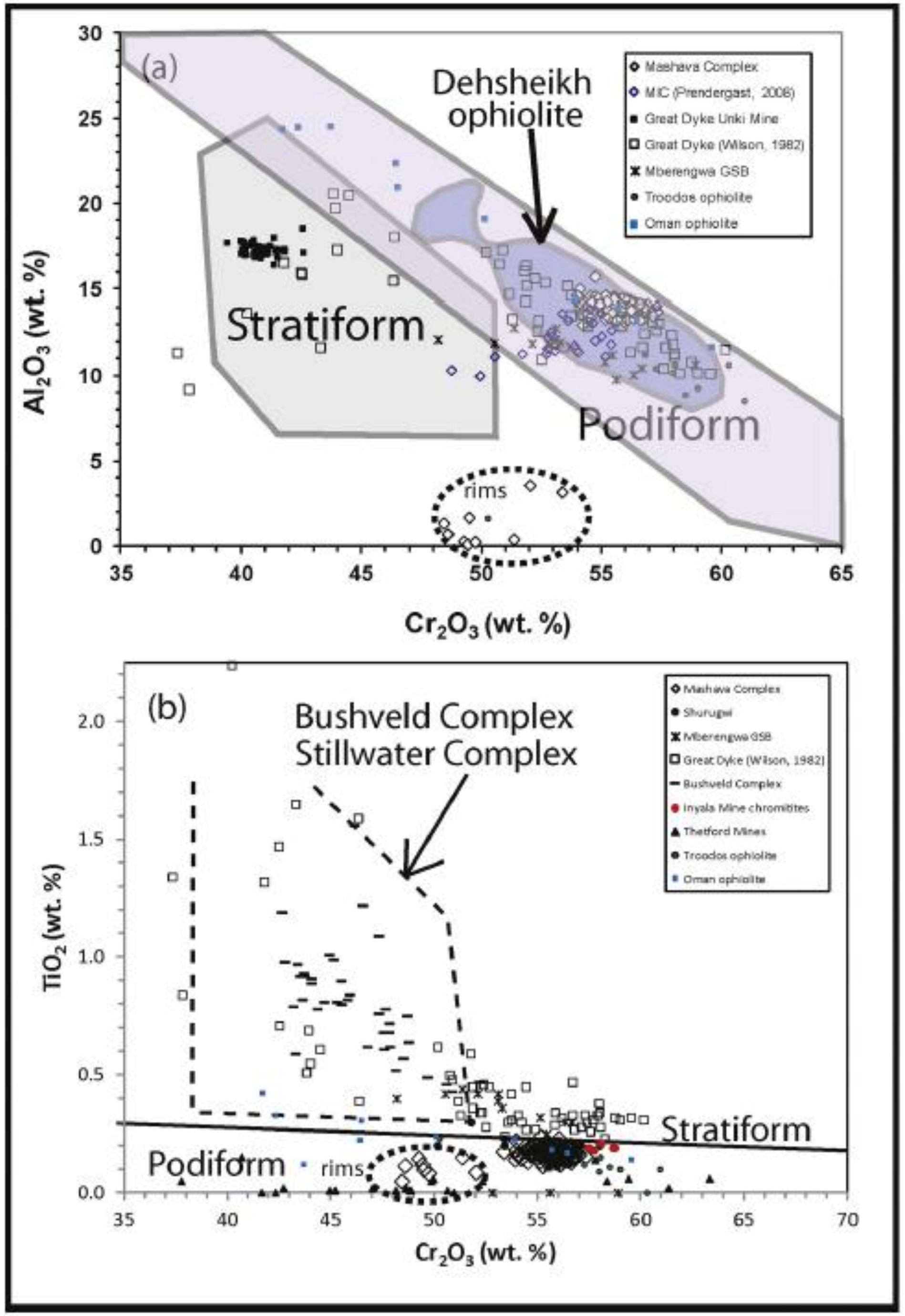
Cross section of the chromitite seams of the Great Dyke



(Source: Musa, 1996)

- South Africa's Bushveld Complex holds the largest resources (70 % of the world's total).
- Zimbabwe's Great Dyke is one of the major sources of stratiform chrome deposits.

