

D. DURICRUSTS

Desk Note D3. Silcretes and ferricretes - Overview



Hilltop silcrete.

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Whereas controversy still surrounds the development of the coastal platform, geologists agree that the upper erosion surface of boulder beds, gravels, sands and clays is an early to mid-Tertiary peneplain (the 'African Surface'; see Chapter W), is preserved by silcrete and ferricrete cuirasses. The silcrete is so abundant in the Eastern Cape that it has been given the status of *formation*. Nevertheless, the South African Committee for Stratigraphy has never published a description of this formation (Figure 1).

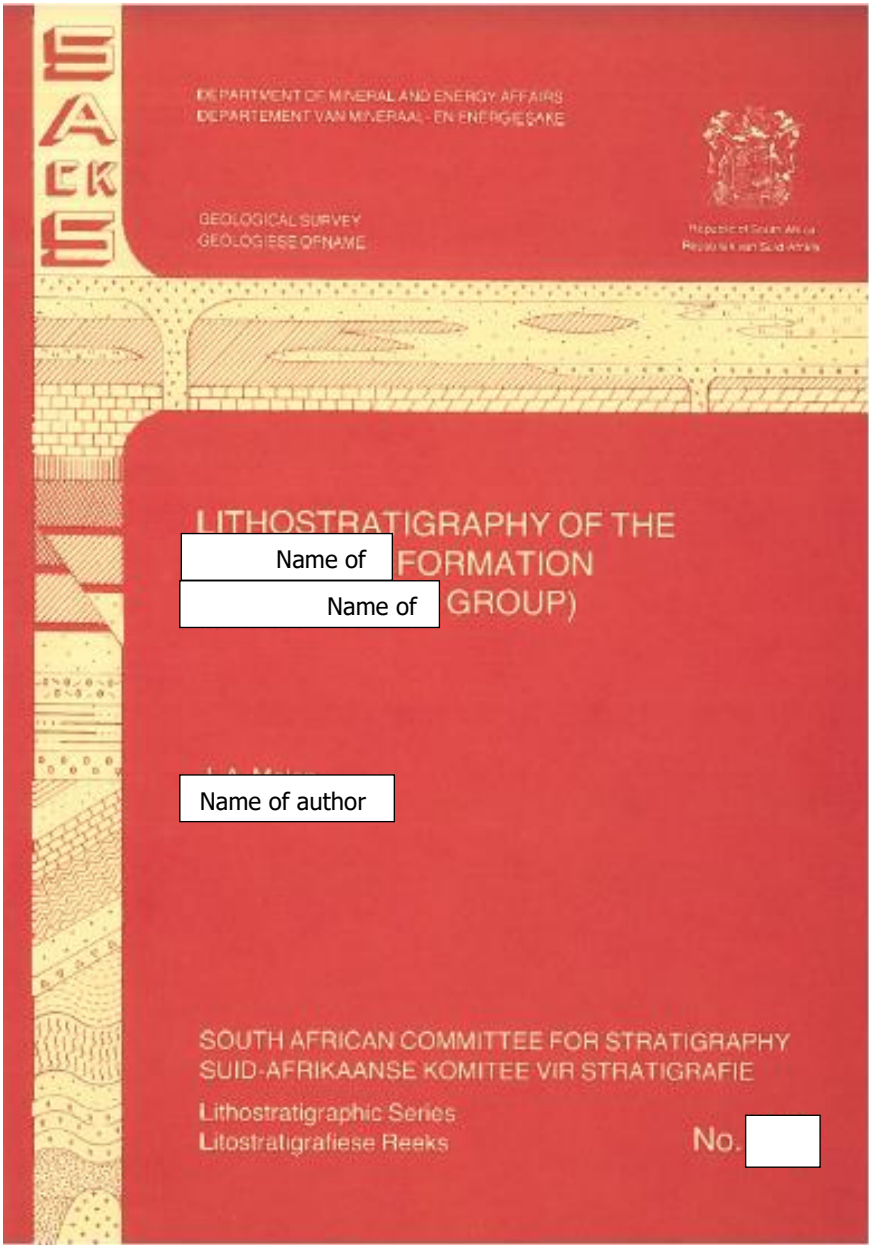



Figure 1. The front page of a typical publication for any formation by the SACS (South African Committee for Stratigraphy). There is no such publication for the Grahamstown Formation.

<p><i>Secrets of De Hoop and Environs</i></p>	<p>Field notes on the GEOMORPHOLOGY, HYDROLOGY and ARCHAEOLOGY Between CAPE AGULHAS and CAPE INFANTA</p>	 <p>Geomorphological Research</p>
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The Grahamstown Formation is inclusive of all the silcrete and ferricrete outcrops, which are found in the coastal areas of the Eastern, Southern and Western Cape, at elevations ranging from 40 to 650 m. Its name is derived from Grahamstown, a town in the Eastern Cape, around which silcrete forms extensive sheets on the Grahamstown Plateau.

On the other hand, researchers of the silcreted coastal belt of SA (MA Summerfield 2016, DJ Nash 2007, and DL Roberts 2003; see Bibliography Appendix) did not use the name 'Grahamstown Formation' in their papers. As will be shown in the following Field Notes in this chapter, assigning all silcrete (and ferricrete) outcrops to the Grahamstown Formation is incorrect).

[It is noteworthy that calcrete – a third type of duricrust in the area, which 'deserves' the description of 'cuirass', as it is continuously covering the entirety of the Bredasdorp Group limestones (see former Field Notes in this Chapter) - was never given the *formation* status.

This Website will not debate the assignment of silcrete and ferricrete to any formation.

Silcrete and ferricrete can be briefly and simply described as follows (from the Internet):

Silcrete is an indurated (resists crumbling or powdering) soil duricrust formed when surface sand and gravel are cemented by dissolved silica. The formation of silcrete is similar to that of calcrete, formed by calcium carbonate, and ferricrete, formed by iron oxide.

Silcrete is a surface or near-surface deposit of soil, saprolite, or sediment that has been cemented by secondary silica, to form an indurated mass.


Silcrete, silica-rich duricrust, an indurated, or hardened, layer in or on a soil. It generally occurs in a hot, arid climate where infrequent waterlogging causes silica to dissolve and be redeposited to cement soil grains together. Silcrete is extremely hard and resistant to weathering and erosion but eventually integrates and weathers down to boulders and blocks.

Ferricrete is a hard, erosion-resistant layer of sedimentary rock, usually conglomerate or breccia, that has been cemented into a duricrust by iron oxides. The iron oxide cements are derived from the oxidation of percolating solutions of iron salts. (Afrikaans-speaking farmers call this crust "Koffieklip").

Ferricrete is a ferruginous duricrust, cemented by iron oxides occurring as indurated continuous crusts and soil horizons in the landscape. Fundamental to the formation of ferricrete and laterite is the formation and accumulation of insoluble ferric iron in soils and regolith (*regolith*: unconsolidated, loose, heterogeneous superficial deposits which cover the bedrock).

