WITWATERSRAND COMGLOMERATE GOLD – WEST RAND

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Applied Geochemistry and Engineering Geology Research Group

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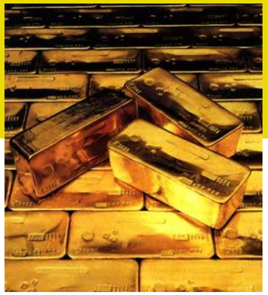
1. Introduction



- Source of Au - Alluvial concentration of heavy minerals(placer deposits)
  e.g. Yukon, the Mother Lode area

- Output is dwarfed by production from deposits
  in quarts pebble conglomerates that appear to be fossilized placers

- Witwatersrand (ridge of white waters) – 37% of all Au production with U

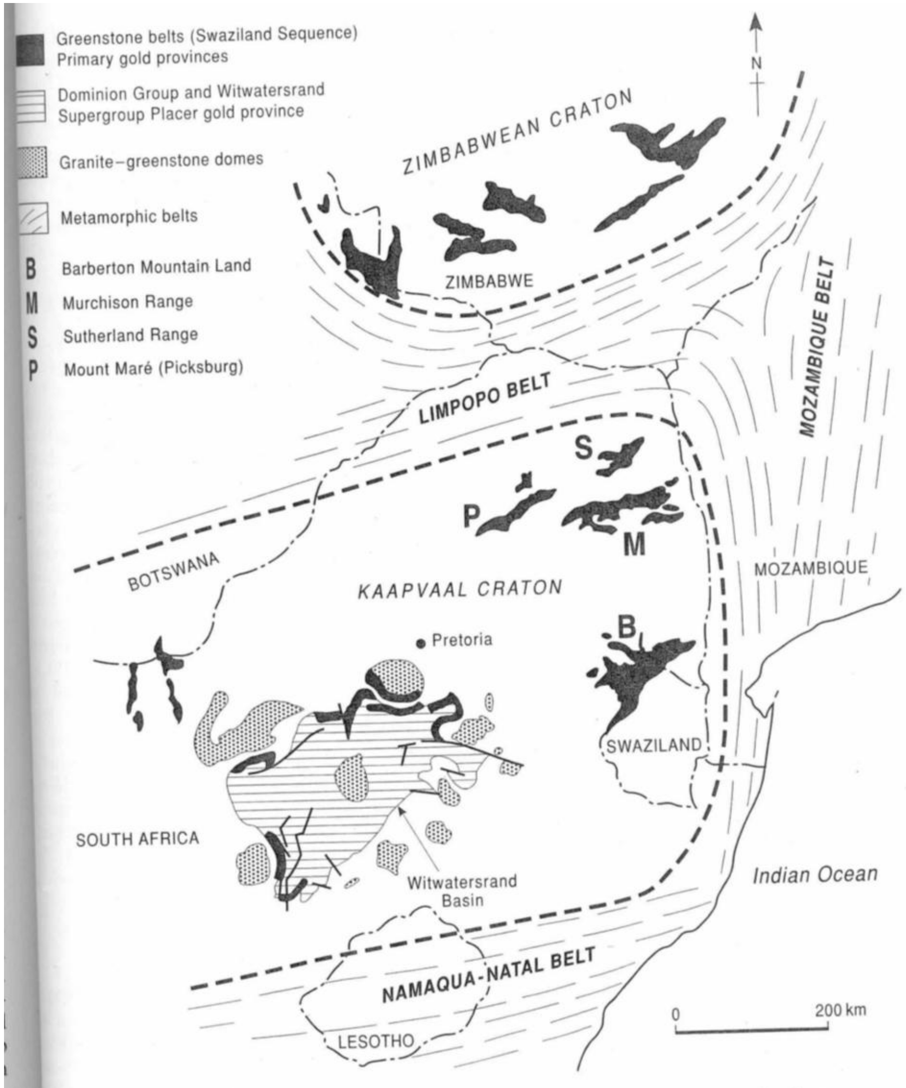
- Large tabular orebodies – large metalliferous underground mines,
  reach more than 3500m below surface

- Long and interesting exploration history involving large expenditures on deep drilling and geophysics

2. Geology

- Mineralized conglomerates found within Kaapvaal Craton (Fig 14.1), Au production has come from Witwatersrand Supergroup (7000-m thick)
- 350 * 200 km basin formed after consolidation of Kaapvaal Craton, from a series of greenstone belts and granitic intrusives
- Witwatersrand sediment history; in rift setting of bimodal volcanics and limited sediments, termed the Dominion Group
- Volcanics 3074±6 Ma, underlying granites 3120±6 Ma

Fig 14.1



14.1 Regional tectonic setting of the Witwatersrand Basin. Mesozoic and younger cover has been moved. (After Saager 1981.)