Composition of Zimbabwe chromites *(fields after Bonavia et al (1993) and Ahmed and Arai (2003).*



- MIC, Inyala & Shurugwi chromites plot in the podiform fields (Chaumba, 2018; Prendergast, 2008, Rollinson, 1997).
- Other Zimbabwe greenstone belt hosted chromitites also plot in the podiform field.

Fields for data for ophiolitic chromitites from Dehsheikh ultramafic complex in Iran are from Peighambari et al. (2016), data from Oman (Rollinson, 2009) and Troodos (Merlini et al., 2011).

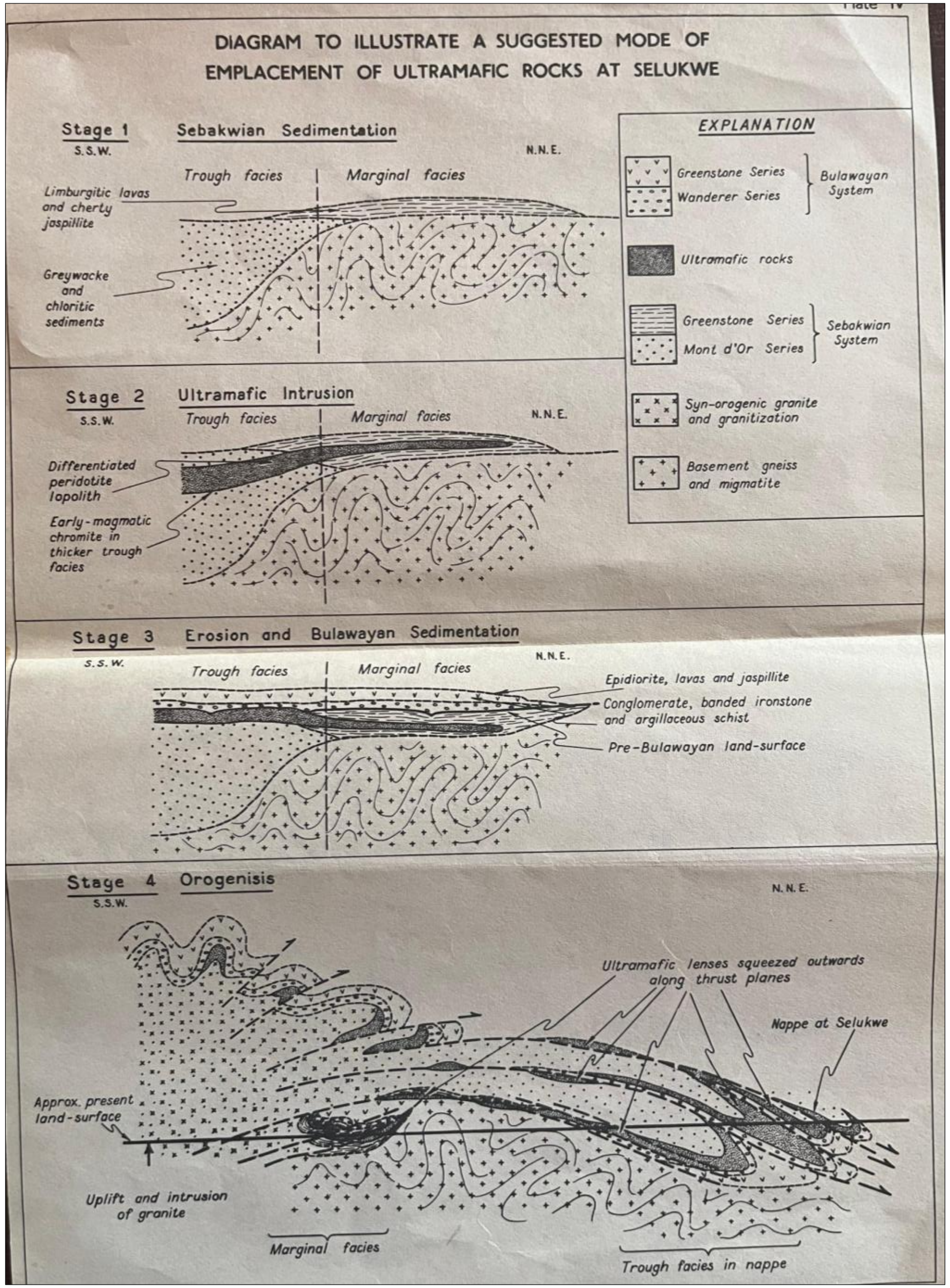
Podiform deposits in Zimbabwe

EMPLACEMENT SEQUENCES

Upper System	• Sedimentary rocks
Podiforms	• ULTRAMAFIC SEQUENCE: Host to chromite • Serpentine, Talc carbonates , Silicified Talc carbonates
Basement complex	• Gneiss and Tonalites

