

**'ERTS-1 IMAGERY' AS AN AID TO THE UNDERSTANDING OF THE REGIONAL SETTING OF BASE METAL DEPOSITS IN THE NORTH WEST CAPE PROVINCE, SOUTH AFRICA**

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**ABSTRACT**

A number of base metal finds have recently focussed attention on the North Western Cape Province of South Africa as an area of great potential mineral wealth. Extensive exploration programmes were initiated by many organizations but these programmes were hampered by the fact that the area is geologically unsurveyed. Available geological maps cover only a strip of country along the south bank of the Orange river, and areas to the west and south of the Springbok - O'Kiep copper mining region.

From the point of view of competitive mineral exploration it was essential that an insight into the regional geological controls of the base metal mineralization of the area be obtained as rapidly as possible. Conventional methods of producing a suitable regional geological map were considered to be too time-consuming and ERTS-1 imagery was consequently examined.

This imagery has made a significant contribution in the compilation of a suitable map on which to base further mineral exploration programmes. Major structural features, including folds, faults and lineaments, as well as the lateral extent of various important stratigraphic units, are clearly discernable on the available images. Important new data have come to light even in areas where published maps are available. In some instances, older stratigraphic trends can be deciphered through thin flat lying younger cover sequences.

Reconnaissance field work aimed at the identification of major rock units and other conspicuous features seen on the images was found to be important prior to interpretation. In addition a more detailed map was produced by identifying less obvious features on the images from a light aircraft flying at an altitude of approximately 2 000 m above ground level.

The time involved in the compilation of maps of this nature was found to be only a fraction of the time necessary for the production of similar maps using other methods. ERTS imagery is therefore considered to be valuable in producing accurate regional maps in areas where little or no geological data are available, or in areas of poor access. Furthermore, these images have great potential for rapidly defining the regional extent of metallogenic provinces

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## INTRODUCTION

The region discussed in this paper comprises a portion of the north western Cape Province of the Republic of South Africa and lies mainly to the south of the Orange river. It also includes a small portion of southern South West Africa on the northern side of the river and is bounded by latitudes  $28^{\circ}\text{S}$  -  $31^{\circ}\text{S}$  and longitudes  $16^{\circ}\text{E}$  -  $24^{\circ}\text{E}$ . (Figure 1).

The region is one of very low rainfall, so that in most places vegetation cover is sparse or non-existent. Erosion caused by the Orange river has resulted in the development of a broad strip of excellent rock exposures along both flanks of the river. To the north and south of this zone, outcrops become progressively poorer and eventually the older geological formations of the river valley are covered by flat lying younger strata at an elevation of some 500 meters above the river bed.

Despite the fact that copper deposits associated with small plugs of basic igneous rock have been known and mined in the western portion of the terrain (Springbok - O'Kiep area) for many years, the rest of the area was never considered to be particularly interesting as far as base metal mineralization was concerned. With the discovery of a major Cu - Zn deposit in the eastern part of the region (Prieska area) several years ago, followed by other significant base metal finds between this occurrence and the Springbok - O'Kiep copper occurrences, it became apparent that the entire region might represent a metallogenic province of considerable economic importance.