2. Geology
2.1 Stratigraphy of the Witwatersrand Supergroup

- Lower West Rand Group and upper Central Rand Group(Au)

- West Rand Group – shale and sandstone, volcanics, the Crown lavas
  Iron-rich shale gives magnetic response
  Deposition – littoral or subtidal (upward coarsening)
  some fluvial (upward fining with conglomerate at base)
  35t of Au, dating on detrital zircon – 2990~2914 Ma

- Central Rand Group – predominantly of coarse-grained subgreywacke

- Changes in sedimentation – shape and size of the basin
  Fan delta complexes prograding into a closed basin
  distinct entry points; correspond with Au fields
  Tectonic setting (folding, faulting) – collisional
  Dating of detrital zircon – 2910~2714 Ma

- Two types of Reef – sheet conglomerates and channelized conglomerates

Fig 14.2

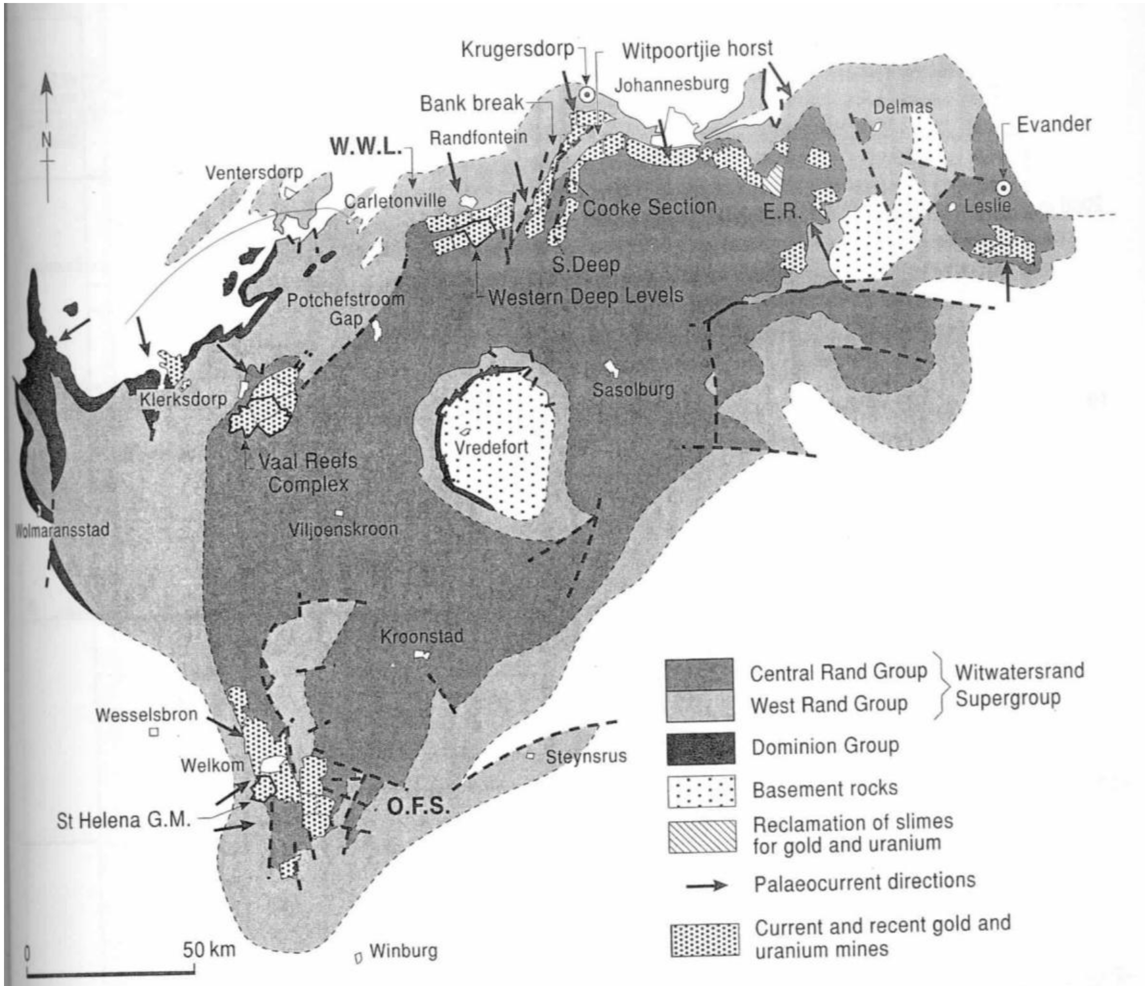


FIG. 14.2 Witwatersrand Basin with later cover removed, E.R. indicates location of East Rand Basin (Fig. 3.7). Note that the mine names are those referred to in the text and many of the current mines have new names. The new target mine is ~40 km north of Welkom. (Modified from Camisani-Calzolari et al. 1985.)