- Serpentinite, silicified talc carbonate and talc carbonate from a dunite and harzburgite protolith: indicated by relict micro-textures (Stowe, 1997; Rollinson, 1997; Prendergast, 2008).
- Silicified talc-carbonate: is a metasomatic, cherty, silicious rock. Formed by regional hydrothermal replacement of carbonate by silica.
- Carbonated talc schist and serpentinite: form metasomatic replacement rocks (e.g., Selukwe Peak Mine) from shearing of ultramafic protolith.
- Chromitite bodies formed as layered segregations from an ultramafic magma.

- The high Cr/Fe ratio in large deposits and near the stratigraphic base indicates an early separation from the magma.



(Stowe, 1968)

Origin of the primary podiform chromite deposits

- Chromite podiforms are hosted in an ultramafic sill emplaced between sediments & c. 3.5 Ga basement gneiss rocks.
- Ore bodies are formed by magmatic differentiation by crystal settling & mixing/contamination.
- The main, thicker, Cr-rich ore bodies could indicate either a very large ultramafic sheet or a magma rich in chromite (high Cr budget).

- After crystallization, host rocks & chromitites underwent several phases of complex structural deformation.

- Tectonism: at least 3 tectonic cycles recognized: Sebakwian & Bulawayan orogenies:
- Tectonism resulted in repetition and en echelon array of lenses.
- Deposits typically consists of discontinuous and scattered groups of chromite lenses.

- Significant pods are elongated (15-120m width) cigar shaped discontinuous lenticular ore bodies.

- Pods occur as dispersed pods in each area and some stretching in depth beyond 1.2 km

Selukwe Peak Mine

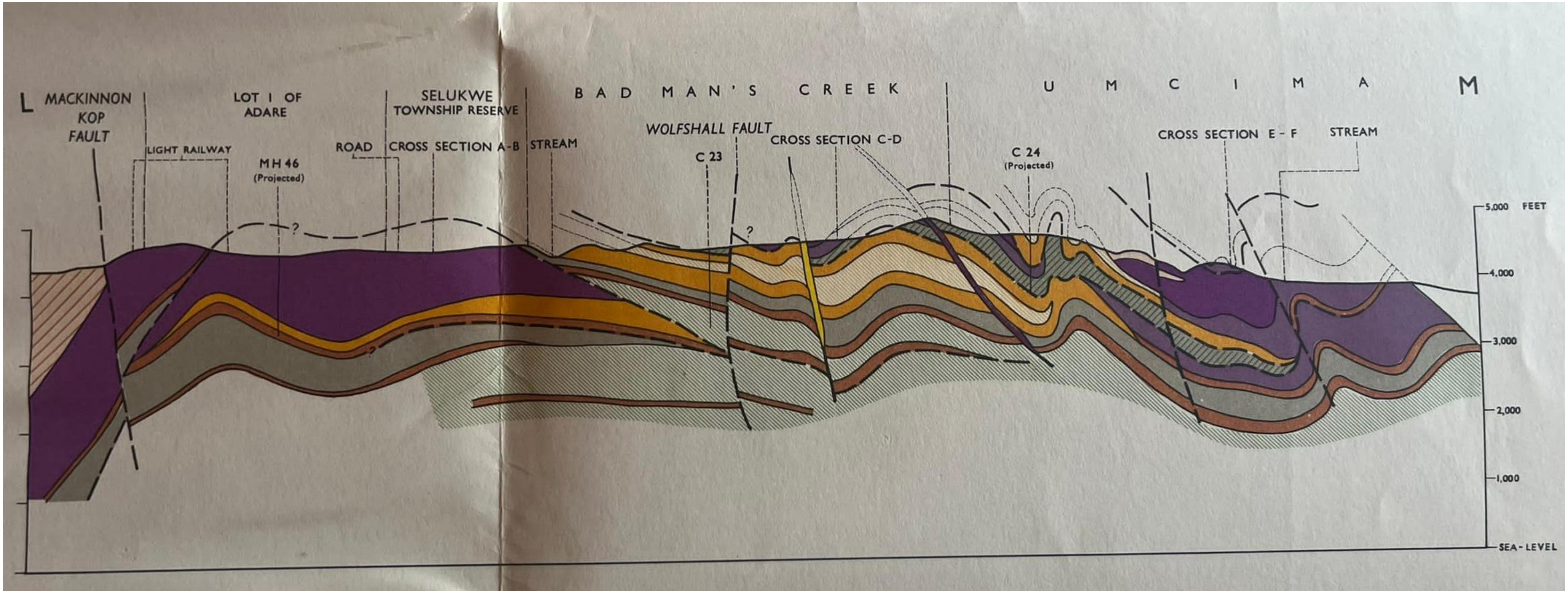
- Reached 29th level (435m from surface) by 1961.
- Chromite bodies hosted in ultramafic rocks or related rocks which form a sill-like body, intrusive into Sebakwian sediments.