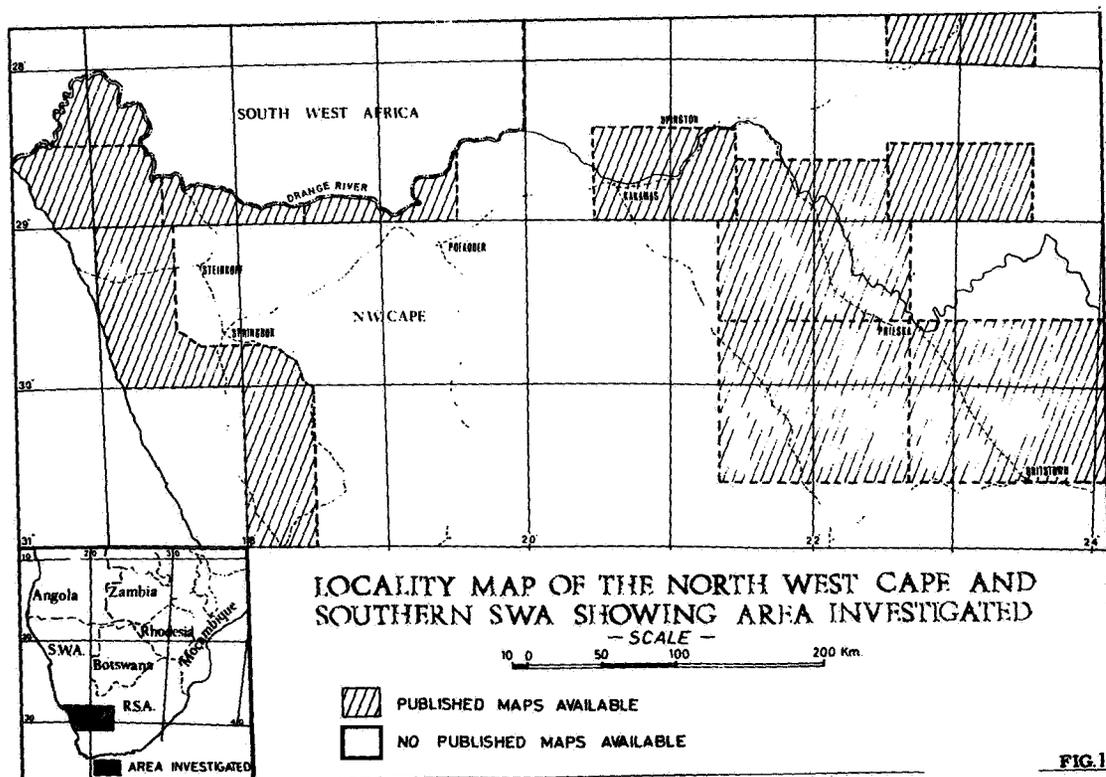
Numerous organisations commenced exploration in the area and from a competitive point of view it was imperative that the relationship between the various deposits and the regional geology of the area be established as rapidly as possible.

Previous geological work in the region included good mapping along the Orange river by the South African Geological Survey, as well as mapping in areas to the west and south of the Springbok - O'Kiep copper mining district where most of the work has been carried out by Dr. Joubert of the Precambrian Research Unit of the University of Cape Town. (See fig. 1). Nevertheless, large areas and particularly those where the new base metal finds were made, remained unmapped and the regional structure of the terrain was not understood. Conventional methods of producing suitable regional geological maps were considered to be too time consuming and ERTS-1 imagery was consequently examined.

## METHODS OF STUDY

Eight ERTS-1 colour composite images enlarged to a scale of 1:500 000 were used for the compilation of a regional geological map of the area. A mosaic constructed from the images used in this compilation has been reduced in fig. 2 to a scale of approximately 1:2 000 000. A generalized map illustrating the interpretation is shown in fig. 3. A number of details have been omitted from this interpretation because of the competitive nature of mineral exploration in the area at the present time.

Before any interpretation was carried out, a detailed study of all the available published maps was made in order to correlate the expression of various formations with features seen on the ERTS images. Reconnaissance road traverses were undertaken in both the mapped areas and unmapped areas to establish ground truth. Final interpretation was carried out after a certain amount of mapping had been done directly on the images correlating geological features from a light aircraft flying at an altitude of about 3 000 meters above ground level. These data were then plotted onto 1:500 000 topographic sheets, somewhat simplified and finally reduced to a scale of approximately 1:2 000 000 (fig. 3).