Ferricrete is an iron-rich duricrust, an indurated, or hardened, layer in or on a soil. Soil particles are cemented together by iron oxides (such as Fe_2O_3) precipitated from the groundwater to form an erosion-resistant layer. Often the soil covering is eroded from the surface of the ferricrete layer, which is exposed as a rock surface; parts of old ferricrete layers may remain as remnants of old erosion surfaces.

Silcrete and ferricrete appear also as isolated and large fields of boulders and nodules. In many places on the coastal platform, silcrete has been transformed into ferricrete by ferrugination (a metamorphic process of the iron liberalisation from the minerals during their weathering and sedimentation in situ, accompanied by brown or red colouration of the soil-forming rock). Several intermediate forms of silcrete turning ferricrete have been located in the Study Area.

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Silcretes and ferricretes

Silcretes

The formation of silcretes is not very clear, and still pausing many questions. The quotations below (see references in Chapter Z - Bibliography), from several articles on silcretes are brought here, not in a particular order, and with the necessary omissions, to make the reader aware of the difficulties in understanding and classifying silcretes:

We know how most rocks are formed. Silcrete is something of an enigma, for although there are many interpretations of the origins of individual silcrete bodies, an overarching hypothesis capable of explaining all occurrences is still to be found.

Most silcretes must have formed in climates where there is an abundance of water, perhaps seasonally, and of organic acids. The age of a silcrete can be constrained by the fossils it may contain.

Silcretes commonly exhibit a number of fabrics (textures).

Silcretes are supergene accumulations of silica within pre-existing host materials. The silica may be present in any of its mineralogical forms and in a wide range of crystallinity. In the past, silcretes were also referred to as 'desert sandstone', 'silicious duricrust' and 'surface quartzite' (see the bottom of Page 6 below).

Silcrete is a variety of highly indurated duricrust formed as a result of the near-surface accumulation of secondary silica within a soil, sediment, rock or weathered material.

Silcrete is particularly widespread in Australia and southern Africa, where it is commonly found outcropping in association with ancient land surfaces. Silcrete also occurs as more spatially limited outcrops, as a surface lag or as isolated boulders in many other areas.

Silcretes develop in a variety of landscape settings and over different timescales. Investigations in Australia and South Africa, for example, show that pedogenic* silcrete formation is directly associated with the development of palaeosurfaces, thus the silcrete effectively forms on or very close to a former land surface.

***Pedogenesis** (from the Greek pedo-, or pedon, meaning 'soil, earth,' and genesis, meaning 'origin, birth') (also termed soil development, soil evolution, soil formation, and soil genesis) is the process of soil formation as regulated by the effects of place, environment, and history.

Silicification in the above context proceeds over potentially large areas and at timescales of millions of years via the gradual progradation of the silcrete profile into the landscape.

Non-pedogenic silcrete development may be more localised and is often controlled by the position of the local water table; while this would imply an overlying palaeosurface, the silcrete itself does not mark the position of the former land surface.

Formation of silcrete may also be much more rapid, in the order of 30,000 years.

A few groups of silcrete are recognised in the literature (Figure 2). The most widespread, in terms of areal extent, are *pedogenic silcretes*. These silcretes develop within soil profiles as the result of a succession of phases of silica dissolution and recrystallisation caused by multiple episodes of water infiltration and percolation. [**Infiltration** delivers water from the surface into the soil and plant rooting zone while **Percolation** moves it through the soil profile to replenish ground water supplies or become part of sub-surface run-off process].

Other silcrete types are often grouped together, for convenience, as *non-pedogenic varieties*. Of these, *groundwater silcretes* form under phreatic conditions (in the zone of saturated groundwater; YE) through silicification at or close to a water table, or at zones of groundwater outflow. *Drainage-line silcretes*, in contrast, develop as a result of the silicification of alluvial fills in contemporary or former fluvial systems. The third variant, termed *pan/lacustrine silcrete*, results from the silicification of sediments at the margins of ephemeral lake basins.

Distinguishing between pedogenic and non-pedogenic silcrete can, in many cases, be difficult.

For the purposes of this Website, the study made no distinction between the two sub-types of the pedogenic silcretes. The non-pedogenic silcretes do not constitute parts of the Grahamstown Formation. They are described in the following Field Notes.

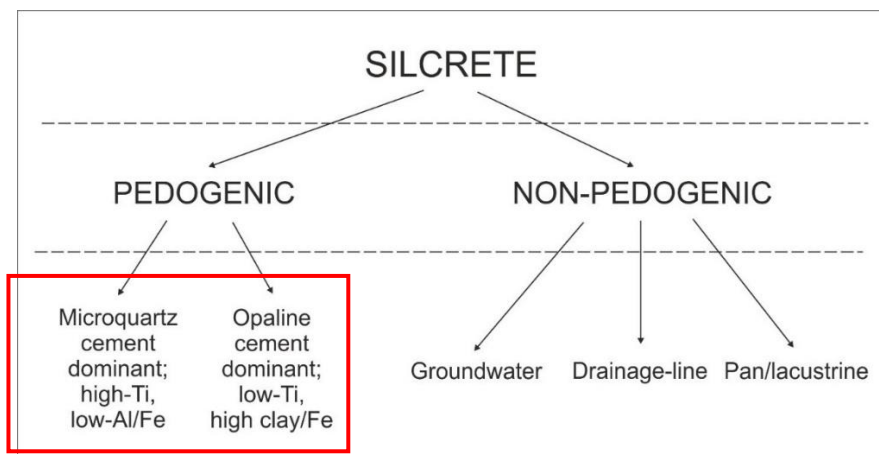


Figure 2: Classification of silcretes. Source: Nash and Ulliyott, 2007.

The following Field Notes do not differentiate between the two types of pedogenic silcretes, as the silcrete's formation processes and mineralogical compositions are outside the scope of this study.

Ferricretes

Ferricrete is a ferruginous duricrust cemented by iron oxides occurring as indurated continuous crusts and soil horizons in the landscape. Fundamental to the formation of ferricrete is the formation and accumulation of insoluble ferric iron in sediments.

Accumulation of iron can, and frequently does, also occur as a result of migration of iron into soil or regolith from outside the profile. Iron-rich crusts formed in this manner are referred to as ferricrete. Ferricrete can be the result of a variety of formational processes including pedogenic formation, *in-situ* formation, groundwater fluctuations, fluvial, lacustrine, and secondary reprecipitation. They are, thus, the result of the synergistic operation of numerous iron-concentrating processes.

Silcretes and ferricretes in the Cape south coast

The following are quotations about the Grahamstown Formation and of silcretes and ferricretes, are taken (in no particular order), from explanations to the Worcester (3319), Riversdale (3420) and George (3322) geology maps (with some omissions) (see Chapter Z of this Website).

All Tertiary deposits in the region are provisionally included in the Grahamstown Formation. This unit is, therefore, inherently heterogeneous in character.

Ferricrete and silcrete cap low hillocks, which are remnants of the African erosion surface.

High-level silcrete, ferricrete and gravel terraces are widely spread in the southern Cape province. The deposits are associated with Tertiary planation surfaces. At least two successive periods of planation, deposition and cementation took place during the Tertiary period.