2. Geology
2.2 Overlying lithologies

- Basin sediments is almost covered by later rocks (precambrian and Phanerozoic)
- Ventersdorp Contact Reef(VCR, uppermost) is preserved by lavas
- Transvaal Sequence – Black Reef and overlying dolomites
  - Mineable areas - Black Reef cuts Central Rand Gorup mineralisation
  - Black Reef mineralisation; reworking or remobilization of Au from below
  - Dolomites contain water and prone to the formation of sinkhole
- Youngest major sedimentary sequence
  - Ecca group - coal-bearing; methane posing a threat of explosion
  - Karoo sediments - high thermal gradient; reduces working depth
- Intruded by a variety of dykes; disruption to mining
  - Separate dolomites; pumping problem

Fig 14.3

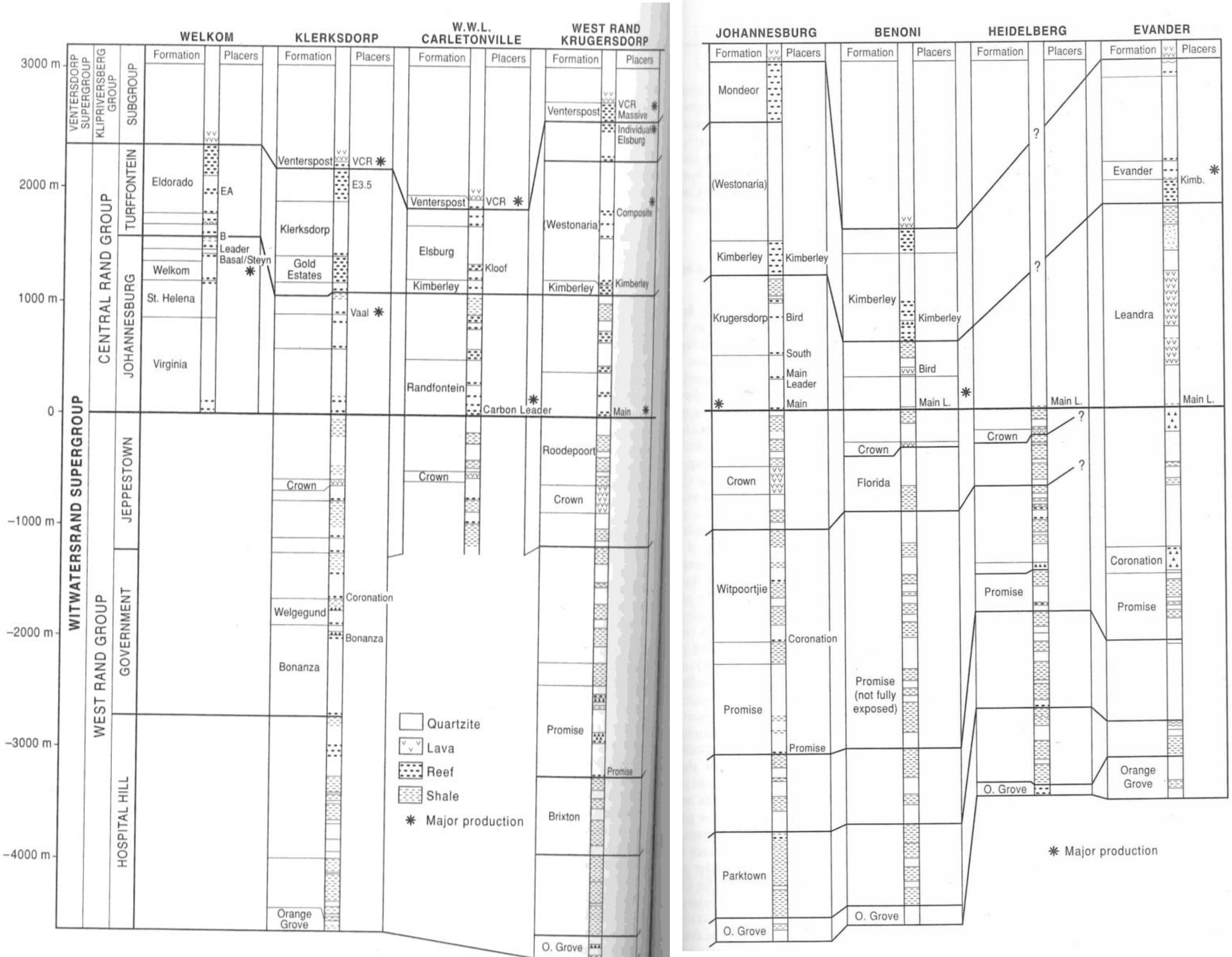


FIG. 14.3 Stratigraphical columns of the Witwatersrand Supergroup in the main gold-producing areas. Note the general correlations between goldfields and major producing conglomerates. (After Tankard et al. 1982.)

2. Geology
2.3 Structure and metamorphism

- Little effort on making a synthesis, an exception is faulting; forms the boundaries of mining blocks

- Activation time

- Occurrence of a pyrophyllite-chloritoid-chlorite-muscovite-quartz-pyrite assemblage; regional greenschist metamorphism, 350±50℃, ~2100-2000 Ma; same age as the intrusion of the Bushveld Complex

2. Geology

2.4 Distribution of mineralisation and relation to sedimentology

- Au and U grade is controlled by sedimentological factors (Fig 14.4)
  - higher grade areas are restricted to the main channels in Fig 14.4a, carbon seams and thin conglomerates in Fig 14.4b
- Sedimentary - homogeneous geostatistical domains for grade calculation
- Oligomictic placers; higher grades / polymictic conglomerates; lower grades
- Smaller-scale sedimentary structure in the OFS Goldfield (Fig 14.5)
  - Concentrated at the top and base of conglomeritic unit
  - Associated with heavy mineral bands
  - (Sheet conglomerates) Associated with carbon; basal few cm
  - Remainder of the reef; mostly waste, mined