## GEOLOGICAL INTERPRETATION

### Introduction

The area under consideration is divisible into four main geological entities, the most important of which is an extensive 1 000 million years old, metamorphic gneiss terrain, the Bushmanland Metamorphic Complex, which is well exposed in the valley of the Orange river. This metamorphic terrain is terminated to the east of Upington by a major NNW - SSE trending zone of dislocation (the Kbos fault zone). This fault zone separates the Metamorphites from a very much older granite-greenstone terrain lying to the east and known as the

Kaapvaal craton. In the area under consideration the Kaapvaal craton is for the most part largely covered by relatively unmetamorphosed, predominantly sedimentary rocks belonging to a series of extensive ancient cratonic basins. Geochronological studies indicate that most of the basement granites of the Kaapvaal craton have ages in excess of 2.5 billion years.

In the western portion of the area, in a region known as the Richtersveld (fig. 3), the structural style and the grade of metamorphism changes and a series of vulcano-sedimentary formations striking roughly north-south are associated with granite (the Vioolsdrift granite) which has an age of about 1 800 million years. In the north and south central portions of the area the Bushmanland metamorphites are overlain by much younger flat-lying sedimentary formations belonging to the Nama and Karroo systems. Each of these major geological entities will be described in turn.

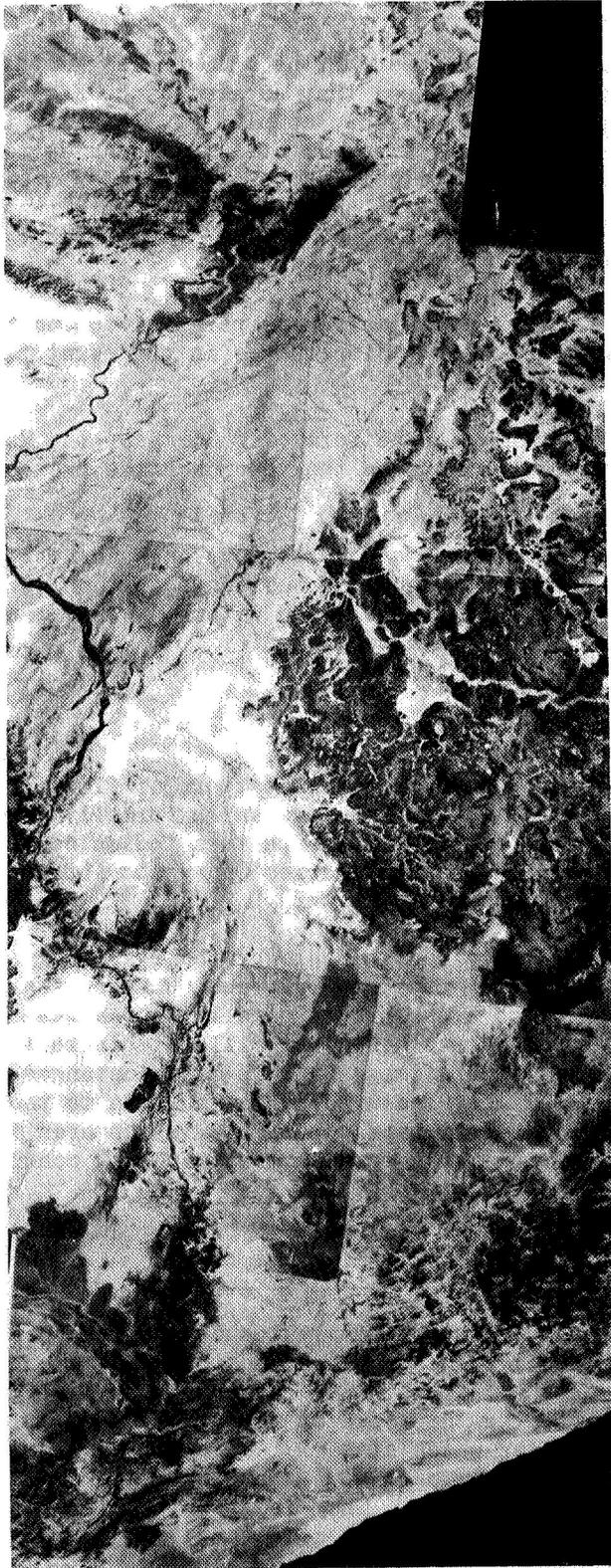


Figure 2.