- Originally there were about 3 to 7 distinct chromite seams/horizons.
- Tectonism: at least 3 tectonic cycles recognized: Sebakwian & Bulawayan orogenies.
- Intense post-Buluwayan deformation events (folding, shearing & faulting) resulted in nappe & cross folding structures, which were later refolded to tilt the sill up on end.
- The bodies were torn apart or crowded together and duplicated, rolled up into pipes, stretched (boudinage structures).

- Chrome bodies attained up to 24 m width; metallurgical grade chromite.

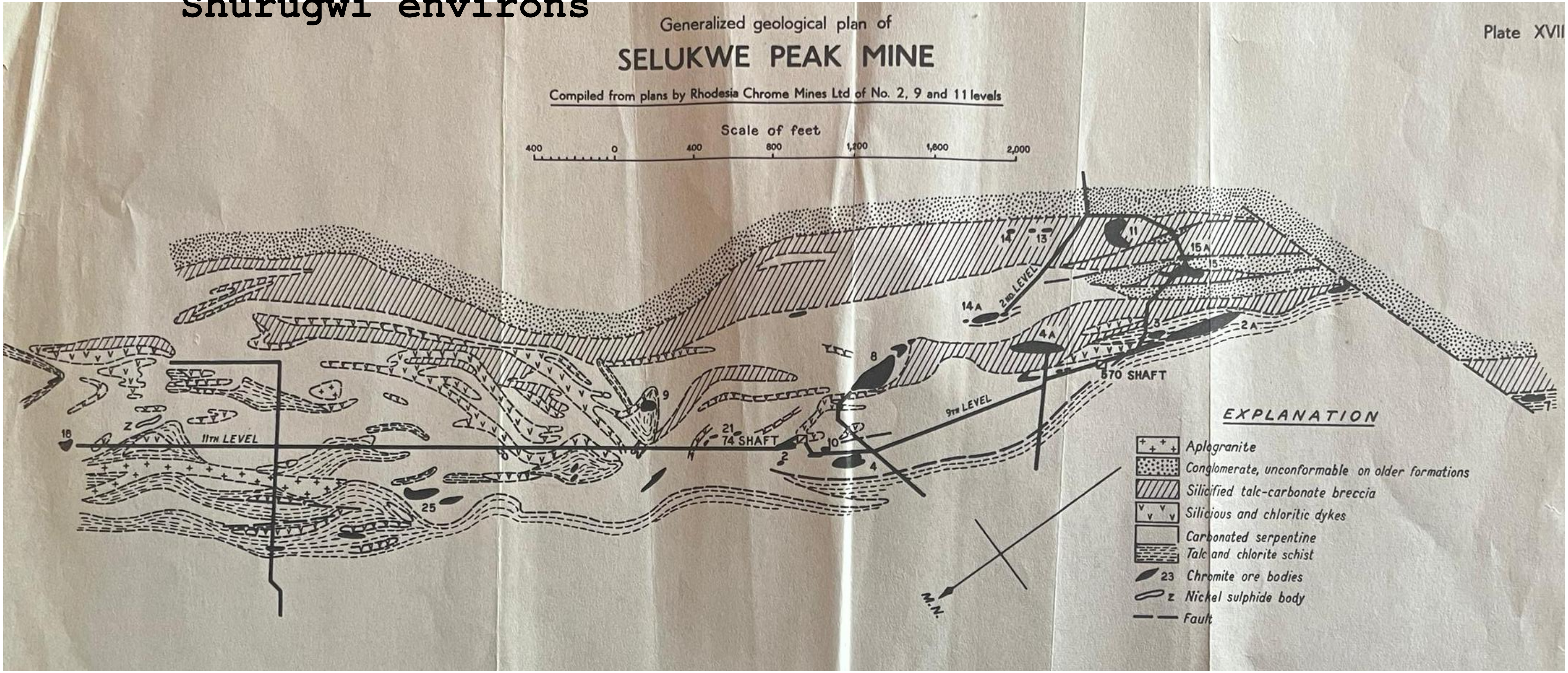
Case study of chromitites in the Shurugwi environs….