Fig 14.4, Fig 14.5

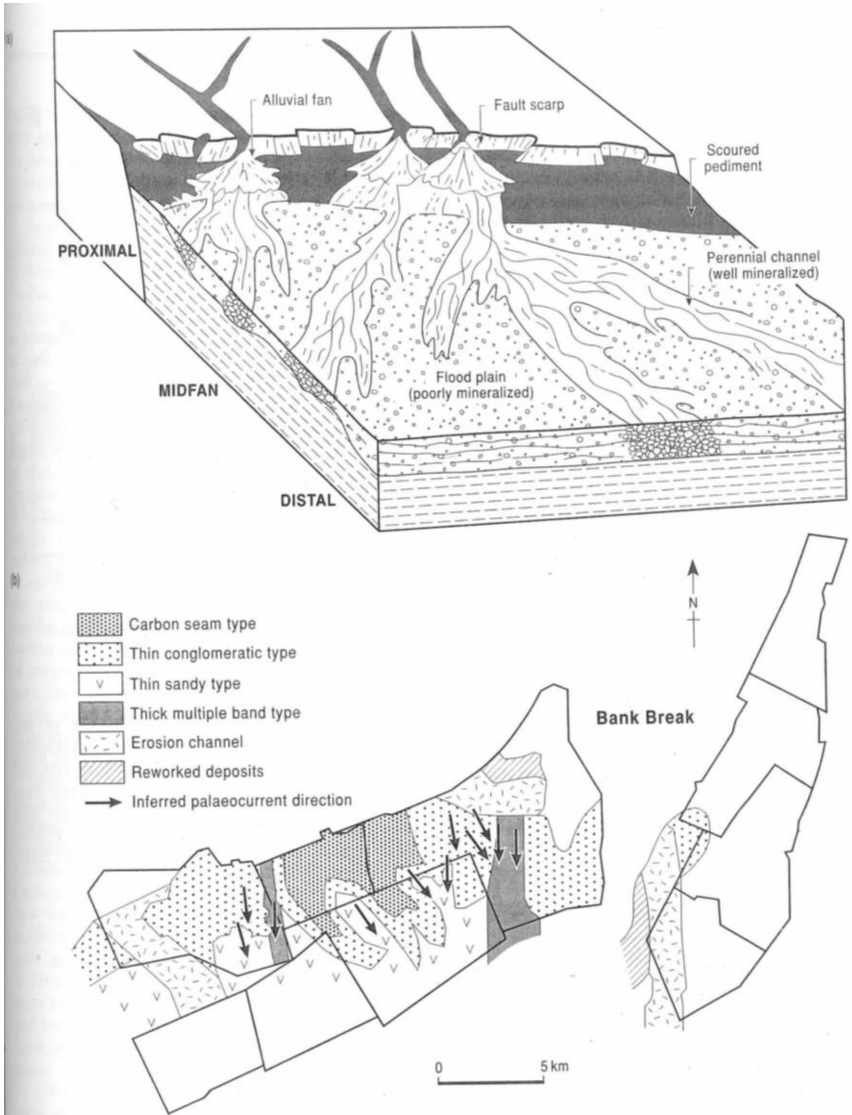


FIG. 14.4 (a) Sketch showing a reconstruction of depositional conditions in a channelized reef and relation to grade. Generalized from the Composite Reef. (From Tucker & Viljoen 1986.) (b) Facies of the Carbon Leader on the West Wits Line. Driefontein is the mine immediately west of the Bank Break. (From Viljoen 1990.)

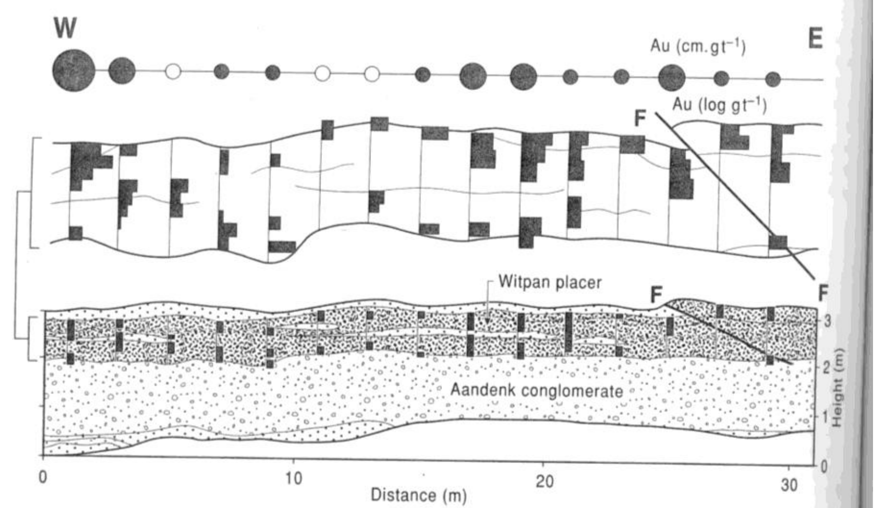


FIG. 14.5 Relation between grade and location in the Witpan placer, OFS Goldfield. The Witpan placer is stratigraphically above the B Reef of Fig. 14.3. The exact grades were omitted for commercial reasons. (After Jordaan & Austin 1986.)