The duricrust layers are normally less than 2 m thick (thicker layers are found in other area; YE) and developed preferentially in areas underlain by pelitic (clay-rich, fine-grained clastic sediment; YE) Bokkeveld and Malmsbury Formations rocks.

This surface slopes seaward, with the result that the duricrust capping occur at progressively lower elevations towards the south and west (not everywhere, and in many places the slope is to the northeast; YE).

The silcrete normally forms a very hard, cream-coloured crust with a glassy matrix and conchoidal fracture but may become softer and more friable lower down.

Silcrete texture ranges from massive, almost glass-like amorphous material to silica-cemented gravels with boulder sizes of up to one metre in diameter.

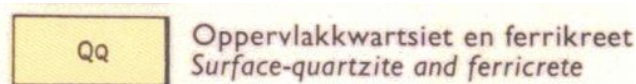
Many of the silcretes appear to be related to breccia (sediment composed of large angular fragments) along major faults. Brecciated quartzite and phyllite (foliated metamorphic rock; YE) have been recemented into hard, ferruginous crusts.

Washed stones of silcrete are found in the Pliocene Basal formation of the Bredasdorp Group. The origin of the southern Cape silcrete is therefore older than the latter.

Iron-cemented gravels (ferricretes) are sporadically developed in close association with silcretes. The transition from silcrete to ferricrete is normally gradational. This suggests that the two pedocrete (duricrusts; YE) types were synchronous and formed largely under essentially similar, but slightly fluctuating geochemical environments. Lowered and raised pH would result in the development of ferricrete and silcrete respectively.

Ferricretes vary from hard, brown, ferruginous layers to nodular or conglomeratic deposits and may grade laterally into silcrete.

In older geology maps of the SW Cape (such as the 1:125,000 combined sheet of 3419 C&D and 3420 C, 1963) the silcrete was called 'surface quartzite':



The Grahamstown Formation, formed during mid to late Tertiary (65 to 30 million years ago), is the youngest formation of the Uitenhage Group. In the Study Area it was formed on the Bokkeveld shales, and now only remnants of the crust are present on top of several hills. The deposition of the much younger (but generally topographically lower) Bredasdorp Group Formations took place on the coast after the deposition of the Grahamstown Formation (Figure 3).

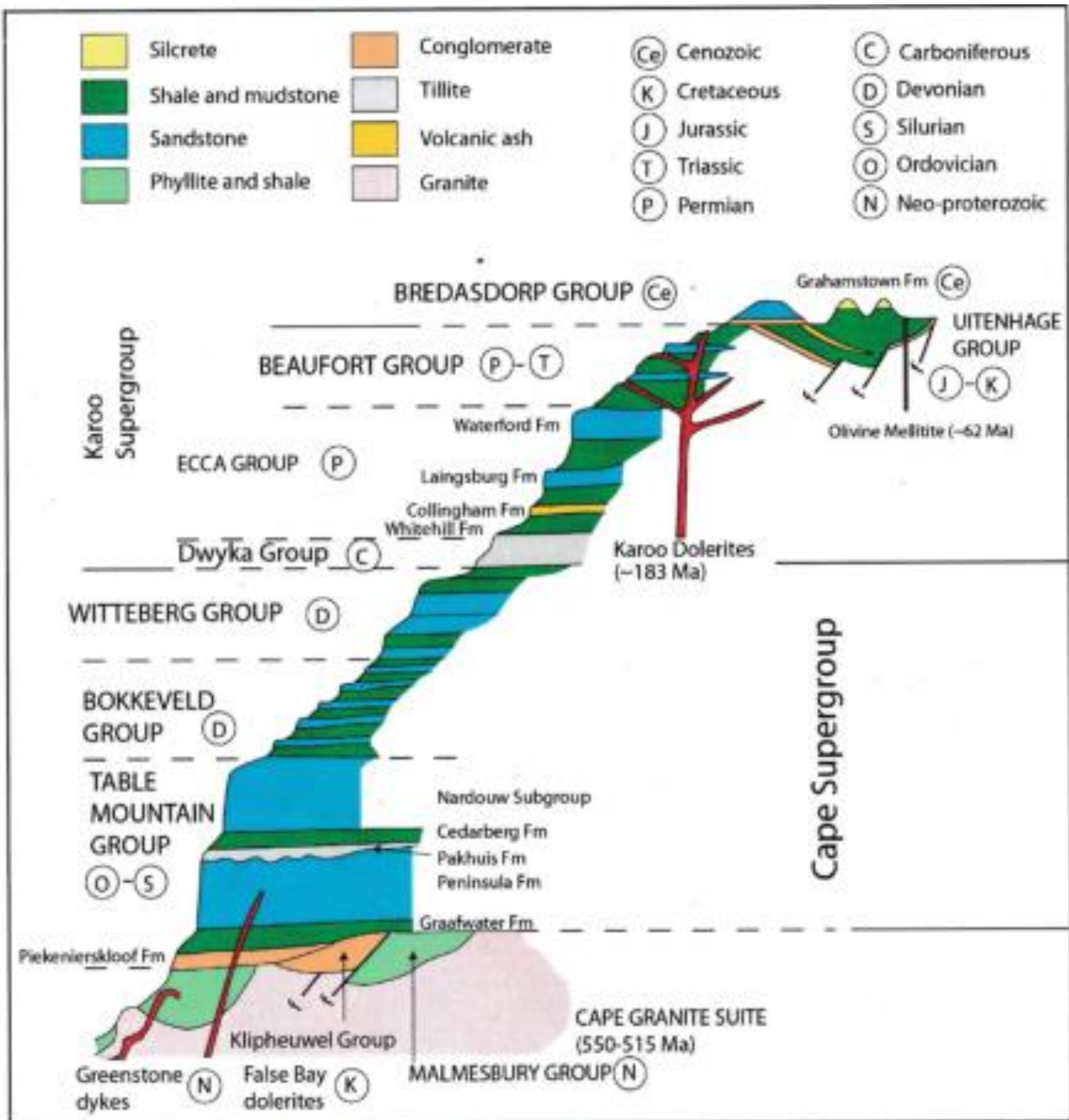


Figure 3. Schematic stratigraphic profile of the Western Cape, showing the Grahamstown Formation capping the hills north of the Bredasdorp Group hills (Hard Dunes).

(From J Malan and J Viljoen: Field Trip Guide, 2016).

The available geology maps in 1:250,000 scale, lump silcrete and ferricrete together as the Grahamstown Formation. The 1:50,000 maps distinguish between silcrete and ferricrete (Figures 4 to 8). (See Chapter W for discussion on African Surface and Post African Surfaces).