- Cross-section showing tectonism in the Shurugwi belt.



(Stowe, 1968)

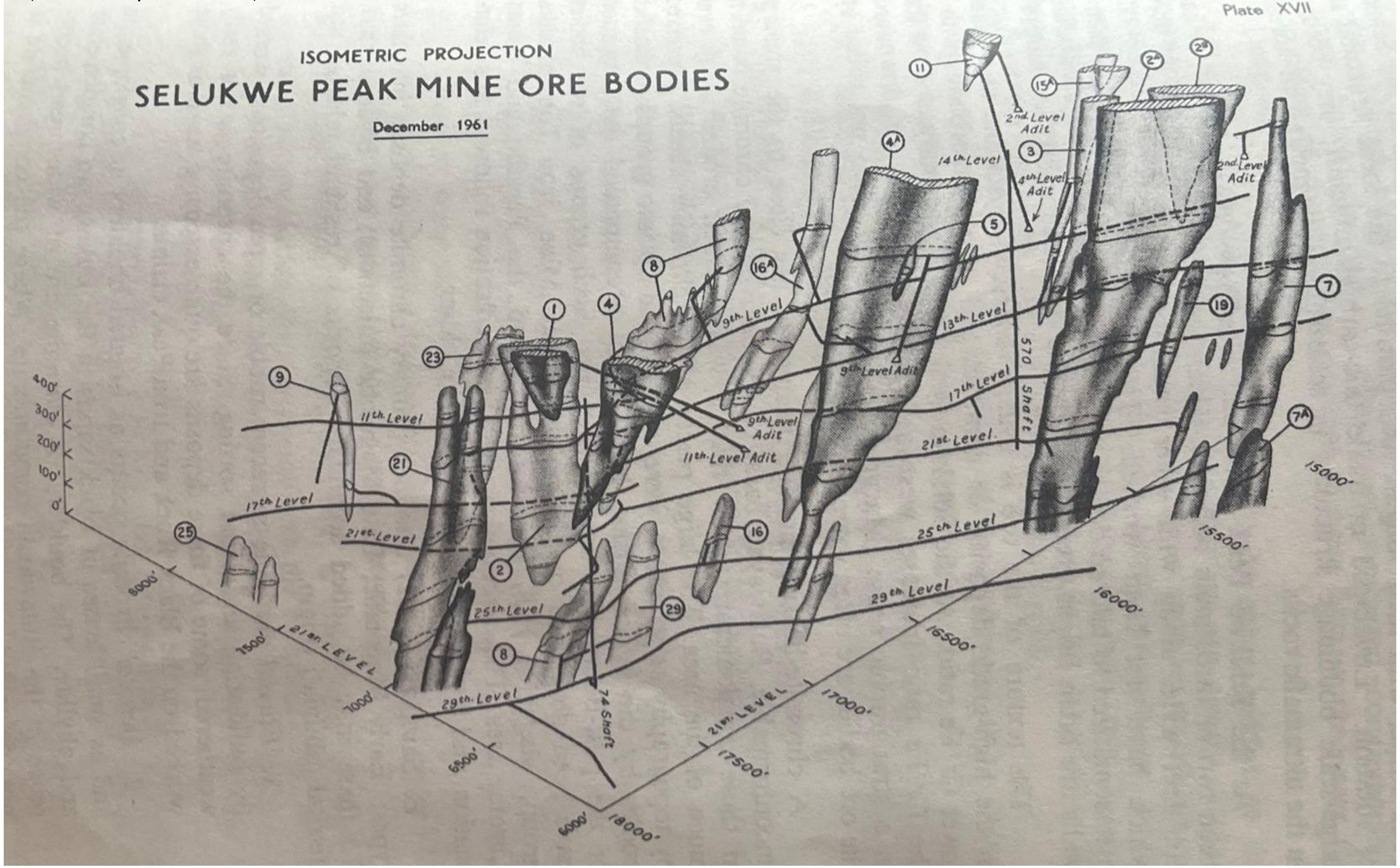
Case study of chromitites in the Shurugwi environs



(Stowe, 1968)

- Chromitite lenses are commonly rolled out & stretched into thin veinlets in the wall rocks.