2. Geology
2.5 Mineralogy

- Underground photograph of a typical conglomerate (Fig 14.6)
- Matrix consists largely of secondary quartz and phyllosilicates, including sericite, chlorite, pyrophyllite, muscovite, and chloritoid
- Opaque minerals; more than 70, predominantly pyrite
- Pyrite; 3% of typical reef, rounded grains, recognizable parting, porous,
    - filled with chalcopyrite or pyrrhotite, concretionary grains
    - Pyritization of other minerals (ilmenite or ferruginous pebbles)
    - Pyrrhotite; metamorphism of pyrite, frequent near dykes
    - Au; In fine-grained matrix between pebbles, plate-like, euhedral, spongy,
        - 0.075-0.15 mm (not visible), remobilization and replacement
        - Commonly associated with secondary sulfides and sulfarsenides
- Uraninite, chromite

Fig 14.6

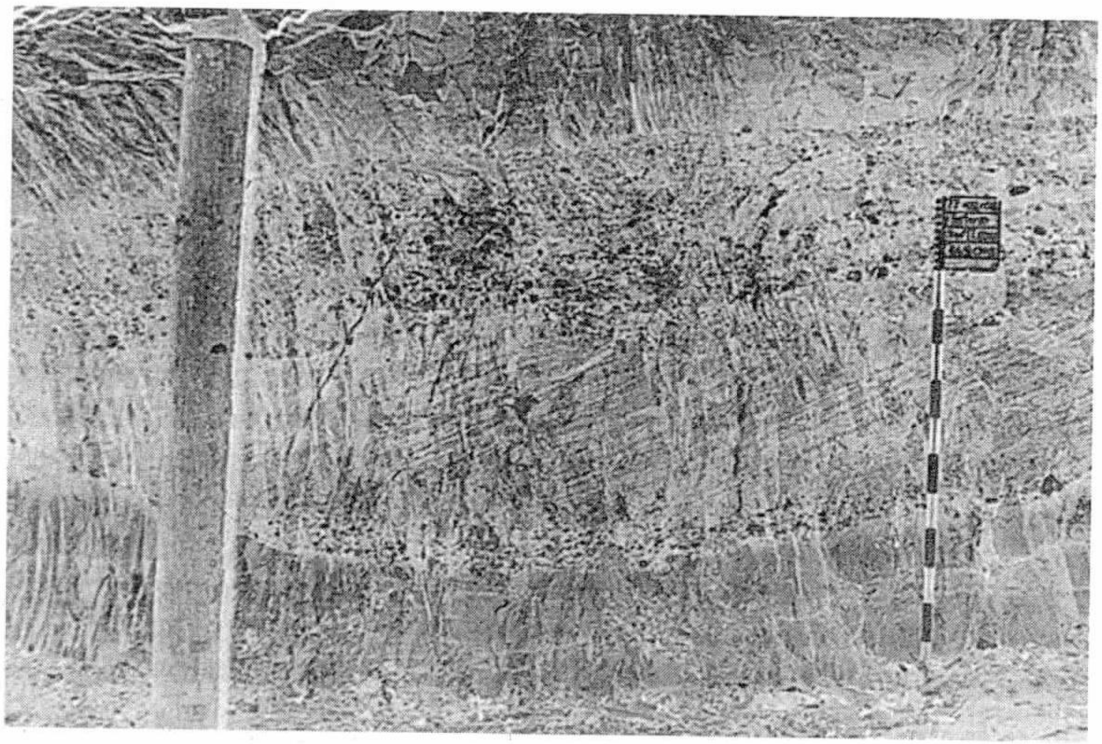


FIG. 14.6 Underground photograph of a typical conglomerate. The UE1a Upper Elsburg at Cooke Section, Randfontein Estates Gold Mine. Courtesy of the Sedimentological Section of the Geological Society of South Africa.

2. Geology
2.6 Theories of genesis

- Sedimentary origin vs hydrothermal origin

- Sedimentary origin
  - Normal placer-forming mechanism (palaeoplacer theory)
  - Precipitation of gold in suitable environments (synsedimentary theory)

- Hydrothermal origin
  - Conglomerates; merely the porous sediments
  - Gold and sulfides were deposited from hydrothermal solution

- Debate between researchers

3. Economic background

3.1 Profitability

- The economics of mining; price of gold
  Not controlled by supply and demand,
  but perception