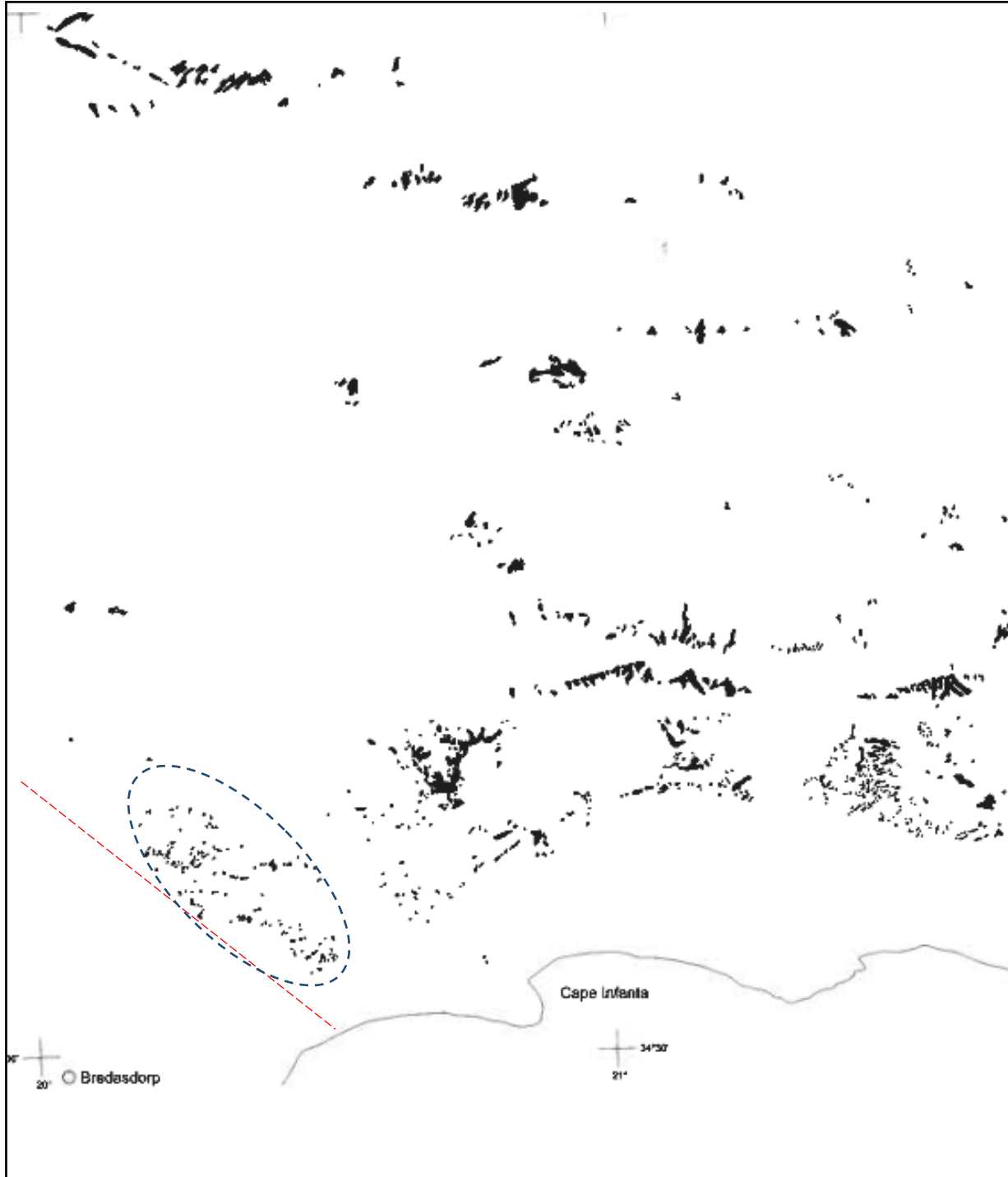


Figure 4. Section of a map showing the distribution of partially silicified and ferruginised sediments in the Southern Cape. Note the lack of outcrops south-west of the dashed line (also see the Field Note on spatial distribution). The ellipsoid indicates the outcrops which are within the Study Area.

Source: DL Roberts: Age, genesis and significance of South African coastal belt silcretes. 2003.

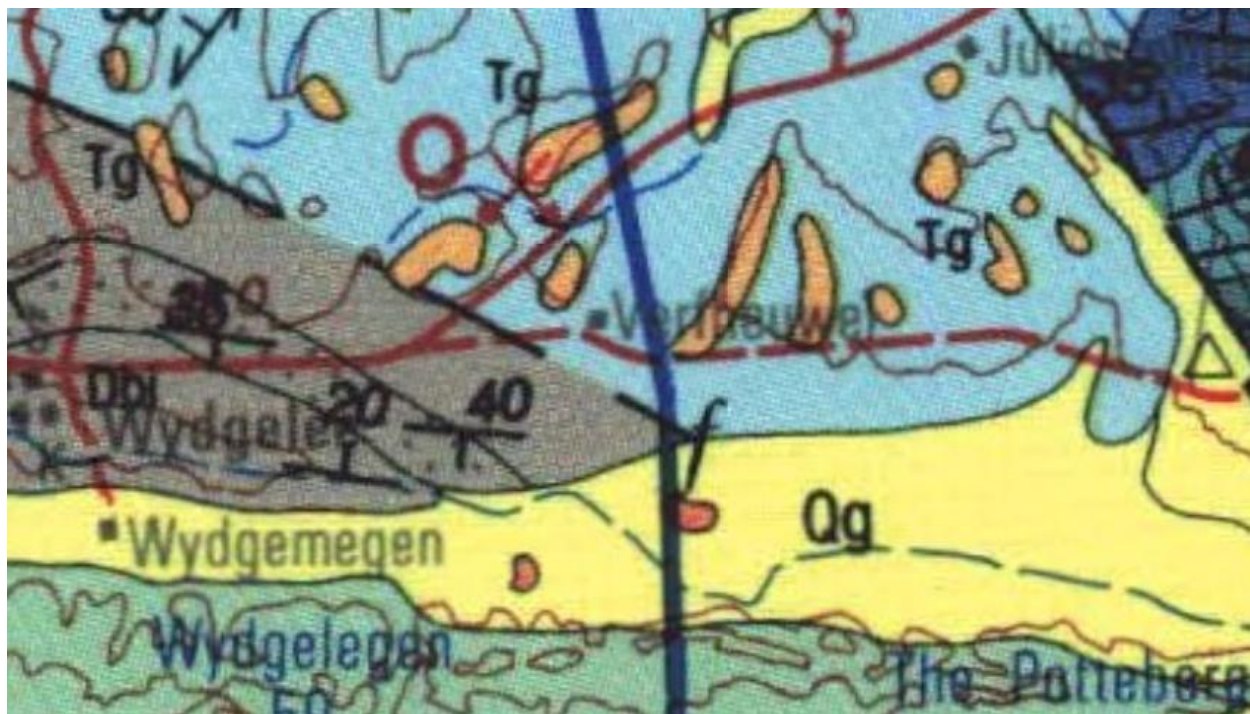
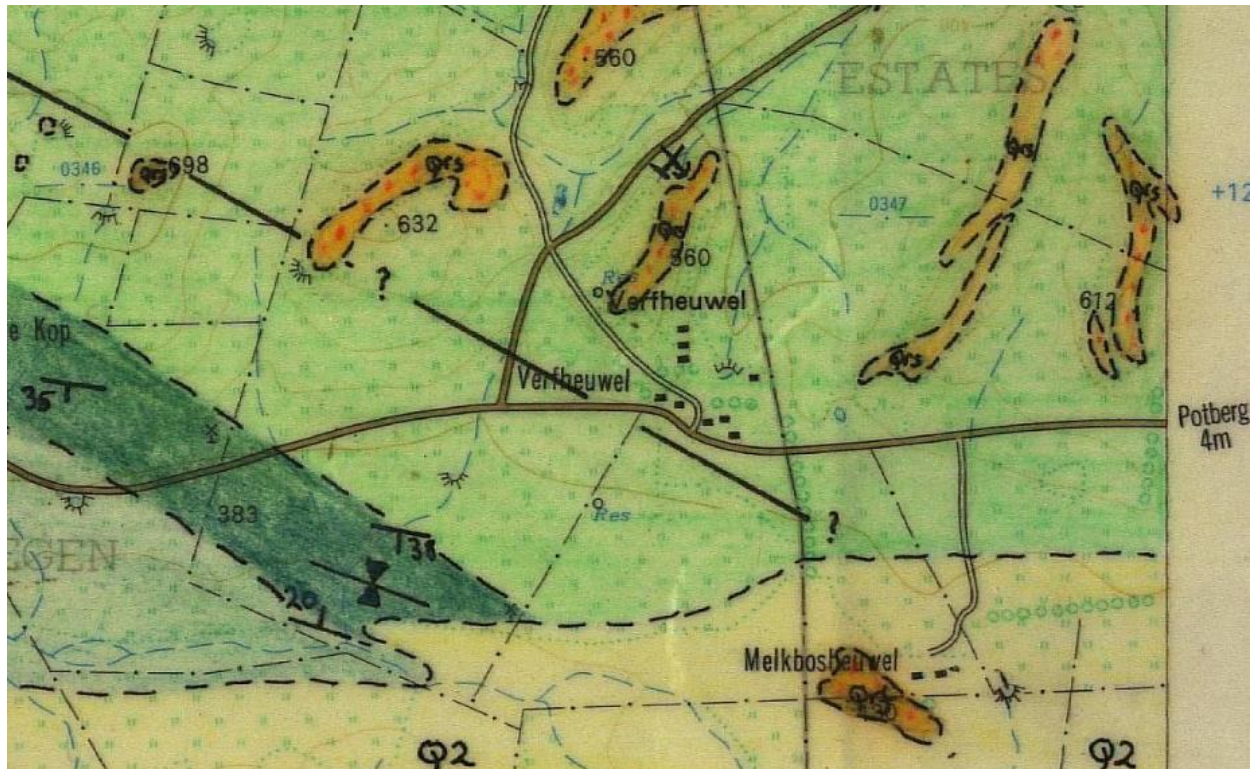