(Stowe, 1968)



Morphology: variable sizes, lenses to pipe geometry.

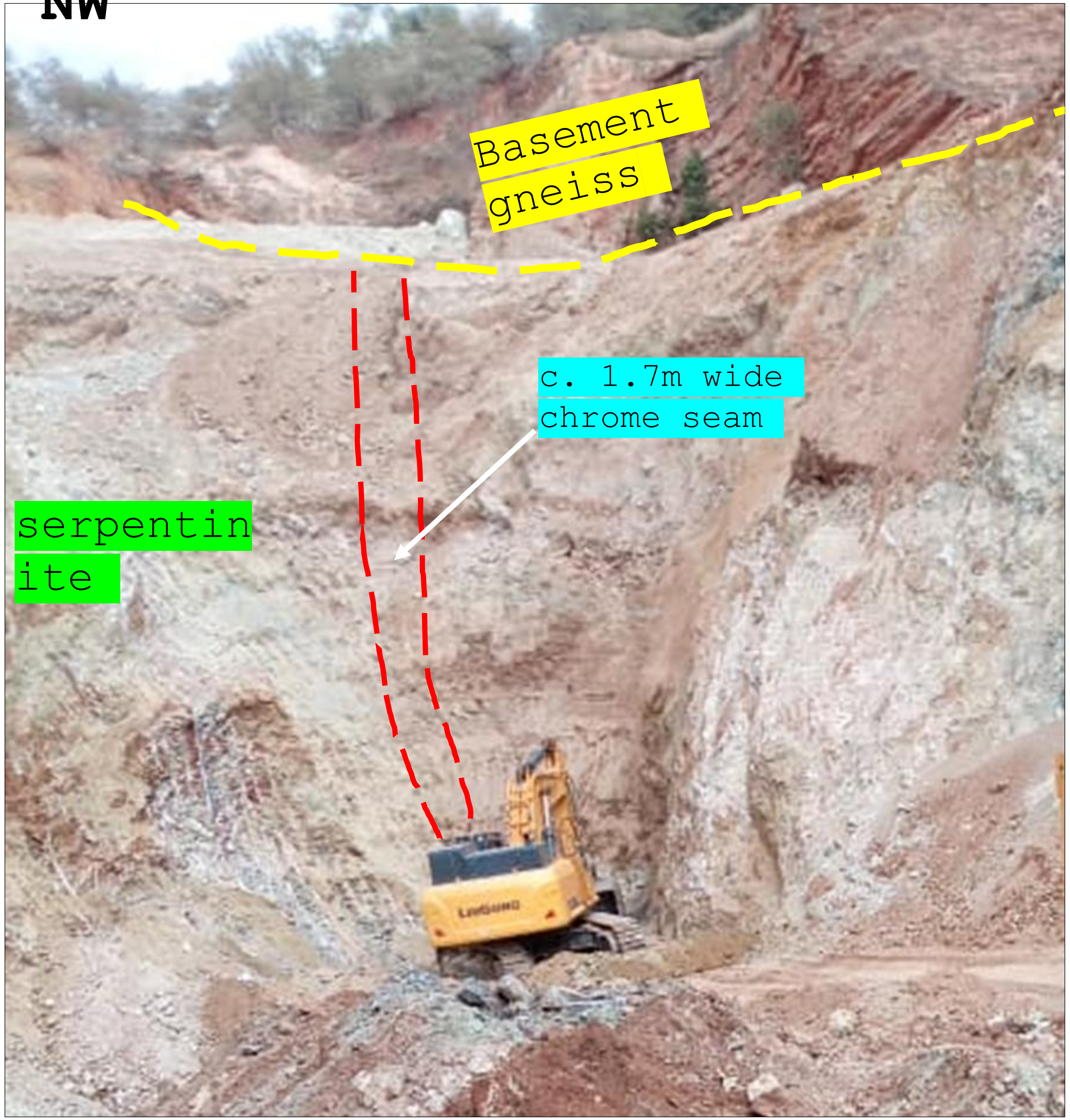
- More than 25 elongated and rolled up into lenticular or pipe-like ore bodies hosted in metasomatized ultramafic rocks have been worked.
- Bodies are enveloped in talc-carbonate schist, occurring as large-scale boudinage structures in series along magnesia-rich horizons in the ultramafic rocks.