### Sedimentary formations of the Kaapvaal craton

One of the most striking features seen on the ERTS images is the spectacular discontinuity (the Brakbos fault zone) that separates the Kaapvaal craton in the east from the Bushmanland metamorphic complex in the west. Although this zone has been described briefly by a number of authors and detailed mapping aimed at establishing geological relationships is at present being undertaken, no definitive results have as yet been published. In this respect a number of features observed on ERTS imagery might well prove to be invaluable in the final assessment of the problem. These are:-

- a. The existence of a number of major faults parallel to and lying east of the Brakbos fault zone, clearly discernible in the country immediately west of the town of Prieska.
- b. Intense deformation mainly in the form of folding of the north-south striking sedimentary formations as they approach the Brakbos fault zone from the north east.
- c. All the sedimentary formations appear to have been abruptly truncated by the Brakbos fault zone and there is no evidence of them straddling this discontinuity and thus being represented within the Bushmanland metamorphic complex as has been suggested.

### Flat-lying Sedimentary cover rocks

The imagery clearly reveals the distribution pattern of flat lying sedimentary beds belonging to the Karroo and Nama systems which formerly covered most of the Bushmanland metamorphic complex. This pattern indicates both the erosive action of the Orange river and its tributaries and yields information regarding the underlying basement structure (see later).

The Karroo sediments are clearly recognisable by their grey or dark grey colours whereas the Nama strata are characterized by brownish hues. Areas of thick and thin Karroo cover are also apparent, especially in the region to the south of Pofadder. In addition dolerite dykes and sills within this formation can be mapped in great detail from the images and in many instances appear to be partly controlled by major linear features as in the area to the south west of Kenhardt (fig. 3). Numerous salt pans especially in the area to the south of Kenhardt (not indicated on the map) are even more strongly controlled by these linear features.

### Older volcano-sedimentary formations of the west coast

A number of generally north-south trending vulcano-sedimentary formations have been mapped in the Richtersveld area adjacent to the west coast (fig. 3). These rocks have not been involved with the 1 000 million years old metamorphic overprinting which has affected the rocks of the Bushmanland sequence. They have been intruded by granites which have radiometric ages of approximately 1 800 million years and thus form part of a zone that is probably marginal to the Bushmanland Metamorphic Complex. The extent of the Stinkfontein formation, which comprises one of the most important components of the volcano sedimentary formation under consideration, is clearly discernible on the ERTS imagery (fig. 3).

### The geology and structure of the Bushmanland Metamorphic Complex

The Bushmanland Metamorphic Complex forms part of a more extensive belt of 1 000 million years old metamorphic rocks which extend across the southern portion of South Africa and includes both basement and supracrustal sequences. Rock types encountered in the latter group are of considerable importance from an economic point of view and comprises a large variety of quartz-felspathic gneisses with variable amounts of biotite and muscovite, banded amphibolitic and calc silicate assemblages and a variety of quartzitic rocks. The basement upon which they rest is ill defined but is probably represented by porphyroblastic augen gneisses.

The entire assemblage has undergone intense deformation and several periods of folding have been described by Joubert from the area to the west and south of the Springbok - O'Kiep mining district. Numerous fault zones and lineaments also feature prominently and have played an important part in the overall tectonic framework of the region.

The supracrustal sequence has been recognised from a point some 30 kilometers from the west coast striking in an easterly direction towards a major zone of dislocation (the Tantalite valley fault zone) situated a short distance to the north east of the town of Pofadder and trending NW - SE (fig. 3).

As each major sequence of east-west striking rocks crosses this zone of dislocation it is deflected to form large refolded lobate structures on the north eastern side. The latter structures have a general north-south strike but are themselves deformed by younger folds with axes trending parallel to the Tantalite valley fault zone. This phenomenon is well illustrated in the area immediately north of the Orange river by the sequence of rocks which commences in the Goodhouse area. It is also shown by the sequence portrayed by the black ornament which commences in the region to the north west of the Springbok - O'Kiep mining district and strikes in an overall east east direction towards the town of Pofadder. Immediately east of the town the assemblage swings sharply northwards and then north west culminating in a position to the west of Kakamas on the Orange river (fig. 3).