Figure 5. Sections of geology maps (of the Wydgeleé Area) showing Grahamstown Formation outcrops (orange). Top – JA Malan’s 1984 1:50,000 field sheet; Qrs and Qrf stand for Quaternary silcrete and ferricrete respectively (not indicating the Quaternary Age but that they are younger than the underlying formations; as per personal communication with JA Malan, September 2020). Bottom – Riversdale 1:250,00 sheet, 1993. Tg – the symbol for Grahamstown Formation.

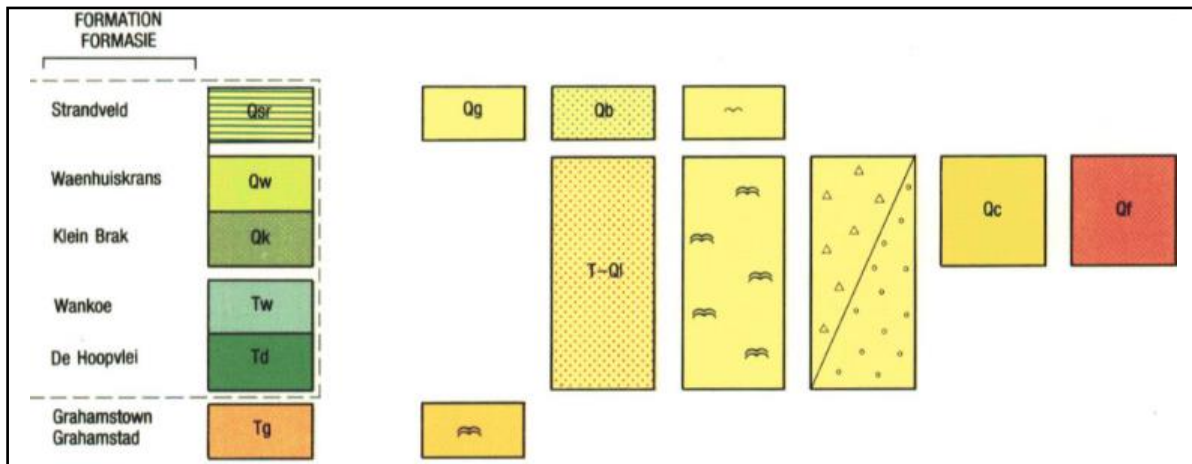
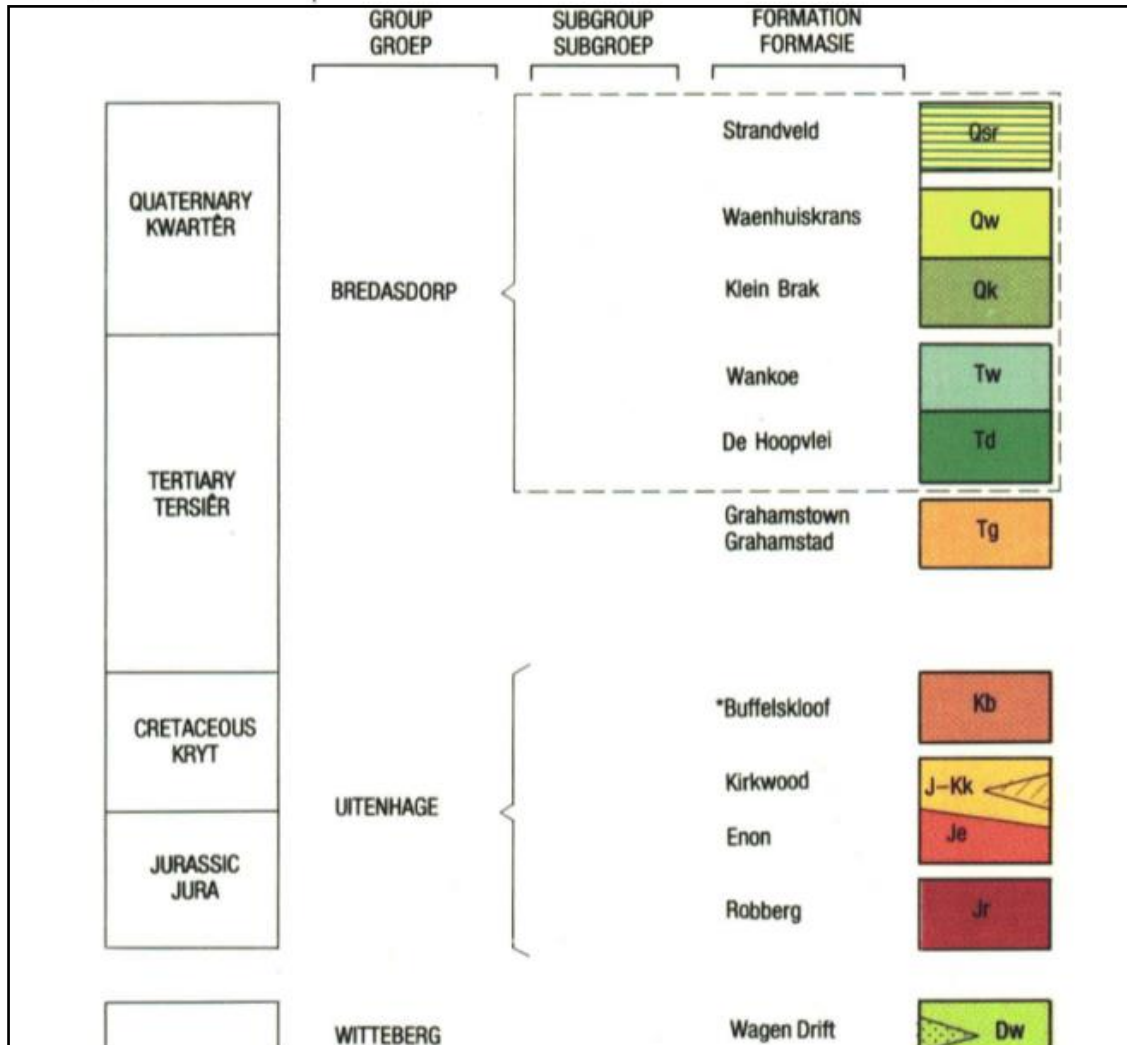