- Two or three main horizons, confined to 60 m wide zone, along with other small bodies of lower Cr/Fe ratio.

Alteration of host rocks…usefulness to exploration

- Regional hydrothermal carbonatization and silicification in the Shurugwi environs is post-Bulawayan.
- Alteration post-dates formation of chromites.
- There is occurrence of fuchsite (Cr-rich, bright-green mineral) in some chromite deposits.
- The silicified zones are mylonite and breccia-zones; locally favour the conglomerate-ultramafic contact (which is often a chromite horizon).
- At Railway Block Mine, chromite zones are at least 240m from the Bulawayan conglomerates contact.

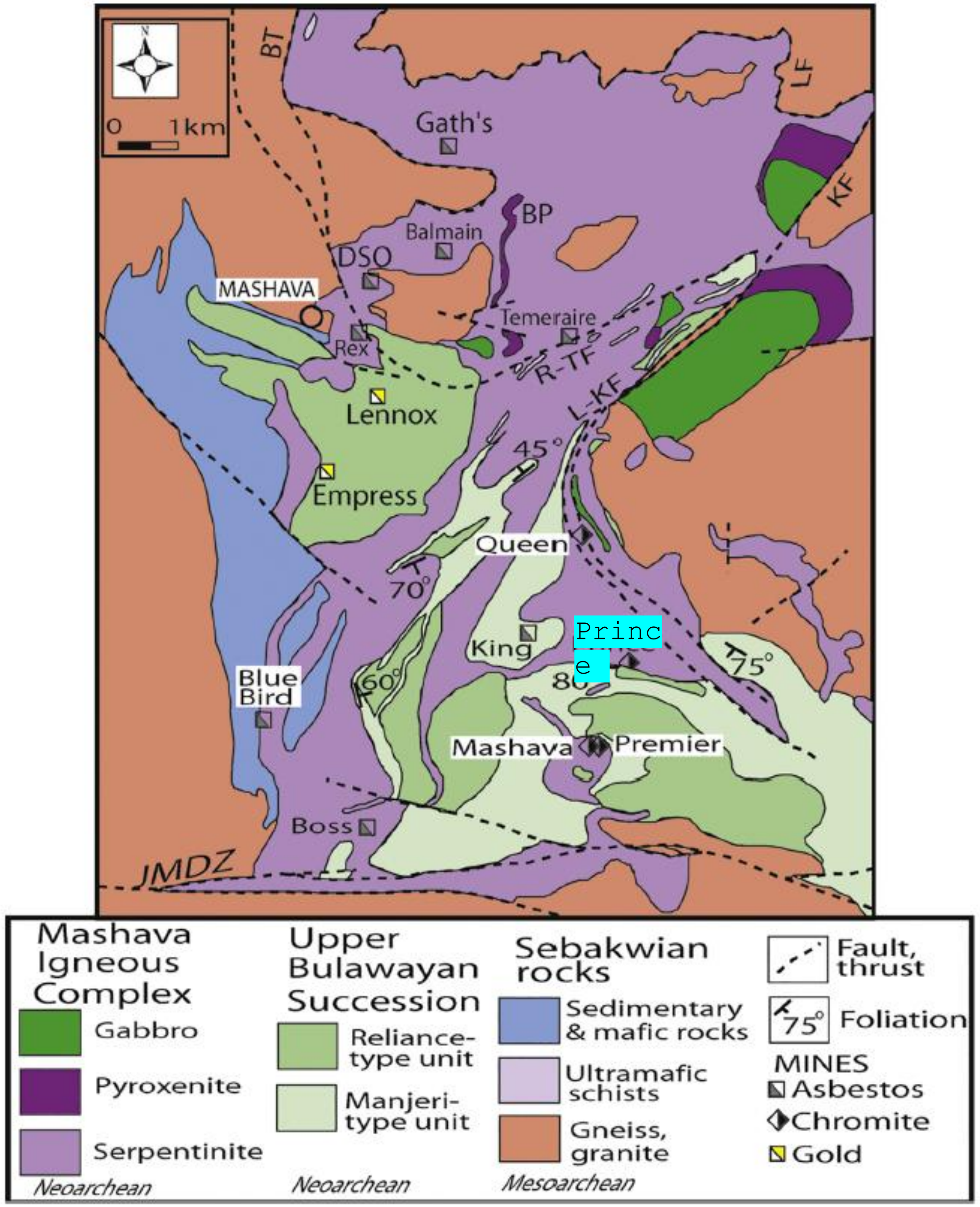
Rhonda Mine Pit looking NW



Rhonda Mine Pit looking SW

- Chromitites from Mberengwa (Inyala, Rhonda & Mlimo) are located within high-grade granulites.
- Tectonism structurally modified original ultramafic sills & chromitites, resulting in formation of irregular pods or lenses.

Geology of part of the Mashava-Masvingo greenstone belt showing the Mashava Igneous Complex



- Mashava Igneous Complex (MIC): concordantly intruded between c. 2.7 Ga Upper Bulawayan basal sedimentary rocks and 3.5 Ga basement gneisses, prior to regional folding (Prendergast & Wingate, 2007).
- MIC has well differentiated horizontal sills including the Prince Sill.
- The Prince Sill which hosts the Prince Mine chromitite deposits is located in the serpentinized dunite which lies within the shear zones that formed during regional deformation associated with the formation of asbestos at King Mine (Wilson & Nutt, 1990).
- A total 3m coarse-grained cumulate chromite layer was mined at Prince Mine.

(after Wilson, 1968; Prendergast & Wingate, 2007)

Challenges for exploring lenticular chromite ore bodies

- Ore bodies vary in size from small lenses (cm scale) to large bodies of few tens metres both of strike & width.
- The lack of **marker horizons** and the strong shearing in the ultramafic rocks, makes it impossible to locate the chromite horizons with any precision (Stowe, 1968).
- In the environs of Shurugwi, the challenges of locating ore horizons is a structural problem (Stowe, 1968).