- (Fig 14.7) exchange rate, increasing working costs

3.2 Organization of mining

3.3 Mining rights

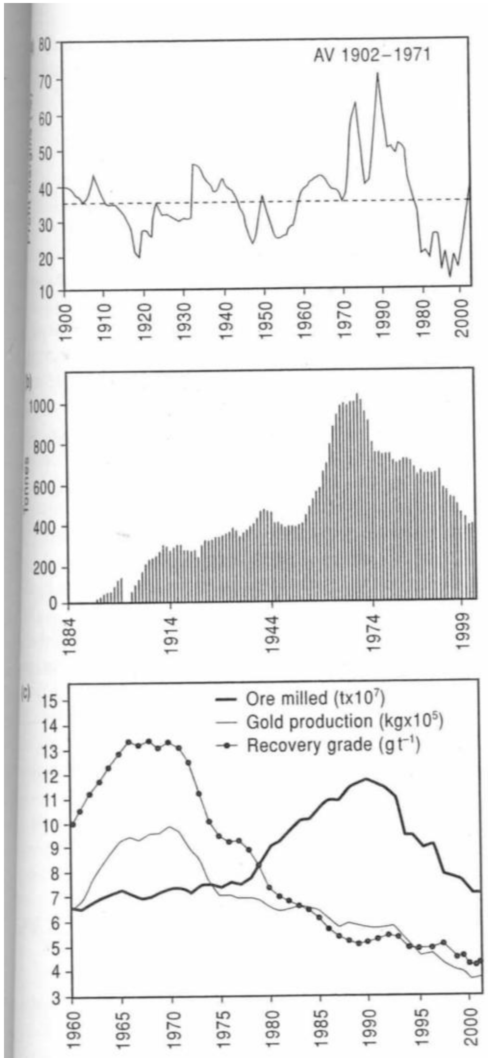


FIG. 14.7 Plots of (a) profit margins, (b) gold production, and (c) gold production, tonnes milled, and grade for the Witwatersrand Basin. (From Willis 1992, updated from Handley 2004.)

3. Economic background
3.4 Mining methods

- Development; due to narrow width, increasing depth, wages
- (Fig 14.8) Development in the footwall -> raise -> gullies -> stopes
- Drilling and blasting -> scraped -> high pressure jets -> primary crusher
- Hanging wall - supported by hydraulic props -> timber packs
- Rockburst – back filling, careful monitoring of stress build ups
- (Table 14.1) Lower operating costs, higher productivity, greater flexibility, improved grade control and safety