The stratigraphic sequence lying to the south of the Springbok - O'Kiep mining district also strikes east - west but is covered as one proceeds east, firstly by sand and then by younger flat lying sediments of the Karroo system. When these rocks again make their appearance from under the Karroo cover in the vicinity of Kenhardt, they strike in a generally north west direction from this town to Kakamas on the Orange river (fig. 3). The relationship between mineral deposits and various stratigraphic components of the sequences described above is naturally of great importance and in this respect the regional geological map presented in this paper has acted as a most important and invaluable guide to the longer term planning of mineral exploration programmes. The results of the exploration carried out to date are encouraging and further work is continuing.

### Faults and linear features

Numerous well defined linear features, some of them undoubtedly representing faults and in most cases not mapped previously, constitute conspicuous features

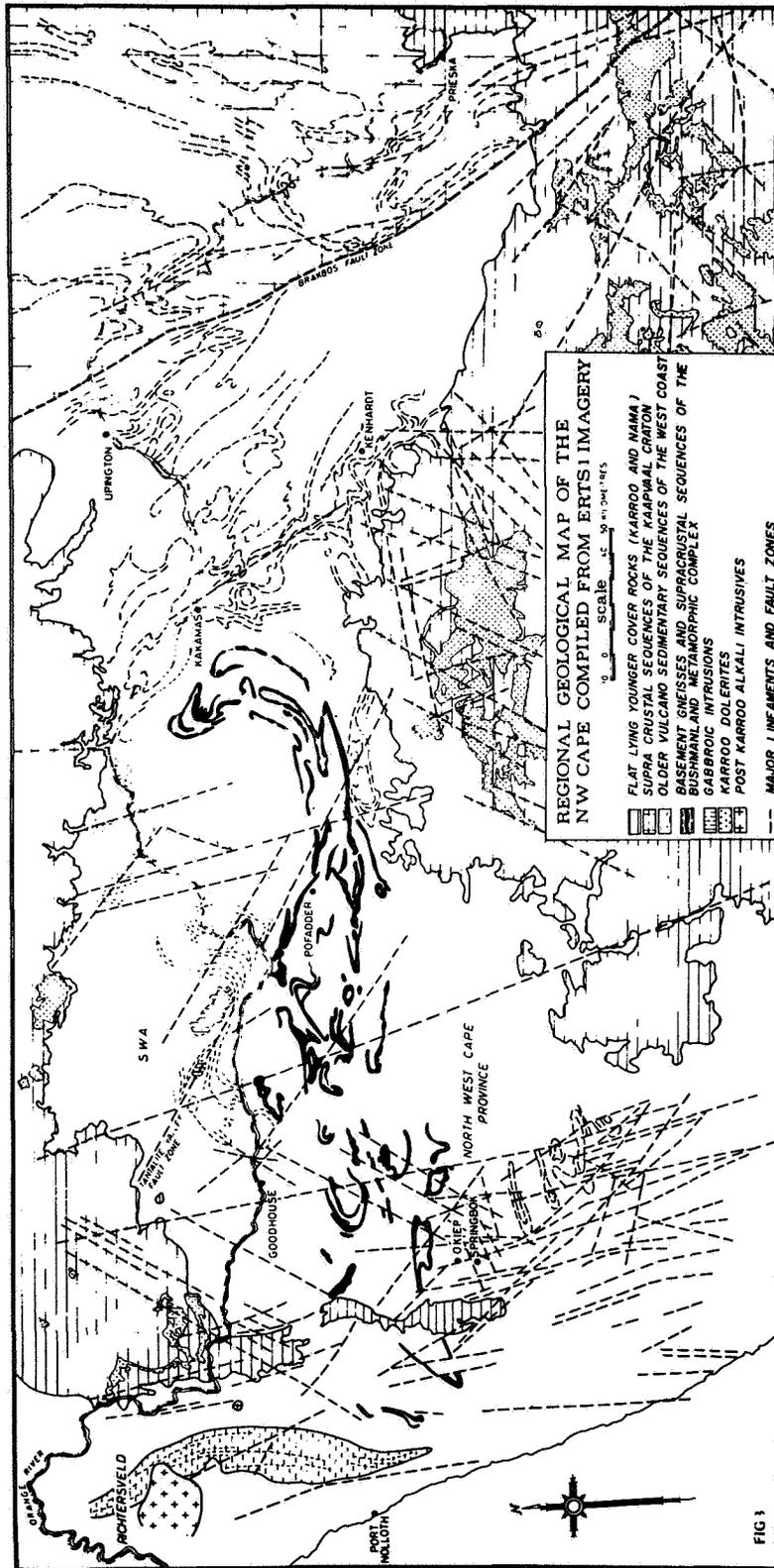


Figure 3.

on the imagery. A number of prominent directions have influenced the geology to a large extent.

a. NNW - SSE Direction

A very strong set of fractures conforming to this direction, which parallels the west coast, occurs in a strip of country occupying the coastal region for a distance of some 120 kilometers inland. Features such as the termination of younger cover sequences at this point, the preservation of cover sequences in a NNW - SSE trending belt between the eastern Richtersveld and the Springbok - O'Kiep mining area, the north south trending zones of older vulcano-sedimentary rocks in the Richtersveld and the general attenuation of the Bushmanland supracrustal rocks in this area, suggest that the entire coastal strip has been an area of active uplift with attendant faulting which has preserved both younger and older sedimentary sequences in the area.

This direction of fracturing becomes less intense further east but is again manifested by the large fault zone to the east of Goodhouse which clearly controls the distribution pattern of the younger flat lying cover sequences. Features with the same direction are also clearly to be seen in the area to the north east of Pofadder and to the south west and north west of Kenhardt, and the Brakbos fault zone itself, further east, constitutes a spectacular expression of this direction.