Figure 6. Legend of the Riversdale 1:250,000 geology map of 1990. Top - top section of the legend; bottom – legend extension to the right. The symbol of the Grahamstown Formation is Tg:
High-level silcrete and ferricrete
Hoëvlaksilcrete en -ferrikreet

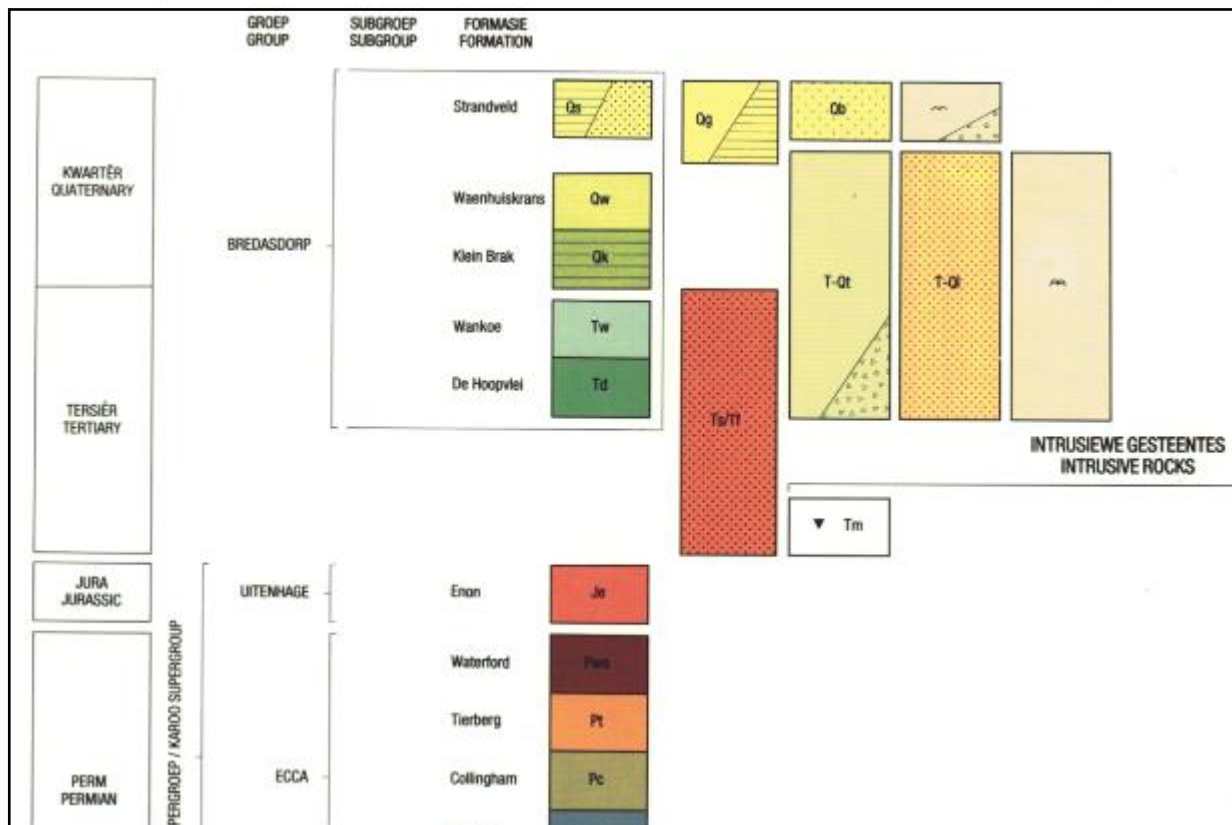
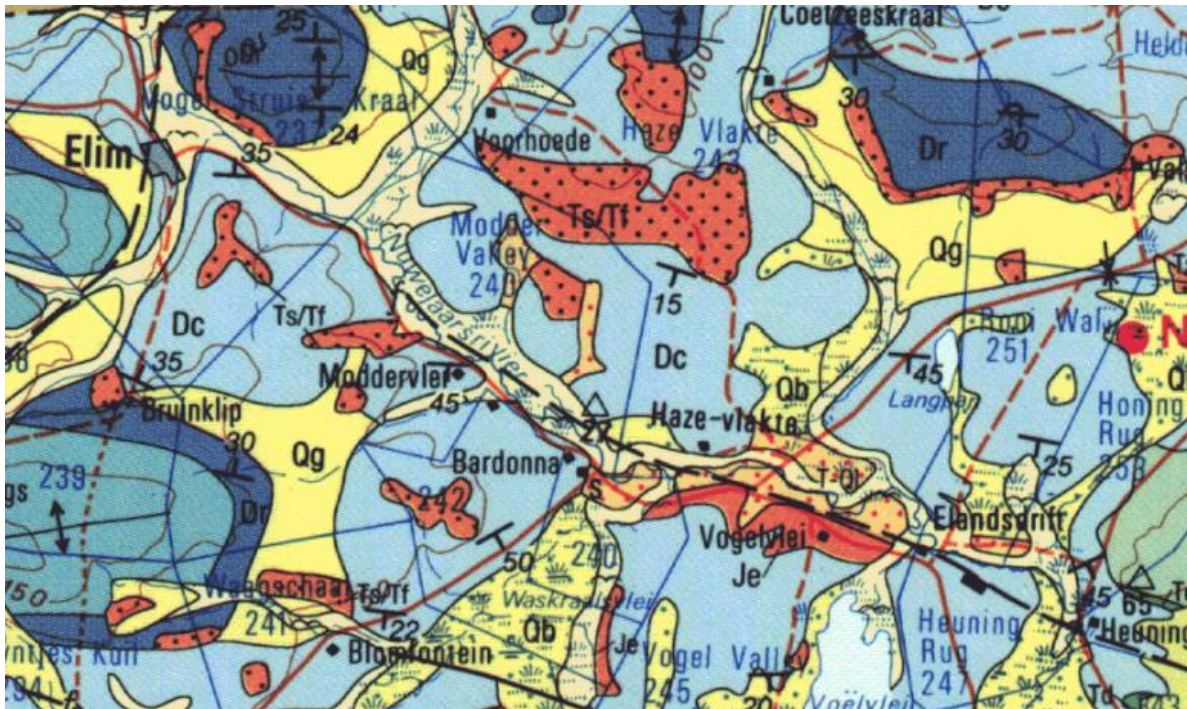