Fig 14.7

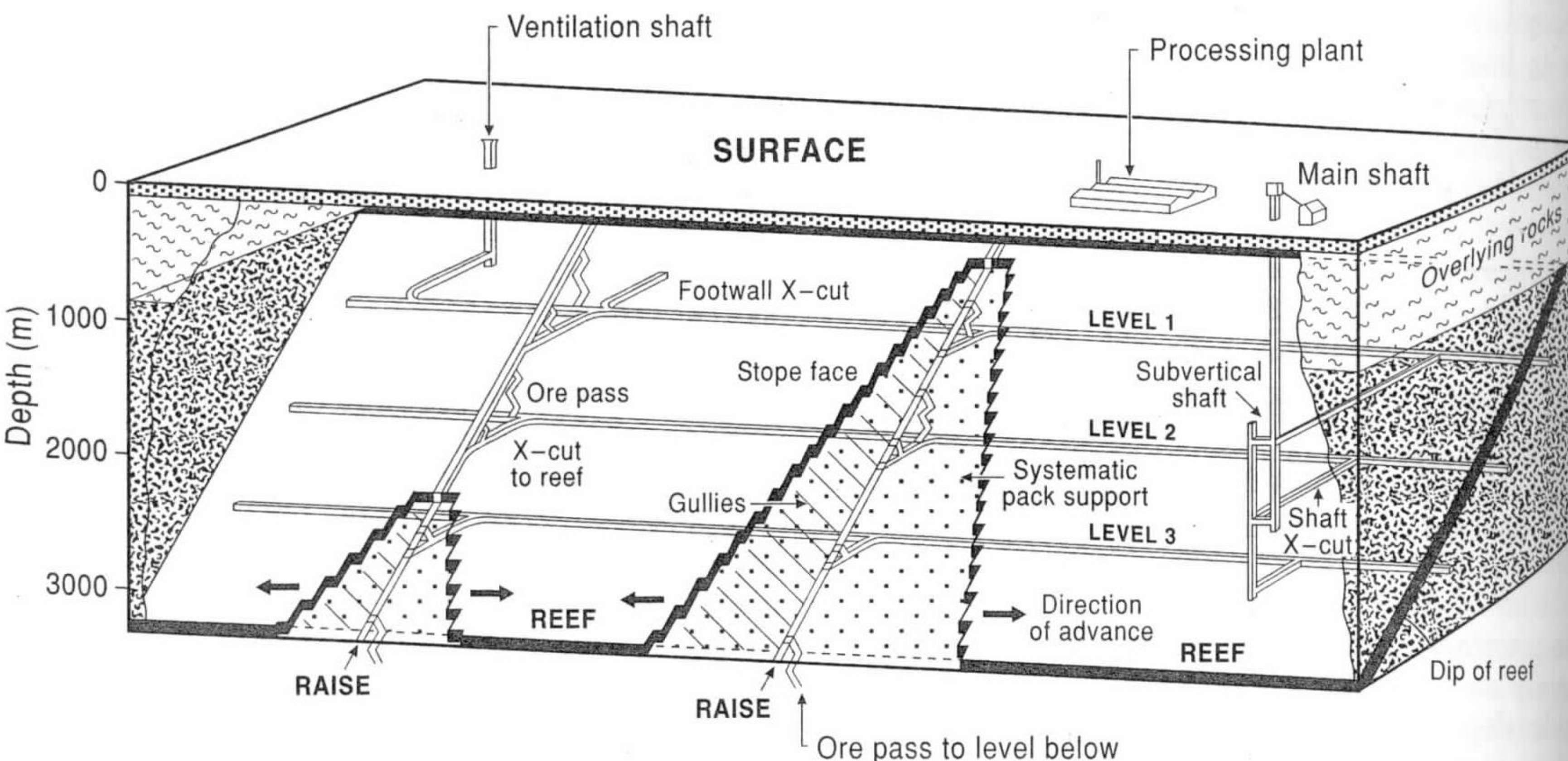


FIG. 14.8 Diagram showing a typical Witwatersrand mine. (From International Gold Mining Newletter April 1990.)

4. Exploration models

- Delineating extension of known payshoots, search for a new goldfield
- Detection of extensions to known goldfields (Fig 14.9)

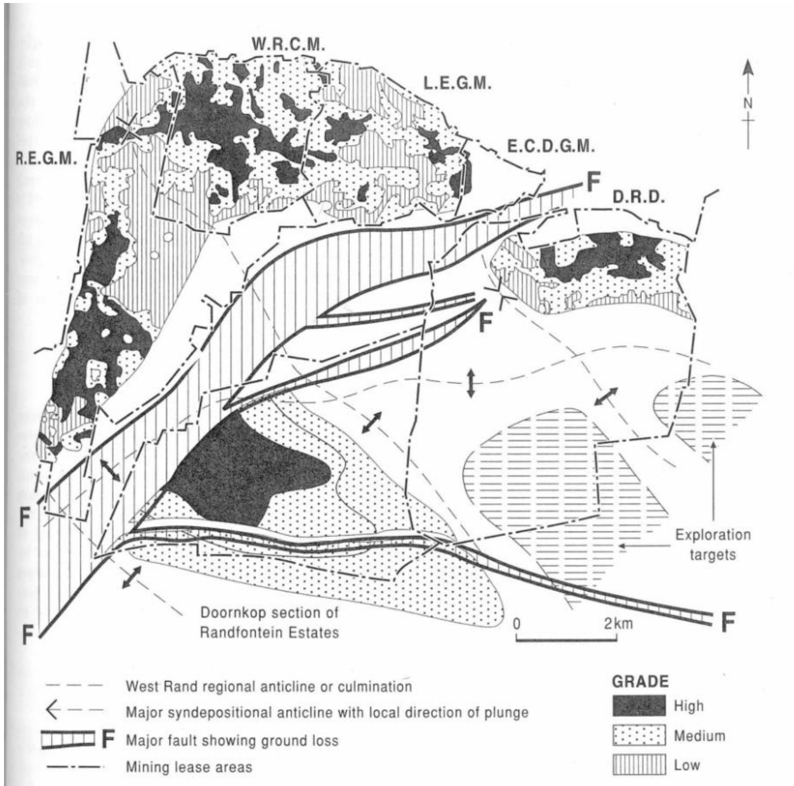


FIG. 14.9 Integration of regional grade distribution and structure to generate areas for drilling, West Rand. (After Viljoen 1990.)

5. Exploration method
5.1 Surface mapping and down-dip projection

- Iron-rich conglomerate -> surface prospecting, outcrop mapping
- Not surface enrichment but continued down dip
  - Surface iron oxides turned to pyrite -> poor recovery (amalgamation)
  - Cyanide process of extraction demonstrated
- Drilling

5. Exploration method
5.2 Magnetics and the West Wits Line

- Search for blind deposits
- Shaft sunk in 1990 had to stop due to an inflow of water (dolomites)
- Magnetometer; possible to trace the iron-rich shale
- (Fig 14.11)