The latter zone with its associated parallel faults also represents a zone of relative uplift as is manifested by the southward swing of the outcrop pattern of younger cover rocks between Kenhardt and Prieska and the northward swing of similar rocks to the north of Upington.

b. NW - SE Direction

The Tantalite Valley fault zone is the most important linear feature conforming to this direction and can clearly be traced through Karroo cover in the area to the south east of Kenhardt. This fault zone has acted as the basis for the intrusion of gabbro plugs in the area to the north west of Pofadder. (fig. 3). Parallel linear features are to be seen to the north and south west of Pofadder and in the area surrounding the Springbok - O'Kiep copper mining district.

c. NE - SW Direction

Linear features conforming to this direction are well developed along the west coast zone particularly between the Richtersveld and the Springbok - O'Kiep area. The intersection of these with the other fracture directions described probably acts as the locus for the emplacement of younger igneous rocks including the Post Karroo alkali intrusives of the Richtersveld. (fig. 3).

## CONCLUSIONS

ERTS imagery has proved to be invaluable in compiling a regional geological map of the N.W. Cape Province of South Africa. The area represents one in which few published geological maps exist but in which important base metal deposits have been located. Interpretation of the imagery was carried out with a limited amount of ground truth. Mapping directly onto the images from a light aircraft has clearly defined the lateral extent of potential zones of mineralization and is considered to be an important technique. This has acted as the main basis for the implementation of regional mineral exploration programmes in the area. The structural framework of the area has been well established and significant geological features have been recorded even in areas where published maps exist. Major linear features not appreciated before are clearly seen on the imagery and have played a large part in contributing to the overall geological pattern. The use of ERTS images in defining accurately the extent of metallogenic provinces in a relatively short period of time, especially in unmapped or poorly mapped areas, is unrivalled. Techniques developed during this study could act as the framework for similar investigations in other regions.