Figure 7. Top – Geology map of the area southeast of Elim, from the 3419 Worcester Map 1:250,000, 1997. Bottom - Legend of the map. The Grahamstown age extends through the entire Tertiary. The map symbol for the outcrops is Ts/ Tf:

Ts / Tf Silkreet (Ts) en ferrikreet (Tf)
 Silcrete (Ts) and ferricrete (Tf)

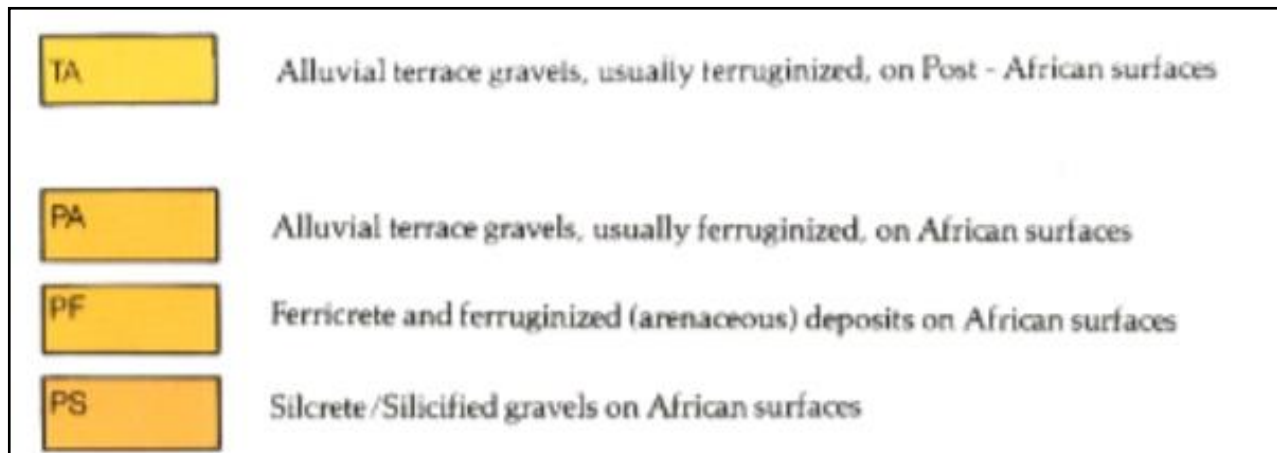
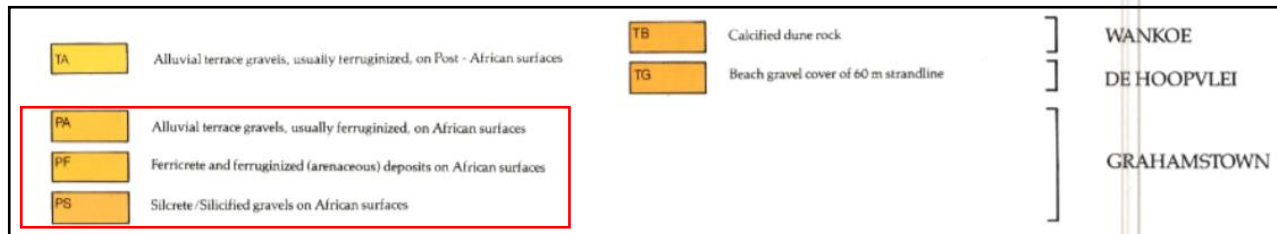
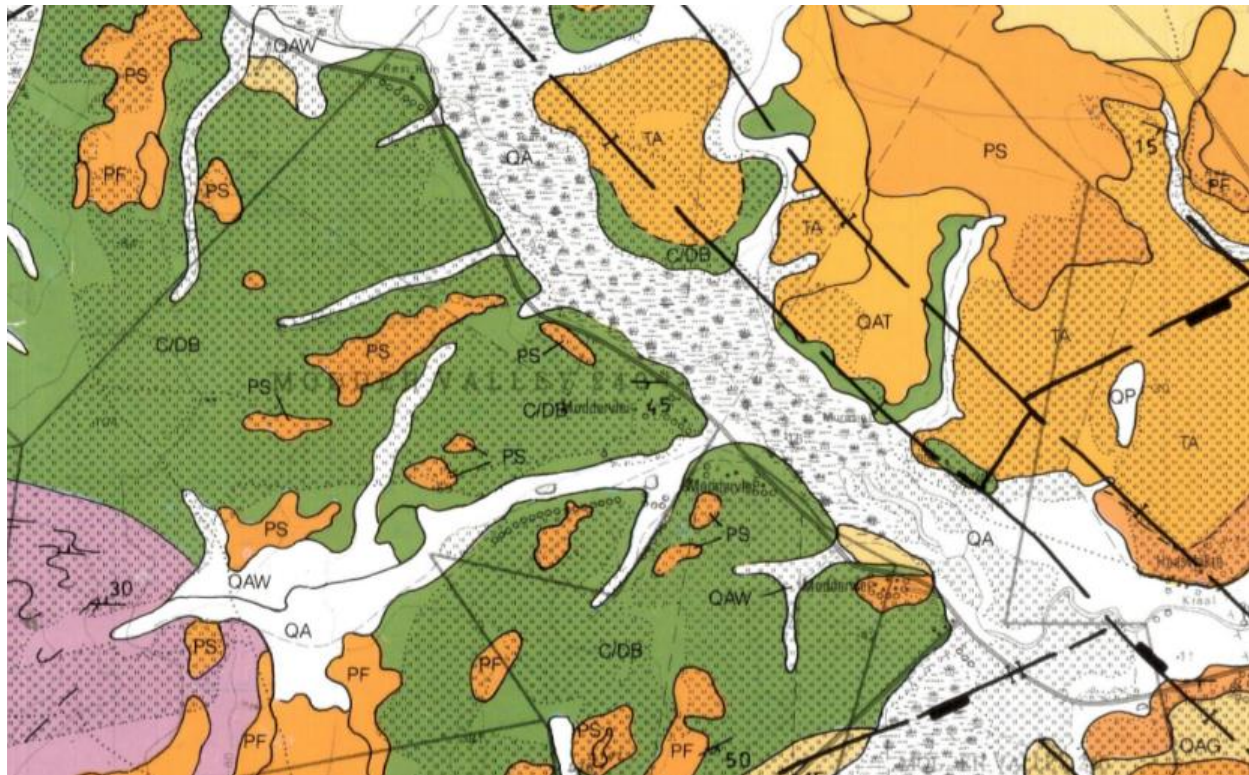