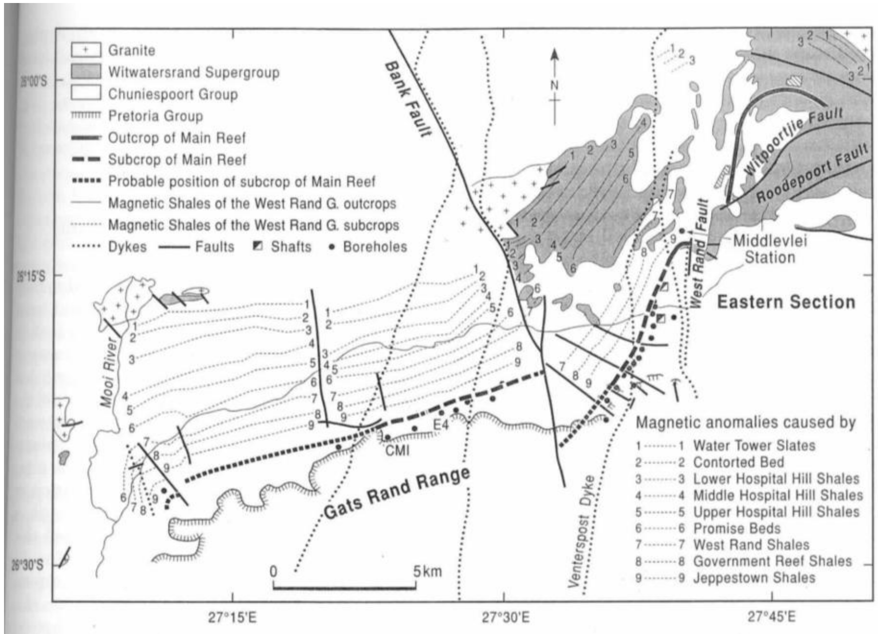


FIG. 14.11 Exploration on the West Witwatersrand line 1936. Drillhole E4 is the Carbon Leader discovery hole on the farm Driefontein, now (West) Driefontein Mine, and CM1 the discovery hole on the farm Blyvooruitzicht. (After Englebrecht 1986.)

5. Exploration method

5.3 Gravity and the discovery of the OFS Goldfield (Fig 14.12)

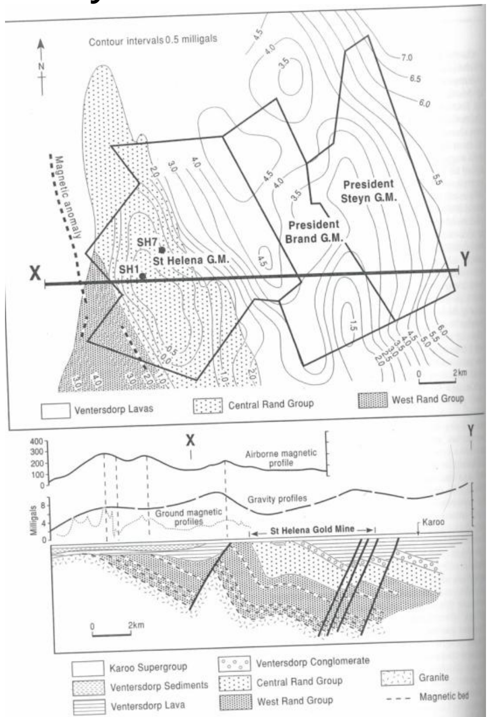


FIG. 14.12 Gravity and magnetic anomalies over the St Helena Gold Mine, OFS Goldfield. Note how the discovery hole (SH7) is on the flank of the main anomaly. (From Roux 1969.)

5.4 Reflection seismics, gaps, and upthrown blocks

5. Exploration method
5.5 Drilling

- One of the major financial constraints (fig 14.14, Table 14.2)

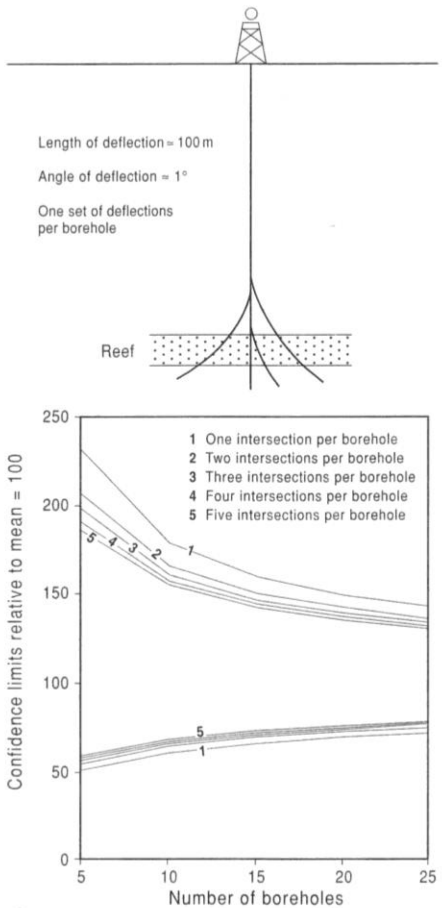


FIG. 14.14 Schematic diagram of deflections and plot of confidence limits for increasing number of drillholes and deflections per hole. There is considerable variation between placers, the case shown is the Vaal Reef. (From Magri 1987.)

6. Reserve Estimation

- Resources calculated during exploration vs
  Reserves estimated during exploitation

- Samples are taken along the raises and the drives ->kriging

- True reef thickness, Mass in tonnes are calculated

8. Conclusions

- Witwatersrand Basin; large tabular orebodies, gold occurrence
- Exploration; down-dip extensions through recognition of blind districts
- Geophysical methods have proved very successful
- Definition of mineable areas depends on an understanding of the sedimentological and structural controls
- Estimation -> large expenditures (shaft sinking)
- Discovery of Sout Deep deposit; large deposits remain,
  very few in number,
  difficult to develop

Thank you
for listening