This talk reviews on how may be the blind ore bodies be discovered.

(a) **Geochemical methods:** Increases in Cr/Fe ratio across the ultramafic body (i.e., downwards in a stratigraphic sense: Macgregor, 1938) has been employed to indicate the base of the sill.

- At Selukwe Peak Mine: chromite is spatially associated with Mg-rich zones (> 32 % MgO) (Cotterill, 1959).

(b) **Magnetic methods:** successfully used to locate some shallow bodies of chromite (e.g., Ironsides Mine).

(c) **Gravity methods:** successfully used to locate some shallow bodies of chromite (e.g., Railway Block Mine).

(d) **Resistivity methods:** successfully used to locate some shallow bodies of chromite (e.g., Rhonda Mine).

(e) **Alteration :** Hydrothermally carbonatized and silicified zones are associated with the chromite (Shurugwi & NMZ).

(f) **Diamond drilling:** Most of the new ore bodies were found by systematic underground diamond drilling.

Take-Aways

- Chromite bodies are hosted in ultramafic rocks or related rocks which form a sill-like body, intrusive into c. 3.5 Ga gneissic basement and overlying sediments such as BIFs.
- Across Zimbabwe, podiform chrome deposits are distributed in the Tokwe Segment including its southern extension into the NMZ. Deposits are associated with older/remnant greenstone belts.

- Two or more primary chromitite seams/horizons were formed as magmatic segregations during crystallization of komatiitic (>24 % MgO) magmas.

- Chromitites were complexly structurally deformed by several orogenic events, resulting current lenticular geometries.
- Challenges for exploring lenticular deposits relate to their relatively small size and discontinuous nature.
- A suite of geophysical exploration techniques including magnetics, gravity and xxx have been employed with mixed outcomes.

- Geochemical methods (Mg-rich domains and high Cr/Fe ratio) are useful in locating chromitites horizons.
- Most of the new ore bodies in were found by systematic underground diamond drilling.
- As shallow deposits become increasely exhausted, there is need to develop effective integrated techniques to identify blind and deeper deposits.


Thank
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