Figure 8. Top – The geology of the Elim area from MAG Andreoli’s 1:50,000 geology map, 1989; map symbols for the outcrops are PS and PF for silcrete and ferricrete respectively, and PA and TA for gravel terraces. Middle – section of the legend of the map, showing the three types of Grahamstown Formation patches. Bottom – enlargement of the red box in the middle figure. Note that the Grahamstown Formation age extends through the entire Tertiary Age (in the Riversdale sheet it only extends from early to mid-Tertiary).

Silcretes and ferricretes in the Study Area

Whereas here are very few articles about the silcretes in the Southwestern Cape, the author did not find any research of the ferricretes in that area.

As the geology maps of the area show, the Grahamstown Formation silcretes were formed on the African Surface, which is – in this cross-section - slightly seaward sloping (Figure 9).

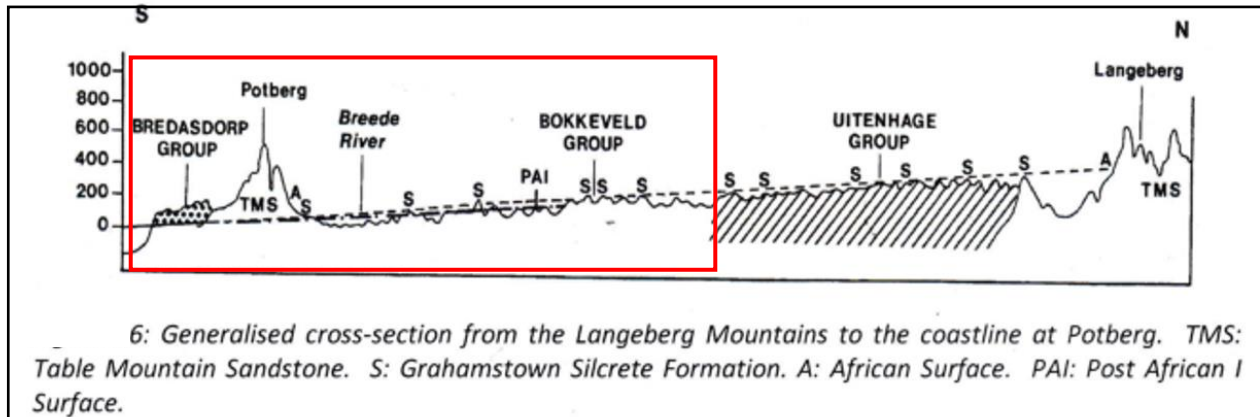


Figure 9. The locations of the Grahamstown Formation silcretes on the seaward-sloping African Surface. Red box indicates the Study Area section of this profile.

Source: JA Malan, 1990, MSc Thesis: The stratigraphy and sedimentology of the Bredasdorp Group.

The various silcrete levels vary from area to area. Eight elevations between 150 and 350 m have been suggested for the Napier to Riversdale area by MacFarlane (undated, probably 1980), and four elevations between 140 and over 400 m in the Albertinia-Mossel Bay area, have been suggested by Marker and McFarlane, 1997. In the Study Area the 'high-level silcretes' are found on elevations between 140 m and 350 m. See the Field Note on spatial distribution below, and Chapter W.

This study has located silcrete outcrops which do not cap hills. They are present on hill tops and hill slopes as boulders and protrusions, at various elevations.

Whereas individual silcrete outcrops in the Study Area are quite small (1,000-10,000 m² in extent each), the ferricrete nodules covered areas are very large (many km² in extent). Nevertheless, the geology maps do not show their full extent but rather indicate the underlying geology (shales).

Also, the geology maps mentioned above do not distinguish between pedogenic and non-pedogenic silcretes. Only some of the pedogenic silcretes, and none of the non-pedogenic silcretes, are parts of the Grahamstown Formation.

It should be noted that only a very small section of the coastal silcrete outcrops is within the Study Area (see Figure 4).

To get a better picture of the silcrete and ferricretes in the Study Area (and, by extension, the Southwestern Cape), a wider area of investigation is needed, which will include the outcrops associated with the Breede River gravel terraces, the non-pedogenic silcretes and hydrological ferricretes near Elim, and other outcrops in the Study Area).

The genesis, geochemistry and mineralogical compositions of silcretes and ferricretes are out of the scope of this study. As some researchers noted, it is difficult to distinguish between the various types of silcrete, particularly when silcretes of all degrees of ferrugination are present, to the extent that in places silcrete is wholly transformed into ferricrete.

Moreover, the author has mapped in the Study Area pedogenic silcrete types, which have not been reported before, (such as silcrete boulders and protrusions on hilltops and hillslopes), as well as non-pedogenic silcrete types and hydrological ferricrete.

The author's classification of the silcretes adopts the genetic classification suggested by Nash and Ulliyott (2007) and some of the habit definitions suggested by them and by Wopfner (1978). It is presented here in a manner, which will make it easier for readers to distinguish between the various faces of silcretes, ferricretes and silicified / ferruginised outcrops.

The following Field Notes describe the main types of silcrete and ferricretes, which are present in the Study Area, their appearances (habits), textures and morphological characteristics. The non-pedogenic silcrete, ferruginised silcretes, silicified and ferruginised shales and sandstones, are also described in this section. The Field Notes cover these subjects:

Pedogenic silcretes

- Capped elevations
- Hill cap habits
- Multi-habit caps
- Hilltop and hillslope boulders
- Hilltop and hillslope castles and other features
- Silicified shale features
- Textures
- Disintegration and weathering
- Spatial distribution

Non-pedogenic silcretes

- Groundwater
- Drainage lines and rivers
- Lakes and pans

Pedogenic ferricretes

- Habits and textures
- Hotspots
- Spatial distribution
- Ferruginised shales, sandstones and silcretes
- Fault zone ferruginised shales

Non-pedogenic ferricretes

- Habits and textures

The author compiled Field Guides on silcretes and ferricretes in the Study Area and outside it, which are given in this chapter. The pedogenic silcrete spatial distribution and its relation to the African Surfaces and the Post African Erosion Surfaces are discussed in Chapter W. The use of silcrete in prehistoric times is discussed in Chapter S.